



**Towards a Socio-Spatial Parametric Grammar for  
Sustainable Tall Residential Buildings in  
Hot-Arid Regions**

Learning from the Vernacular Model of the  
Middle East and North Africa

Thesis submitted in partial fulfilment of the requirements for the degree of  
Doctor of Philosophy

Cardiff University  
Welsh School of Architecture

By  
**Amer (Moh'D Izzat) Al-Jokhadar**

January 2018



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**VOLUME ONE**

(Volume 1 of 2)

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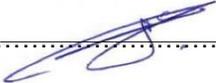
Cardiff University  
Welsh School of Architecture

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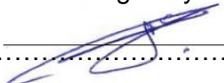
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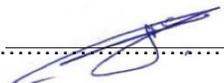
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## **Dedication**

*I dedicated my humble effort to*

***My beloved Dad and Mom***

*Whose love, encouragement, support, and prayers make me able to get  
such success and honour*

***My wonderful wife, Saba***

*For letting me experience the kind of love, and for her patient, care and  
encouragement to achieve my dream*

***My sweet daughter, Ghalia***

***My hero son, Kareem***

*For supporting me and my wife during our PhD journey, and bringing  
moments of laughter and happiness to each day*

***My lovely brothers,***

***Mutaz and Mutasem***

*For their continuous support*

# **Towards a Socio-Spatial Parametric Grammar for Sustainable Tall Residential Buildings in Hot-Arid Regions**

Learning from the Vernacular Model of the Middle East and North Africa

**Amer (Moh'D Izzat) Al-Jokhadar**

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## **Abstract**

In the Middle East and North Africa (MENA) region, high-rise buildings could be considered as a hallmark of the contemporary cityscape, and a solution for the continuous urbanisation. Many benefits, such as preserving natural and green spaces in the city, and increasing the access to views, light, and air at height could be achieved. However, several impacts of such buildings could affect the social life of residents. The social dimension in recent developments has considerably less attention than economic and environmental dimensions. This research aims to develop a method for addressing the social aspect in the design of high-rise residential buildings, which could enhance the social life between neighbours, and improve the well-being qualities, such as privacy and security.

Computation, as a tool for manipulating ideas, managing design parameters, and solving problems, is adopted to create synergies amongst a community's cultural, social, and environmental aspects. Currently, the main focus of computational models is primarily limited to building performance, optimisation, and functional requirements. Yet, qualitative factors, such as social, cultural and contextual aspects are also important as they. The study aims to offer architects a computational tool that guides the emergence of sustainable solutions for high-rise residential buildings, and leads the building to be in harmony with the context and preferences of users.

According to social survey conducted by the researcher in the study area, through distributing questionnaires to families from 17 countries, results of 173 responses showed that there are lower levels of social interaction between neighbours in contemporary buildings due to the lack of gathering areas. Moreover, the excessive use of glazed facades, and the sudden transition from public to private zones, destructed the privacy of the family and the specifics of the cultural context. On the other hand, the survey exposed potentials and impacts of vernacular houses and neighbourhoods on residents that could have effects on social interaction between families and their privacy. Yet, the vernacular model might not be compatible with the requirements of modern constructions while employing the latest technologies and materials.

The study adopted a critical regionalism approach that creates a balance between tradition and the importance of progress and development. A systematic model of analysis, which combines 'spatial reasoning' and 'space syntax' methods, was suggested to discover the morphology of vernacular houses and neighbourhoods, and explore spatial topologies that have social or experiential significance. The model added new aspects, such as hierarchy of spaces, orientation, type of enclosure, shared surfaces, and geometric properties of spaces, to the justified graph of Hiller and Hanson, as a representation of formal and social realities.

A total of 13 social indicators, with different units of representation, such as numbers, diagrams, and textual descriptions, were identified, and used to define spatial parameters, rules, and constraints. Results extracted from the analytical process for historical cases showed that courtyards, public spaces, and hierarchy of spaces are major features that have potentials to create a balance between social interaction and privacy. These results were combined with principles of shape grammars, and transformed into spatial rules that are associated with parameters and descriptions.

Grammars that address the design of vernacular houses and neighbourhoods, were combined with requirements of high-rise buildings, and used for the construction of a parametric computational tool for the design of vertical residential developments. The developed tool supports the recognition of the design brief for high-rise residential buildings, with the possibility of changing geometric and spatial parameters. Moreover, it offers an alternative method for implementing strategies of social sustainability and maximising the connection with the context, culture, and people. The tool was used by the researcher, in addition to professionals and architecture students through an experimental study, to generate different solutions for high-rise residential buildings. The analysis of new alternatives showed that most cases achieved successfully principles of social sustainability. Moreover, usability evaluation for the tool that assesses the efficiency of the tool in the early stage of the design was conducted through distributing a questionnaire on the same participants. Results of the evaluation process showed that the developed interface offers designers a tool to investigate a class of satisfactory design alternatives that are not expected rather than a single best solution. It gives the user a flexible way to capture the relationship between public and private zones, and insert a series of public courtyards distributed on the different levels of the building, with the possibility of generating a private courtyard inside each apartment. Such a process, which is managed by a set of predefined social and spatial rules, confirming the design process as a balance between creativity and rationality. Moreover, it is a transition from standard mass buildings to contemporary-vernacular projects that respect the cultural context, climate, and people.

## List of Publications

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The following papers have been published according to the results of this research:

1. Al-Jokhadar, A. and Jabi, W. (2017-a). Vernacular neighbourhoods as models for socially-sustainable vertical cities: a computational approach. *International Conference for Sustainable Design of the Built Environment (SDBE 2017) Proceedings*, London, UK, 20-21 December 2017, pp. 76-87. ISBN: 978-1-9997971-0-2.  
[http://newton-sdbe.uk/wp-content/uploads/2017/12/SDBE2017\\_Proceedings-v1.pdf](http://newton-sdbe.uk/wp-content/uploads/2017/12/SDBE2017_Proceedings-v1.pdf)
2. Al-Jokhadar, A. and Jabi, W. (2017-b). Spatial reasoning as a syntactical method for programming parametric socio-spatial grammars. *Journal of Space Syntax (JOSS)*. A peer-reviewed, open access academic journal focused on research investigating relations between society and space. (In the review process).
3. Al-Jokhadar, A. and Jabi, W. (2017-c). Applying the vernacular model to high-rise residential development in the Middle East and North Africa. *International Journal of Architectural Research (Archnet-IJAR)*, 11(2), July 2017, pp. 175-189.  
<http://www.archnet-ijar.net/index.php/IJAR/article/view/1254/pdf>
4. Al-Jokhadar, A. and Jabi, W. (2017-d). Qualitative representation and spatial reasoning in a rule-based computational design model. In: Spaeth, B. and Jabi, W. (eds.). *The Virtual and the Physical: between the Representation of Space and the Making of Space - Proceedings of the 5<sup>th</sup> eCAADe Regional International Symposium*. Cardiff University, UK, 26-28 April 2017, pp. 35-44. Brussels: eCAADe Education and Research in Computer Aided Architectural Design in Europe, and Wales, United Kingdom: the Welsh School of Architecture, Cardiff University. ISBN 978-1-899895-26-7.
5. Al-Jokhadar, A. and Jabi, W. (2016-a). Humanising the computational design process: integrating parametric models with qualitative dimensions. In: Al-Attili, A., Karandinou, A. and Daley, B. (eds). *Parametricism vs. Materialism: Evolution of Digital Technologies for Development – Proceedings of the 8th International Conference of the Arab Society for Computer Aided Architectural Design (ASCAAD-2016)*. SOAS University of London, London, UK, 7-8 November 2016. London: Imperial House Publishers. ISBN 978-0-995569-10-2.
6. Al-Jokhadar, A. (2016-b). A spatial-parametric perspective for measuring social sustainability in residential buildings. *The 5<sup>th</sup> ResArchi Conference: Perspective(s)*. Welsh School of Architecture, Cardiff University, Cardiff, UK, 24 November 2016.
7. Al-Jokhadar, A. and Jabi, W. (2016-c). Towards a ‘contemporary vernacular’ high-rise residential development in the Middle East and North Africa: learning from the socio-spatial qualities of the vernacular model. *The 5th International Jordanian Architectural Conference: Contemporary Architecture in the Arab World*. Amman, Jordan, 1-3 November 2016. <http://www.jeaconf.org/PapersAndPublications/Papers.aspx>
8. Al-Jokhadar, A. and Jabi, W. (2016-d). Enhancing social-cultural sustainability in tall buildings: a trace from vernacular houses. In: Wood, A., Malott, D. and He, J. (eds.). *Cities to Megacities: Shaping Dense Vertical Urbanism - A collection of state-of-the-art*,

*multi-disciplinary papers on urban design, sustainable cities, and tall buildings - Proceedings of the CTBUH 2016 International Conference*. China, 16–21 October 2016, Volume 1, Chapter 9, pp. 633-641. Chicago: Council on Tall Buildings and Urban Habitat. ISBN 978-0-939493-51-7.

<http://global.ctbuh.org/resources/papers/download/2929-enhancing-social-cultural-sustainability-in-tall-buildings-a-trace-from-vernacular-houses.pdf>

9. Al-Jokhadar, A. and Jabi, W. (2016-e). Exploring potentials of sustainability in traditional courtyard houses in hot-arid regions: a socio-spatial syntax method. *UKIEG 2016 Conference: Health and Well-being throughout the Life Course - the Role of Residential and Learning Environments*. Coventry University, Coventry, UK, 16 June 2016.
10. Al-Jokhadar, A. (2015). Towards a socio-spatial grammar for tall residential buildings in hot-arid regions. *The 4th ResArchi Conference: Impacts*. Welsh School of Architecture, Cardiff University, Cardiff, UK, 13 November 2015.

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Chapter One

**Introduction and Overview**

## Chapter One

### **Introduction and Overview**

#### **1.1. Preface**

In the age of globalisation and continuous urbanisation, high-rise buildings are the most viable solution for many urban cities in the Middle East and North Africa (MENA) region. Many benefits, such as preserving natural and green spaces in urban centres, and increasing the access to views, light, and air at height could be achieved in these structures (Hudgins 2009; Yeang 2002; Modi 2014). However, the need of dense and affordable vertical developments leads the creation of standard floors, limits the availability of social and gathering spaces inside buildings, and sometimes creates iconic structures that ignore the specifics of the cultural context and local traditions (Al-Kodmany 2015; Wood 2013; Cuthill 2010).

Architects have a greater responsibility to design high-rise residential buildings with comfortable and sustainable environments. Computation, as a tool for manipulating ideas and solving problems, could help designers for achieving such goals. Currently, the broad attention of sustainable developments and computational tools is primarily concerned with environmental and functional requirements rather than social and cultural dimensions. Yet, sustainable solutions and design models should create synergies amongst a community's cultural, historical, social, economic and environmental aspects (Al-Kodmany 2018).

This chapter expands in Section (1.2) on the context of the research, by providing a brief on the emergence of high-rise residential buildings in the study area, and the needed studies for the design of sustainable developments. Sections (1.3) and (1.4) outlines research aims, questions, and objectives, as well as set out thesis design in which the study will be explored. Finally, Section (1.5) summarises the structure of the following chapters.

## 1.2. Research Context and Background

This study focuses on addressing issues that face high-rise residential buildings in the Middle East and North Africa (MENA region).

### 1.2.1. The Hot-Arid Regions of the Middle East and North Africa

Geographically, the study area could be divided into three zones:

1. The Middle East: Jordan, Palestine, Lebanon, Syria, Iraq, and Turkey.
2. The Gulf Area: Saudi Arabia, Bahrain, Kuwait, Oman, United Arab Emirates, and Yemen.
3. North Africa: Egypt, Algeria, Tunisia, Morocco, and Libya.

Most countries share the same social and cultural values, local traditions, living patterns, and lifestyle. These issues could be noticed in the design of buildings, especially the traditional houses. However, most of the current residential buildings in the study area are constructed as iconic structures that ignore such values and traditions.

Another shared feature in these countries is the hot-arid climate. The Köppen climate classification system is one of the most widely-used methods for dividing the World according to climate. The system features five basic climate types. Four of these types are based on temperature (tropical, temperate, continental, and polar), while the fifth (arid) is based on precipitation<sup>1</sup> (Table 1.1).

Table 1.1: Criteria of climate types across the World  
(Source: <http://www.essential-humanities.net/history-supplementary/climates-biomes/>)  
(accessed on 15/10/2015)

| Climate Types | Criteria                   |
|---------------|----------------------------|
| Tropical      | Warm year-round            |
| Temperate     | Warm summers, cool winters |
| Continental   | Warm summers, cold winters |
| Polar         | Cold year-round            |
| Arid          | Low precipitation          |

In arid regions, the weather is very cold in winter and hot in summer. Also, temperature varies strongly from day to night (Ettoumia et al. 2003). Therefore, buildings must be designed to ensure comfort for users. Arid climate can be further divided into hot-arid climate, which stays hot year-round; and cold-arid climate, which has hot summers and cold winters (Figure 1.1).

<sup>1</sup> <http://www.essential-humanities.net/history-supplementary/climates-biomes/>  
(accessed on 15/10/2015)

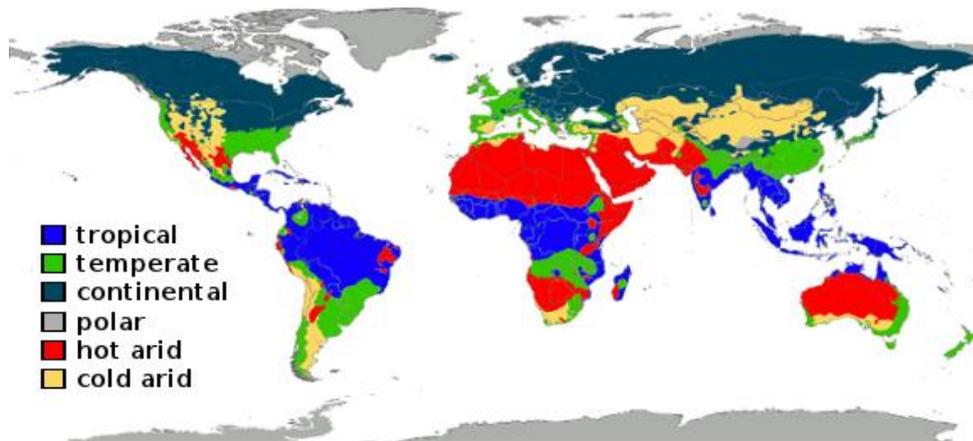


Figure 1.1: Köppen classification World climate map  
(Source: <http://www.essential-humanities.net/history-supplementary/climates-biomes/>)  
(accessed on 15/10/2015)

The climate in hot-arid regions is characterised by the following<sup>2</sup>:

- Long, hot, and dry summers.
- Short and cool winters.
- Differences in temperature between day and night.
- Scarcity of rain.
- Strong glare reflected from the land.
- The air is loaded with dust due to the rough landscape.

### 1.2.2. The Emergence of High-rise Residential Buildings in MENA Region

The world population presently stands at 6.9 billion – a figure is expected to reach 10.1 billion by the year 2100 (United Nations 2015). Globally, statistics show that more people live in urban areas (54%) than in rural areas, and it is expected, by 2050, that the world will be two-thirds urban (66% = 5.2 billion) and one-third rural (34%), which is roughly the reverse of the global rural-urban population distribution of the mid-twentieth century (United Nations 2015) (Figures 1.2 and 1.3). According to a study on urban developments, conducted by 'The World Bank Organization' in 2013, the Middle East and North Africa (MENA) region, which is currently home to 357 million people, has one of the world's most rapidly expanding population, with more than 60% of urban population in 2014<sup>3</sup>. This percentage, which is expected to reach to nearly 400 million by 2050 (The World Bank

<sup>2</sup> <http://www.essential-humanities.net/history-supplementary/climates-biomes/>  
(accessed on 15/10/2015)

<sup>3</sup> <http://data.worldbank.org/topic/urban-development> (accessed on 11/4/2016)

2013), has been driven by several factors such as economic development, water shortage in rural areas, and displacement of people due to wars (Serageldin *et al.* 2015).

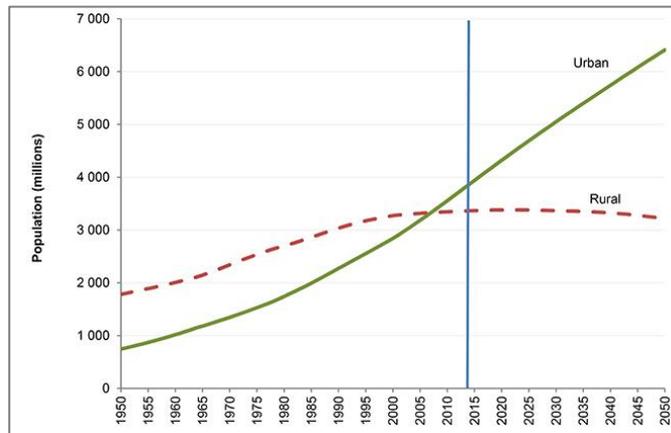


Figure 1.2: The world's urban and rural population (1950-2050) (United Nations 2015)

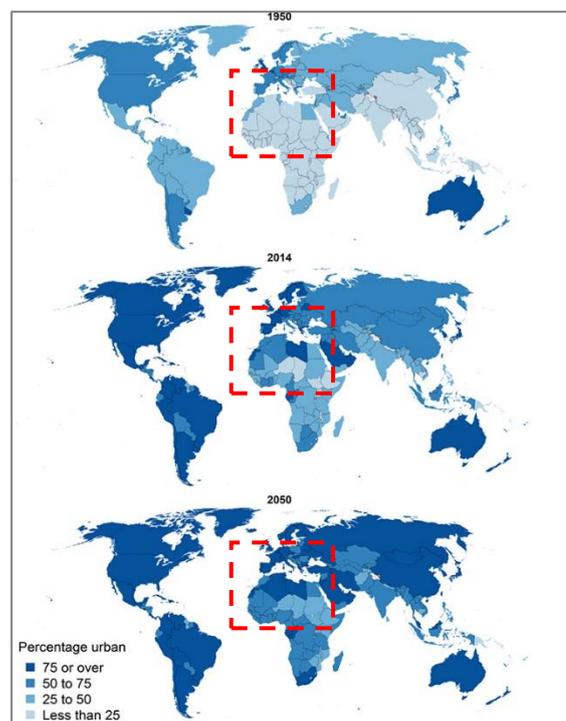


Figure 1.3: Percentage of the population residing in urban areas in the Middle East and North Africa, 1950, 2014 and 2050. (United Nations 2015)

These trends could have significant impacts on the built environment and the building construction industry (Losantos and Cañizares 2007). For instance, global urbanisation, scarcity of lands and high land prices, increase the demand on affordable living and working spaces, and therefore, push the emergence of high-rise and high-dense buildings.

Such developments could be considered a hallmark of the contemporary cityscape, and the most viable solution for many urban centres (Hudgins 2009; Yeang 2002; Modi 2014). More than 70% of high-rise developments in the world are located in Asia, the Middle East and Africa (Kearns *et al.* 2012). Dubai, for instance, ranked in 2015 as the ninth city in the world with more than 1025 completed high-rise buildings, while Abu Dhabi, Sharjah, and Doha ranked 32<sup>nd</sup>, 33<sup>rd</sup>, and 58<sup>th</sup> respectively<sup>4</sup> (Table 1.2).

Table 1.2: Skyline ranking according to the statistics of completed high-rise buildings (Emporis Standards Committee (ESC), <http://www.emporis.com/statistics/skyline-ranking>, accessed on 19/4/2016)

| #  | City          | Population | Area size  | Number of completed tall buildings | Points (*) |
|----|---------------|------------|--|------------------------------------|------------|
| 1  | Hong Kong     | 7,061,200  | 1,053 km <sup>2</sup> = (407 mi <sup>2</sup> )     | 7,827                              | 136,960    |
| 2  | New York City | 8,336,697  | 800 km <sup>2</sup> = (309 mi <sup>2</sup> )       | 6,198                              | 44,027     |
| 3  | Chongqing     | 6,300,000  | 82,403 km <sup>2</sup> = (31,816 mi <sup>2</sup> ) | 1,719                              | 40,250     |
| 4  | Shenzhen      | 3,538,275  | 2,020 km <sup>2</sup> = (780 mi <sup>2</sup> )     | 1,091                              | 28,811     |
| 5  | Seoul         | 10,581,728 | 616 km <sup>2</sup> = (238 mi <sup>2</sup> )       | 4,148                              | 26,841     |
| 6  | Singapore     | 5,312,400  | 710 km <sup>2</sup> = (274 mi <sup>2</sup> )       | 4,916                              | 26,605     |
| 7  | Guangzhou     | 6,560,500  | 7,434 km <sup>2</sup> = (2,870 mi <sup>2</sup> )   | 910                                | 23,702     |
| 8  | Moscow        | 11,503,501 | 1,080 km <sup>2</sup> = (417 mi <sup>2</sup> )     | 11,697                             | 23,218     |
| 9  | Dubai         | 2,104,895  | 3,885 km <sup>2</sup> = (1,500 mi <sup>2</sup> )   | 1,025                              | 23,112     |
| 10 | São Paulo     | 11,316,149 | 1,523 km <sup>2</sup> = (588 mi <sup>2</sup> )     | 6,346                              | 22,836     |

(\*) This calculation does not include TV towers, masts, bridges, or other structures. Each building is assigned points based on its floor count:

|                            |                             |                                 |
|----------------------------|-----------------------------|---------------------------------|
| 12 - 19 Floors = 1 Point   | 50 - 59 Floors = 100 Points | 80 - 89 Floors = 400 Points     |
| 20 - 29 Floors = 5 Points  | 60 - 69 Floors = 200 Points | 90 - 99 Floors = 500 Points     |
| 30 - 39 Floors = 25 Points | 70 - 79 Floors = 300 Points | 100 or more Floors = 600 Points |
| 40 - 49 Floors = 50 Points |                             |                                 |

The surrounding structure is a major factor for considering a building to be characterised as a 'high-rise' or 'tall' (Kloft 2002). For instance, if an urban setting has an average of two-floor to three-floor buildings, then a five-floor structure could be considered as a high-rise. However, several bodies define this term differently. According to the 'Emporis' database on Buildings and the Real Estate Industry, a '**high-rise building**' is defined as '*a multi-story structure between 35 and 100 meter tall, or a building of unknown height from 12 to 39 floors*'<sup>5</sup>. These structures are also called '**tall buildings**' in some countries, and '**tower blocks**' in the United Kingdom and some European countries (Craighead 2009). In the United States, the National Fire Protection Association defines a 'high-rise' as being

<sup>4</sup> <http://www.emporis.com/statistics/skyline-ranking> (accessed on 12/4/2016)

<sup>5</sup> <http://www.emporis.com/building/standard/3/high-rise-building> (accessed on 14/12/2015)

higher than 23 metres (75 feet), or about seven stories<sup>6</sup>. In India, the building codes of Hyderabad indicate that a ‘high-rise’ is a building with four floors or more, or 15 metres or more in height (Narayan Reddy 1996). The Council of Tall Buildings and Urban Habitats (CTBUH) claims that if a tall building is higher than 40 floors, then it is called a ‘*skyscraper*’. Moreover, the term ‘*super-tall*’ is used when a building is higher than 300 metre, and a ‘*mega-tall*’ when skyscrapers reach beyond 600 meters (CTBUH 2011).

### 1.2.3. Sustainability in Residential Buildings

Sustainable development, in general, rests on three pillars that interact with each other: environment, economy, and society. A sustainable high-rise building, which could be defined as a ‘vertical city’, requires designers to take into account these three dimensions during the design process (Yeang 2002).

Currently, high-rise developments create a challenging environment, with both benefits and impacts (Ali and Al-Kodmany 2012). In terms of potentials, a tall building offers a small area of envelope that could reduce costs, materials, heat loss or gain, and the overall *heat island* effect (Yeang 1999; Li 2013). Moreover, locating various services within suitable walking distances from units could be achieved. In terms of negative aspects, scholars pointed out the impact of these structures on occupants (Al-Kodmany 2018; Lotfabadi 2014; Pomeroy 2014; Thomas 2012; Wood 2013). Most buildings depend on the use of cooling and heating mechanical devices in different spaces instead of natural resources due to the marginal existence of nature inside buildings. Moreover, the limited availability of open and public spaces has social and psychological impacts on users. Finally, the excessive use of glazed facades could destruct the privacy of the family, and create iconic buildings that ignore the cultural context (Figure 1.4).



Figure 1.4: Recent high-rise developments in the downtown of Amman, Jordan  
(Photo credit: Researcher, 2015)

<sup>6</sup> [www.nfpa.org](http://www.nfpa.org) (accessed on 14/12/2015)

In the same context, the horizontal model of vernacular houses and neighbourhoods has also advantages and impacts on the built environment (Akbar 1988; Al-Masri 2010; Goethert 2010; Rabbat 2010; Bianca 2000). The availability of open spaces, such as the introverted courtyard, provides natural lighting and ventilation to be entered to the different spaces, and at the same time protects the privacy of the family (Figure 1.5). Yet, such an element could not be efficient during rain or dust storms, and could affect thermal comfort of users (Bahammam 2006). Moreover, such houses are expanded on the plot area with no setbacks. At the scale of the neighbourhood, many scholars outlined the dynamic relationship between the physical form, such as size, shape patterns, orientation, availability of public spaces; and social/environmental dimensions, such as privacy, social interaction, and energy performance (Mohamed 2010; Crouch and Johnson 2001; Al-Masri 2010; Edwards *et al.* 2005).



Figure 1.5: A typical courtyard house in Damascus, Syria  
(Source: [http://www.habitz.ch/Bildergalerie/Syrien/syrien\\_en.htm](http://www.habitz.ch/Bildergalerie/Syrien/syrien_en.htm), accessed on 20/4/2018)

#### 1.2.4. The Design of Sustainable Residential Developments

Architects are trying to transform all design requirements into forms and spaces through adopting processes, and series of goal-oriented steps. Computation, as a tool for manipulating ideas and solving problems that are routinely made by computer, could be used for addressing the different dimensions of sustainability. Currently, the main focus of computational models is primarily limited to building performance, optimisation, and the functional requirements of the design problem. Yet, qualitative factors, such as social, cultural and contextual aspects are also important as they lead the building to be in harmony with the context and the needs of users. Integrating these criteria in the

computational process remains a challenge due to the difficulty of algorithmic representation (Yüksel 2014).

Different methods, such as shape grammar and space syntax, consider the morphology and the internal structure of the overall form and its components. Space syntax approach, developed by Hillier and Hanson in 1984, is used to understand spatial topologies and social relations implicit in the architectural setting. However, studies focusing on how such an approach might be used to generate or inspire new designs are limited (Lee *et al.* 2013). On the other hand, shape grammar, developed by George Stiny and James Gips in 1972, is based on the use of typological analysis methods by formulating spatial relationships, parameters, rules and restrictions. Moreover, it is a systematic process for generating new alternatives that depend on the use of shapes rather than symbolic computations. However, designers could face some limitations when they apply such a formal approach. Shape grammars do not show social, cultural or environmental aspects of the composition (Colakoglu 2000). Moreover, some of the design possibilities that are produced by applying shape grammar have no architectural meaning or are irrelevant (Eilouti and Al-Jokhadar 2007).

### **1.3. Research Aim, Questions and Objectives**

Spatial features that promote social sustainability were neither fully explored nor widely recognized in recent developments (Al-Kodmany 2018; Magee *et al.* 2012; Cuthill 2010; Colantonio 2008; Partridge 2005). This study aims to contribute to this growing area of research through developing a method for addressing the social aspect in the design of high-rise residential buildings, which could reflect the specifics of the cultural context, enhance the social life between neighbours, and improve the well-being qualities, such as privacy and security. Moreover, it seeks to find a mechanism for the representation of social realities in computational models, which allows architects to discover logical spatial topologies based on social norms, and produce sustainable solutions for high-rise residential buildings.

In order to accomplish this aim, the research explores the following **key questions**:

1. **What** are factors that affect social sustainability in residential buildings?
2. **How** to measure and code qualitative aspects of designs, and integrate these qualities with geometrical parameters?
3. **How** could provide an evidence about aspects of social sustainability in current high-rise residential buildings and vernacular houses/neighbourhoods in the study area?

4. **How** to design a flexible computational tool that guides the emergence of socially sustainable high-rise residential buildings?

The **research objectives** are set to embrace the following:

1. **A critical/typological analysis study:**

- Identify key indicators of social sustainability in residential buildings, and the different methods/tools for quantifying these criteria spatially.
- Examine aspects of social sustainability in current residential buildings and vernacular houses/neighbourhoods.
- Extract spatial parameters that promote social/cultural sustainability in residential buildings.

2. **A phenomenological study:**

- Investigate residents' experiences of living in new residential buildings, and examine aspects of social sustainability in their apartments.
- Identify social and spatial preferences of residents in the study area.

3. **A computational/parametric design study:**

- Find a mechanism for measuring and coding social qualities of designs, and then integrating these aspects with geometric and spatial requirements.
- Create a computational design tool for architects, which guides the emergence of prototype sustainable solutions for high-rise residential buildings that have cultural relevance, and respond to the preferences of residents and requirements of designers.

## 1.4. Research Design and Methodology

The development of a computational design tool for generating socially sustainable high-rise residential buildings needs a smart and sensitive approach, associated with the ideals, preferences, and expectations of users, and the ability to deliver the local lifestyle for residents.

To achieve these goals, three main approaches are adopted in the study:

1. **A phenomenological approach.** It aims to investigate the current situation of residential buildings in the study area, and address the different preferences of residents. Data in phenomenological approach are presented as an interpretation of meanings, motives, people's experiences, attitudes, perceptions, and patterns of everyday actions within the context (Porta and Keating 2008; Haralambos and Holborn

1995). The goal of such an approach is to build generalisations and suggestions that enhance the different aspects of social life (Packer-Muti 2009). A triangulation of two sets of methods is used. The first set is qualitative, which includes observations, field notes, photographs, and interviews with designers. The second set is quantitative, which includes questionnaires to be distributed to families and residents.

- a. Observations and field surveys: the social world and the behaviour of people could be objectively observed and recorded. It is a useful technique to study the life of individuals, engage in conversations, and develop understanding about the setting (Creswell 2014; Bryman 2016). For this study, non-participant observations are useful for observing the daily lifestyle and routine activities of the family inside their home, documenting the spatial hierarchy and movement inside the house, and searching for any specific treatment and its relation to social and environmental purposes.
- b. Interviews: conducting interviews offers a collection of themes and detailed answers to understand the phenomenon being investigated (Suter 2012). In-depth interviews with architects are useful to outline an understating of their design philosophies of how the context and the cultural identity could be reflected. Moreover, it deals with exploring their different strategies for enhancing social interaction and achieving the privacy of the family.
- c. Questionnaires: As the study area includes different countries, distributing a questionnaire is an affordable method to capture the current situation of residential buildings, and address the different wants and preferences of users.

**2. A 'spatial reasoning' approach.** It aims to explore the spatial design of traditional and contemporary residential buildings. It is a logical process of analysis that enables designers' understanding of the layout complexity, and the exploration of features that have social or experiential significance (Abshirini and Koch 2013). Such an approach includes two types of analysis:

- a. Typological and formal-geometric analysis, which involves categorising components of designs that have shared characteristics according to predefined criteria, such as location, area, geometric properties, and patterns of arrangement (Eilouti 2009).
- b. Space syntax analysis, which explores how spaces are related to each other (topological relations), and social patterns implicit in the architectural setting (Hillier 2014; Sayed 2012; Emo *et al.* 2012).

**3. A computational design approach.** It aims to create a database for designers to generate sustainable high-rise buildings. Information gained from the analytical process, and responses collected from interviews and questionnaires, will be used to establish a database that identifies design elements (vocabularies) and spatial relationships between these features according to predefined criteria (rules and specifications). Shape grammar, developed by Stiny and Gips (1972), is adopted as a rule-based system for generating layouts. A shape grammar is composed of four components: (1) a finite set of shapes; (2) a finite set of symbols; (3) a finite set of shape rules; and (4) an initial shape (Stiny 1980a). However, such an approach needs to address social and cultural aspects of the design. Thus, a method of representation for social/cultural qualities in the computational process will be explored in this study. Moreover, creativity, flexibility, and adaptability are also important issues that need to be considered. Therefore, a parametric design approach that identifies parametric shapes and proportional relationships within certain limits (Stiny 1980b), will be incorporated in the construction of the grammar to generate new solutions that belong to the same stylistic language. Finally, the constructed grammar will be translated into a computation tool, using Rhino/Grasshopper software.

Accordingly, the research is outlined in **five phases**:

**Phase (1): Data collection.** This phase includes:

- Identifying indicators of social sustainability, and how these aspects could be measured.
- Collecting floor plans and drawings for contemporary residential buildings, historical houses and neighbourhoods.
- Conducting field works and observations.
- Conducting interviews with architects.
- Distributing questionnaires to families.
- Reviewing design processes and computational models that could be used for the analysis and the generation process.

**Phase (2): Data analysis.** This phase includes:

- Developing a scheme of analysis for addressing the different qualities of the selected cases.
- Encoding spatial and social qualities of traditional and contemporary residential buildings.

- Comparing results of analysis for traditional houses and clusters of houses, with contemporary residential buildings.
- Encoding and analysing responses from interviews and questionnaires.
- Examining relationships (correlations) between the different factors of the design.
- Translating spatial and social criteria into specific parameters and design briefs.

**Phase (3): Grammar construction.** This phase combines social preferences gained from the social survey, in addition to spatial constraints that promote aspects of social sustainability in residential buildings, in a rule-based parametric design tool, based on shape grammar approach. The grammar will also address the different requirements of high-rise residential buildings through identifying design elements (vocabularies) and spatial relationships between these features according to predefined criteria (rules and specifications).

**Phase (4): The development of a computational design tool.** This phase includes the translation of the constructed grammar for high-rise residential buildings into an interactive computational design tool, using Rhino/Grasshopper software. The tool aims to offer architects a design brief, spatial parameters, and topological relationships between spaces that have the potential to generate a socially sustainable high-rise residential building.

**Phase (5): The generation of new solutions, validation of results, and usability evaluation for the tool.** This final phase includes:

- The generation of new solutions for vertical residential buildings using the developed parametric design tool.
- Validation of results, through examining the different social, spatial, and economic qualities of new solutions generated by the developed tool.
- Usability evaluation for the developed computational tool, through conducting an experimental study. The target sample is professional architects, and architecture students.

The following chart (Figure 1.6) illustrates the framework of the study, which summarises the research questions, aims, objectives, approaches, methods, and stages. A large-size version is included in (Volume 2: Appendix (1-1)).

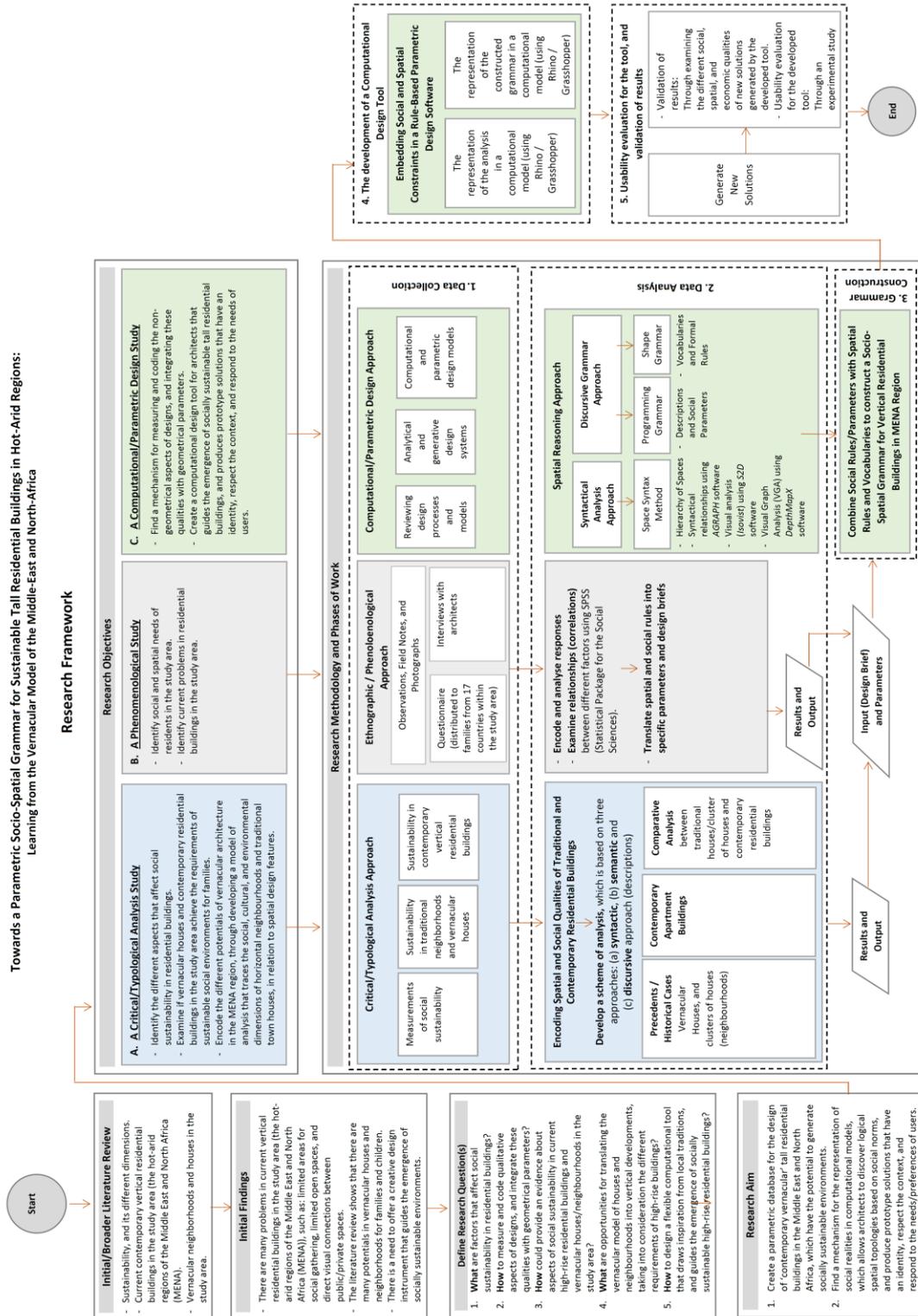


Figure 1.6: Research framework

## 1.5. Structure of the Following Chapters

The thesis includes two volumes. In **Volume One**, the overall structure of the study takes the form of six chapters, including this introductory chapter (Chapter One).

**Chapter Two** include two parts. Part (A) starts with a theoretical background of the research, and looks at the concept of social sustainability in residential buildings, through exploring the morphology of two models: the contemporary model of high-rise residential developments, and the vernacular model of houses and neighbourhoods in the hot-arid regions of the Middle East and North Africa. The conclusion from this part summarises problems and potentials of both models, research gaps, and the approach for generating sustainable living that facilitate the synergy of socio-climatic qualities relevant to the specifics of the place. Such a complicated process needs specific actions and a series of steps that are efficient to be manipulated by computers. Therefore, Part (B) from Chapter Two reviews the different models of design processes. Moreover, an overview about computational design process, and the different potentials and limitations of analytical and generative systems that are useful for achieving the goal of the study, are presented.

**Chapter Three** concerns with the design of this research. It starts with outlining different theoretical paradigms and research approaches. Moreover, it addresses a detailed framework for the study and the different phases, methods, and techniques that are adopted for answering research questions.

**Chapter Four** investigates social and spatial qualities of residential buildings in MENA Region. It includes two parts. Part (A) presents data collected from different resources, such as: observations, interviews, and questionnaires. Moreover, it shows the analysis of the collected data to be used for the extraction of spatial and social preferences of users. Part (B) presents the spatial analysis of different contemporary and historical cases for residential buildings in the study area. Results of analysis are encoded to establish a socio-spatial design brief for residential buildings in MENA region.

**Chapter Five** includes three parts. Part (A) presents the construction of two types of grammars that combine spatial rules and social constraints; the first type is for traditional neighbourhoods, and the other type is for vernacular houses. Part (B) illustrates the construction of a social-spatial grammar for high-rise residential buildings that combines the two types of grammars for the vernacular model of houses and neighbourhoods, in addition to the requirements of high-rise buildings. Moreover, it illustrates the translation of the

grammar into a computational design tool, using Rhino/Grasshopper software, to facilitate the generation of high-rise residential buildings. Part (C) examines the developed computational tool through an experimental study, by asking professionals and architecture students to use the tool for the design of a multi-story residential building. Different solutions generated by participants, in addition to alternative produced by the researcher, are validated through analysing spatial and social qualities of results. Moreover, a usability evaluation for the tool, which assesses three criteria: efficiency, effectiveness, and satisfaction, through distributing a questionnaire to the participants in the experimental study, is presented.

**Chapter Six** presents a summary of the findings, the research conclusions, practical applications and implications, and recommendations for future studies.

**Volume Two** includes appendices that provide detailed drawings and illustrations for spatial and social analyses for the selected cases, the constructed grammars, the developed computational tool, and the analysis of new solutions generated by the tool. Figure (1.7) shows the layout of the overall thesis.

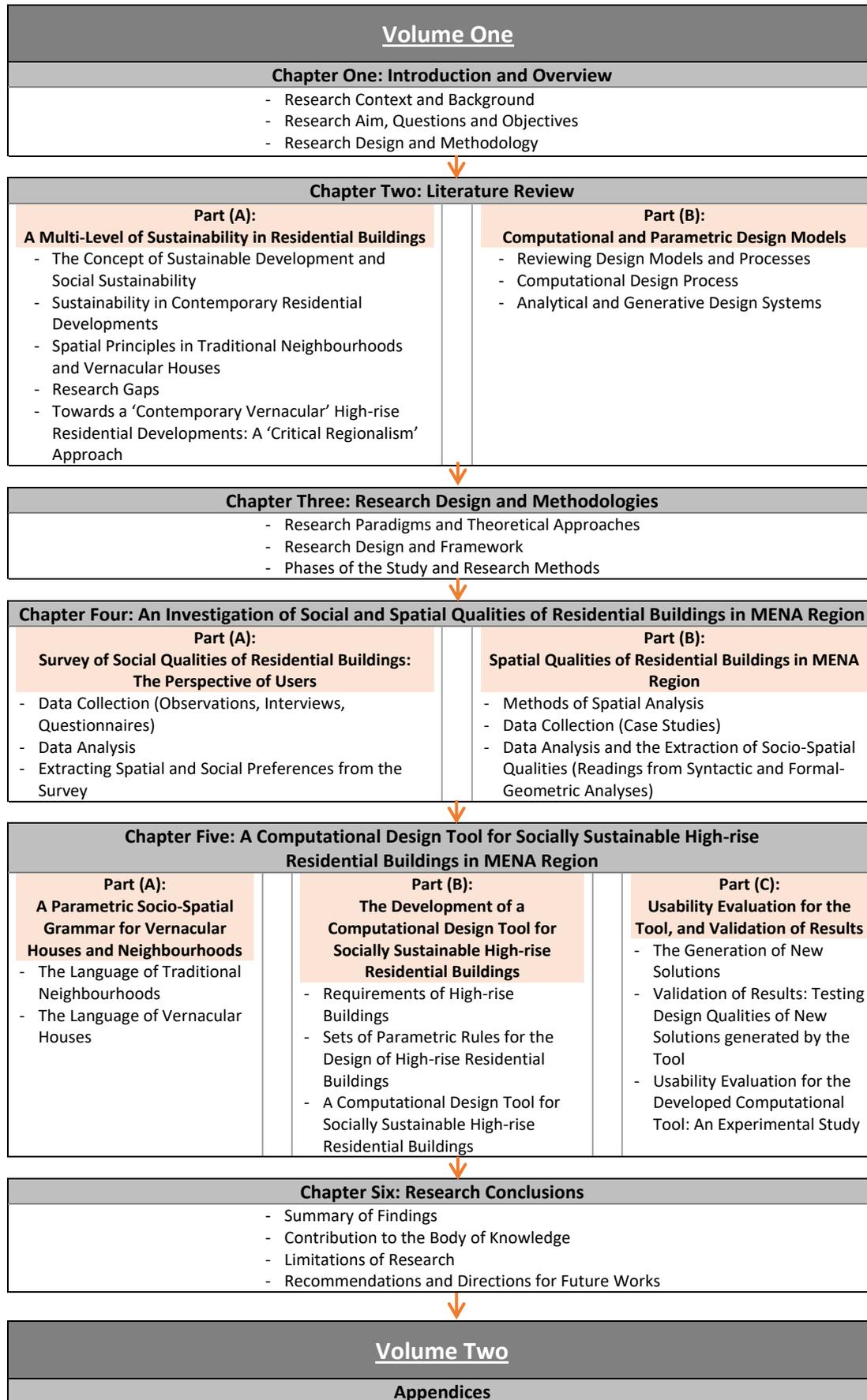


Figure 1.7: Structure of the thesis

## Chapter Two

### **Literature Review**

**Part (A): A Multi-Level of Sustainability in Residential Buildings**

**Part (B): Spatial Qualities of Residential Buildings in MENA Region**

## Chapter Two

# Literature Review

### 2.1. Introduction

This chapter aims to provide a review about the concept of sustainability in residential buildings, which is presented in (Part A), in addition to the different analytical and generative systems that are useful for addressing such a concept in the design process (Part B).

In Part (A): “A Multi-level of Sustainability in Residential Buildings”, the following sections are presented. Section (2.2) addresses the evolution of sustainability in the built environment, and focuses on features that promote social sustainability and human needs. Section (2.3) reviews aspects of sustainability in contemporary high-rise residential buildings, and examines the different potentials and impacts of such developments. Section (2.4) evaluates the vernacular model of houses and neighbourhoods in the study area. The discussion considers advantages and disadvantages of these cases, in addition to relationships between spatial organisations, social patterns, environmental considerations, and economic effects. Section (2.5) addresses research gaps that need further studies. Section (2.6) introduces the approach for designing a contemporary high-rise building that facilitates the synergy of social, economic and environmental qualities relevant to the specifics of the place.

Part (B), “Computational and parametric design models”, starts with reviewing different design models and processes to select the most appropriate approach for achieving the goals of the study. This review is presented in Section (2.7). Moreover, an overview about computational design process, and the different analytical and generative systems that are useful for understanding the social logic of spaces, and its relation to spatial arrangements of design elements, are presented in Sections (2.8) and (2.9). Implications and limitations of these models will be raised in Section (2.10) to be considered during the implementation of the research.

Figure (2.1) illustrates the literature review plan for the study through identifying the research problem, the key terms and resources that were used to define the objectives and construct the research questions.

Literature Review Plan

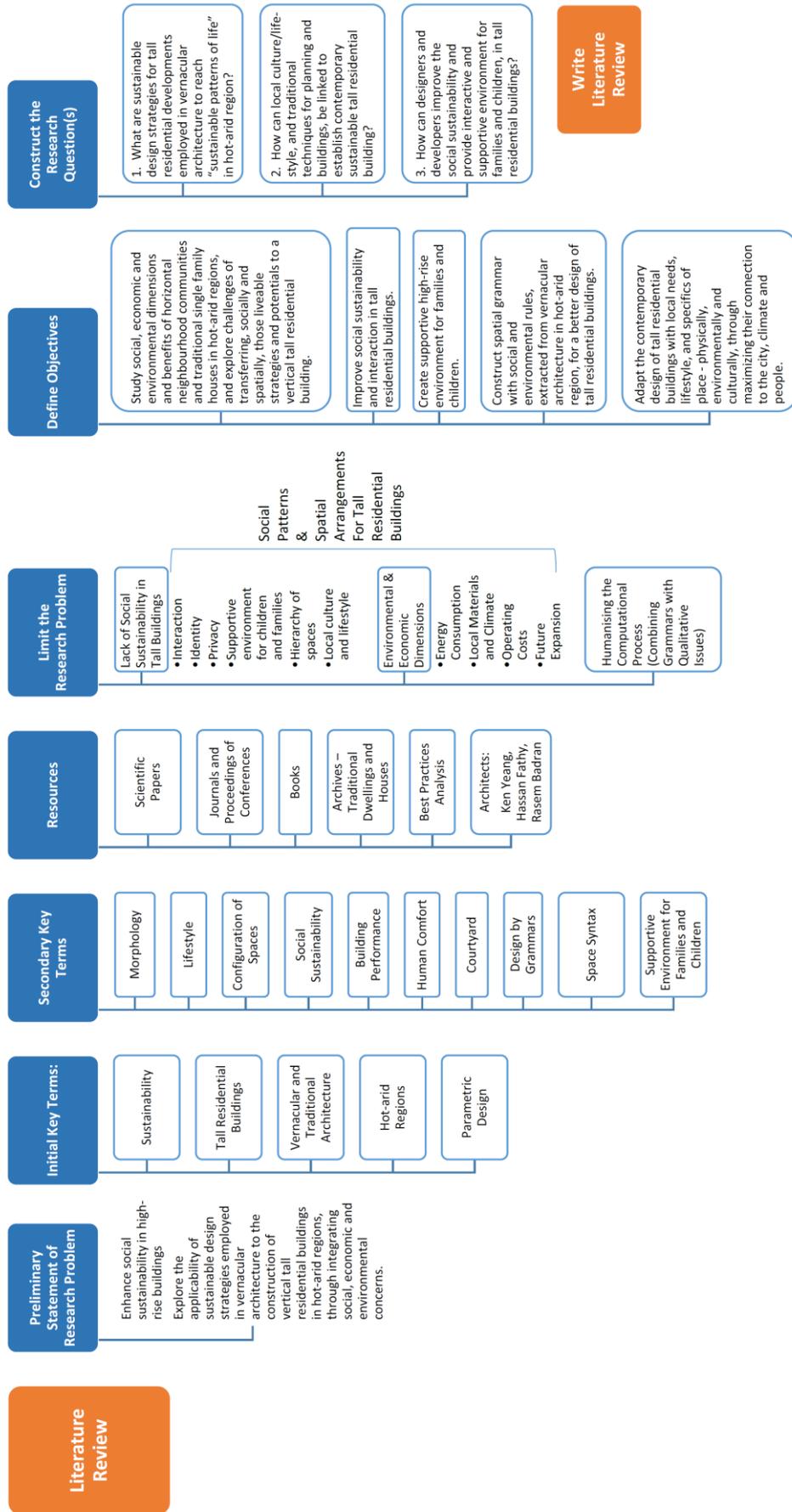


Figure 2.1: The literature review plan

## Part (A): A Multi-level of Sustainability in Residential Buildings

### 2.2. The Concept of Sustainable Developments

The term 'sustainability' or 'sustainable development' has been defined by many scholars in different areas. According to Oxford Dictionary<sup>1</sup>, the term '**sustainable**' is defined as 'able to be maintained at a certain rate or level; conserving an ecological balance by avoiding depletion of natural resources'. The term '**sustainable architecture**' may be defined as the management of the architectural design through employing design techniques that minimise environmental degradation and make use of low-impact materials and energy sources. In economics, the term 'sustainability' is used by nations that had rare resources, and at the same time favoured fast returns and economic growth (Tzonis 2006).

In the field of architecture and built environment, the 'World Commission on Environment and Development (WCED), 1987', which is known as the 'Brundtland Commission of 1987', provides a definition of sustainability as 'a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional changes are made consistent with future as well as present needs'. Johnson (1995) defined sustainability as a concept of utilising technology concerning nature and society, in a morally and socially responsible manner. Alshuwaikhat and Nkwenti (2002) developed a definition that emphasises the practice of increasing energy efficiency and human comfort by using passive systems for heating, cooling and ventilation, and by using natural and renewable materials, to reduce the impact of buildings on the human being and the environment.

However, sustainability is not only concerned with technologies, but it also with sustaining life and creating synergy among economic, environmental, social and cultural qualities (Figure 2.2). These three pillars could be represented as the "3Ps" of people, profit, and the planet (Al-Kodmany 2018), where:

- "People" represents community well-being and equity (the social dimension).
- "Profit" represents economic vitality (the economic dimension).
- "Planet" represents conservation of the environment (the environmental dimension).

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<sup>1</sup> <http://www.oxforddictionaries.com> (accessed on 25/01/2016)

Low operating costs and the use of local materials are major issues that need to be considered to achieve economic sustainability. At the level of environmental sustainability, architects and engineers need to consider the local climate to offer thermal comfort and energy reduction. Finally, social and cultural sustainability is about designing for social impact and improving the quality of life (Schwarz and Krabbendam 2013; Woodcraft 2012; Berkeley-Group and UK-GBC 2012). Such issues could be achieved by combining the design of the physical environment with users, providing supportive environments for families, preserving their privacy, and reflecting the local lifestyle and culture.

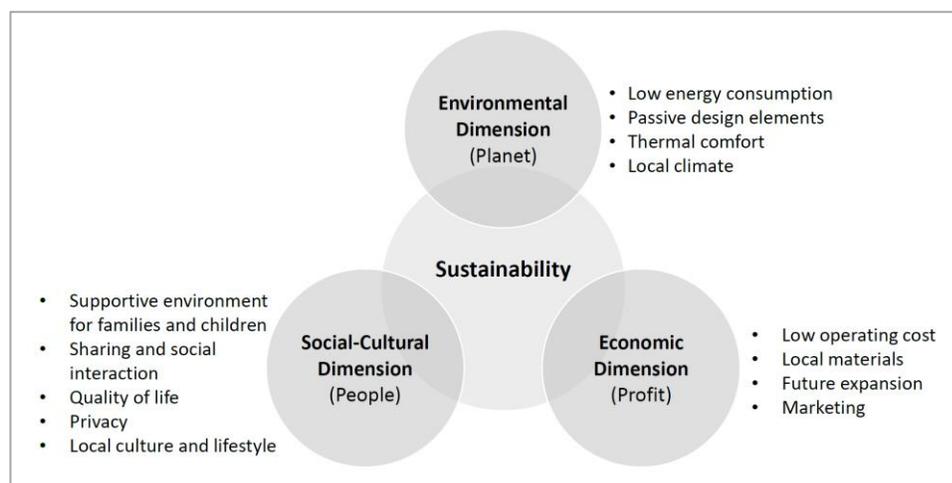


Figure 2.2: Dimensions of sustainability  
(Researcher)

Yet, social sustainability in recent developments has considerably less attention than economic and environmental dimensions, and it was neither fully explored nor widely recognised (Al-Kodmany 2018; Magee *et al.* 2012; Cuthill 2010; Colantonio 2008; Partridge 2005).

### 2.2.1. Social Sustainability

Social sustainability is about creating a good quality of life for current and future generations (Partridge 2005; Newman 2003). According to McKenzie (2004, p.12), social sustainability is a '*process that can achieve a life-enhancing condition within communities*'. Such a system could be promoted through different features:

- Equity of access to key services.
- A system of cultural relations that are valued and desired by individuals and groups.

- A sense of community and responsibility for maintaining the system.
- A mechanism for identifying strengths and needs of the community.

To ensure the realisation of the basic needs of the community, it is useful to review Maslow's theory of human needs. In his paper "A theory of human motivation" in *Psychological Review*, Abraham Maslow (1943) stated that people are motivated to act and respond to various situations to satisfy and achieve a series of physical, psychological and self-fulfilment needs in a hierarchical system. The initial model includes five levels in a pattern that human motivations generally move through:

- Level (1): Biological and physiological needs, which include the physical requirements for human survival (air, food, drink, shelter, warmth, sex, and sleep).
- Level (2): Safety needs, which include personal protection, financial security, health and well-being, order, stability, and freedom from fear.
- Level (3): Belongingness needs, which focus on creating a sense of belonging and acceptance among social groups, friendship, intimacy, and trust.
- Level (4): Esteem needs, which develop a concern with getting recognition, reputation, importance, and respect from others.
- Level (5): Self-actualisation needs, which focus on realising personal potential to accomplish everything that one can, seeking personal growth and peak experiences.

Due to external circumstances and individual differences, Maslow expanded the model in 1970, to include cognitive, aesthetic, and transcendence needs (McLeod 2017):

- Level (6): Cognitive needs, which focus on knowledge and understanding, curiosity, exploration, meaning and predictability.
- Level (7): Aesthetic needs, which entail appreciation, and search for beauty, balance, and form.
- Level (8): Self-transcendence, which is the most holistic level of human consciousness.

Another attempt to develop a model of social sustainability has been undertaken by Schwarz and Krabbendam (2013). They identified four qualities for socially sustainable designs: (1) sharing; (2) reflecting local experiences; (3) connecting people and their living environment with nature; and (4) focusing on proportion and human scale.

In terms of social qualities in residential buildings, Al-Kodmany (2018), in the review about “The sustainability of tall building developments: a conceptual framework”, addressed the following criteria that need to be considered in the design of new developments:

- Suitability for family and community living, which aims to respect the psychological and social needs of children and families, through offering recreational and gathering spaces that enhance social interaction between neighbours, and limit isolation and loneliness, as there is a distance from the social life on the street.
- Security and safety, which considers fire protection and providing secure spaces for children and families.
- Human scale, in terms of the height of the building and proportion of spaces, as these are essential for providing comfort to users.
- Population density and crowding, which considers number of families live in the building in relation to the area of common spaces.
- People’s choice, taking into consideration preferences of residents.
- Health and well-being, to limit emotional stress and other negative psychological conditions.

Based on human needs, and the extensive literature review regarding social sustainability and behavioural studies (Al-Kodmany 2015; Modi 2014; Oldfield 2012; Schwarz and Krabbendam 2013; Lang 1987; Taylor 1985; Rapaport 1969a; Maslow 1943), the researcher identified 13 social indicators that need to be addressed in the design of residential buildings. Such aspects are important for achieving human needs and better qualities of life. Each indicator is linked with the spatial design of buildings, in order to facilitate the design process, and ensure the translation of these social qualities.

- *Social Indicator (1): Population Density and Crowding*

It is important to offer different types and areas of apartments based on the size of the household structure (single, couple, couple with children), as each type needs different number of rooms and functions. Moreover, designers are required to study area of common spaces in the building/neighbourhood, width of alleys and transitional spaces between houses, and number of apartments on each floor of the building, or number of houses in the neighbourhood (Al-Kodmany 2018). Such issues are important to create

solutions that are not crowded and appropriate to the number of residents live in the house, building, or cluster.

- *Social Indicator (2): Hierarchy of Spaces*

The hierarchical transition from public to private zones, and from formal to less formal spaces, are essential considerations in buildings, neighbourhoods, and inside the house to attain an accepted level of privacy and comfort for residents (Taylor 1985; Mitchel 2010).

- *Social Indicator (3): Social Interaction and Area of Living Spaces*

Social interaction between neighbours could enhance social support, sharing, and sense of community (Goethert 2010). Such issues could be easily encouraged through offering gathering spaces and shared areas between houses, where residents and children can meet, talk and play. Moreover, availability of living spaces that have appropriate area in relation to the size of the family offers a comfortable space for daily-living activities.

- *Social Indicator (4): Human Comfort*

Human comfort is affected by three factors: (1) thermal factors that are calculated as a heat transfer energy balance; (2) physical factors, which include: air temperature, mean radiation temperature, relative humidity, light intensity, and air velocity; and (3) personal factors, which include: age, gender, state of health, clothing and the level of activity (Essays-UK 2013; Boduch and Fincher 2009).

Such factors could be achieved through the spatial design of houses, residential buildings, and neighbourhoods. For instance, in hot-arid climate, it is important to offer shaded alleys, open spaces, and green areas that are protected from the direct sun, and at the same time allow the penetration of natural ventilation and lighting. Other aspects that have an impact on thermal comfort is area of glazed facades; availability of special treatments, such as shading devices, louvers, screens, water features, wind towers, or greenery; thickness of walls; and construction materials. Moreover, geometric properties, proportion, height, and orientation of spaces could affect the human comfort inside buildings, apartments, and clusters of houses.

- *Social Indicator (5): Accessibility*

Availability of transitional areas and circulation elements, with proper width, area, spatial arrangement, and special treatments (such as ramps and handrails) are important features that affect movement and accessibility inside buildings and between houses in neighbourhoods. In addition, arrangement of functions and facilities in vertical buildings, or multi-floor houses, and avoiding differences in levels should be considered especially for the elderly and children. Moreover, offering more than one entrance for the building, neighbourhood, or large-size residential units could provide flexibility and different circulation alternatives for residents.

- *Social Indicator (6): Visual Privacy*

Protecting the house from direct views is an essential issue for achieving a visual privacy for the family. A proper distribution of spaces and openings, and offering special treatments, such as screens, partitions or greenery in front of private spaces, are potential solutions for maintaining the privacy of the family (Zako 2006; Bianca 2000).

- *Social Indicator (7): Acoustical Privacy*

Protecting interior spaces from noise is a need in the design of residential buildings as it affects the comfort of users (Essays-UK 2013). Such a quality could be achieved through studying the spatial arrangement of quiet zones and living activities inside the house. Moreover, treatments for walls, floors, and windows using special materials and appropriate thicknesses, and height of spaces are essential issues to avoid the penetration of residents' voices or sound reflections to the outside streets and their neighbours (Sözen and Gedik 2007; Sobh and Belk 2011; Mortada 2003). Ragette (2003) recorded that balconies give 9 dBA noise reduction, windows with staggered openings give 20 dBA reduction, double windows give 40 dBA reduction, 20 cm block walls give 45 dBA reduction, and 25 cm block walls give 50 dBA.

- *Social Indicator (8): Olfactory Privacy*

Controlling smells produced in kitchen and sanitary facilities to spread out to other spaces, primarily the zone for guests, can deeply affect the comfort inside the house (Othman *et al.* 2015; Boduch and Fincher 2009). Such a need could be regulated through the orientation of openings and open spaces, or providing green areas and flowers.

- *Social Indicator (9): Spirituality*

Sometimes, orientation of spaces inside houses could have a symbolic and specific meaning of spiritual focus. Moreover, special treatments for sleeping areas, dining rooms, or bathrooms, and the availability of fountains, trees and green areas play an important role for creating a spiritual atmosphere and comfort for residents.

- *Social Indicator (10): Security and Safety*

Providing secure and safe spaces for children and families is an important issue in residential environments. Such a priority could be achieved through offering fences on balconies and terraces, secure gates for houses and buildings, in addition to proper treatments for open spaces and common areas that are connected with the outside context.

- *Social Indicator (11): Views to the Exterior*

Residents wish to have an access to the outside environment to enjoy the views, especially on upper floors, and to have a connection with the social life on the street. This issue could be treated through offering open spaces, terraces, balconies, and glazed facades that are connected directly with the outside context. However, designers need to consider the privacy of the family during the arrangement of such features.

- *Social Indicator (12): Availability of Services*

Availability of storage areas, suitable number of sanitary services in relation to the area of the house, and a secondary entrance that is connected directly with kitchen, could be considered major requirements for houses. Moreover, allocating residential buildings near commercial facilities and services could have positive impact on residents.

- *Social Indicator (13): Hygiene*

Providing a hygienic atmosphere is an essential requirement inside residential buildings. Adequate natural ventilation and lighting, and good air quality inside houses and common areas in buildings, are important factors for the health of residents, and reducing rates of illness and dampness (Boduch and Fincher 2009). Moreover, special treatments, such as the separation of clean areas from services, entrances, and open spaces, using gates, sunken areas, or thresholds, could be adopted for preventing dust entering spaces. Another issue that could be addressed to block excessive air movement

that carries sand and dust, is the arrangement of alleys in neighbourhoods, and open spaces in buildings/houses.

The following two sections (2.3 and 2.4) provide a critical review about the spatial design of contemporary high-rise residential buildings, and vernacular houses/neighbourhoods in the study area, respectively, and how it could affect aspects of sustainability.

### **2.3. Sustainability in Contemporary High-rise Residential Buildings**

Since the emergence of oil revolution in the middle of the 20<sup>th</sup> century, and the process of modernisation, different social, economic, cultural and urban transformations have led to the construction of new types of villas and apartment buildings (Samizay 2010). The following section inspects aspects of sustainability in these contemporary buildings in the study area, especially the high-rise model, through reviewing advantages and impacts of such developments. This review is useful to define research gaps that need to be explored and solved.

A tall building is a massive built up spaces on a small footprint. Ken Yeang (2012) claims that this considerable volume could be defined as a '*vertical city*', which requires designers to take into account different social, environmental, and economic sustainable requirements during the design process. This '*vertical city*' needs to achieve the following qualities: (1) accessibility and proper pedestrian linkages; (2) availability of public ground spaces and shared services; (3) providing a comfortable environment; and (5) offering a sense of place. It has been argued that if a development is to be genuinely sustainable, a balance between the needs of users and nature is vital through a careful consideration for spatial, cultural, and technological requirements (Pomeroy 2014). In that sense, Bay and Ong (2006) proposed that social and economic dimensions should be developed and integrated with environmental criteria in the assessment of sustainable housing developments, which therefore, could contribute not only towards a more sustainable quality of living, but also to quantitative environmental performances.

Many benefits, such as preserving natural and green spaces in the city, reducing suburban spread and loss of countryside, and locating various services within suitable walking distances from units could be achieved (Wood 2008). Moreover, these buildings increase the access to view, light, and air at height. On the other hand, there are many impacts of these buildings on

the urban fabric of the city, and on users. Most tall structures consume high energy as they depend on the use of cooling and heating mechanical devices in different spaces instead of natural resources such as wind and sun (Al-Kodmany 2012; Al-Sallal 2004; Niu 2004). Moreover, the existence of nature, recreational, communal and open spaces is limited and marginalised (Al-Kodmany 2018; Li *et al.* 2012; Li 2013; Kennedy *et al.* 2015; Kennedy and Buys 2015; Roaf *et al.* 2005).

### **2.3.1. Social-Cultural Dimension**

Cultural sustainability seeks to preserve social and spatial practices against the imposition of a modern built environment that lacks cultural relevance (Pomeroy 2014). In the study area, where the context of increasing population, global urbanisation, high land prices, and developer's egos for height increase, tall buildings are a dominant architectural typology in the city. Although these developments create a prestigious vertical image for the city, and use contemporary materials and glazed facades, many scholars panned these buildings as a reflection of the interests of developers to maximise their profit without considering the specifics of the cultural context (Wood 2013; Goncalves 2010; Kearns *et al.* 2012; Gifford 2007). Alistair Guthrie (2008), for example, noted that many of today's tall buildings promote the concept of environment for elitists rather than support community life. Robert Dalziel (2012) stated that the occupants of a high-rise building cannot identify their cell from the street, so, their sense of appearance of the place is bounded up in the impression of the building and the neighbourhood as a whole. This reflection of the context is much more natural in houses and low-rise buildings as they could be distinguished by colour, facades, roof shapes, or materials.

Another study, conducted by Professor Ade Kearns and his colleagues (2012) in Glasgow, examined the impact of living in high-rise buildings in comparison to other dwelling types. They measured different social outputs (such as cohesion, social contact with neighbours and friends, and social support), and concluded that high-rise flats have the highest negative impacts on residents (Table 2.1). These impacts could be summarised in six categories:

- Fear, insecurity, and crime.
- Mental and physical health effects due to the small size of units and overcrowded spaces.
- Lower sense of community and familiarity with neighbours.
- Lower levels of social support and social development due to isolation.

- Impacts on families and children as parents keep their children indoor due to safety concerns and difficulties of supervision at a distance, which therefore cause psychological distress, behavioural and learning difficulties, slower social development of the children; and more isolation for parents.
- Lack of identity for each unit due to the standardisation of floor plates.

Table 2.1: Impacts of living in high-rise buildings in comparison to other dwelling types (Kearns *et al.* 2012)

| Social Outcomes                               | Dwelling Type       | %    |
|---|---------------------|------|
| Poor cohesion                                 | House               | 15.7 |
|   | Apartment buildings | 15.9 |
|   | High-rise flat      | 26.3 |
| Low social contact with relatives and friends | House               | 15.8 |
|   | Apartment buildings | 16.5 |
|   | High-rise flat      | 20.3 |
| Low social contact with neighbours            | House               | 13.6 |
|   | Apartment buildings | 15.5 |
|   | High-rise flat      | 29.3 |
| No available social support                   | House               | 17.0 |
|   | Apartment buildings | 18.0 |
|   | High-rise flat      | 24.2 |

To find solutions for some of these issues, architects suggest to integrate gardens and communal spaces in the design of tall buildings to enhance social qualities. Pomeroy (2007) proposed the concept of inserting semi-open spaces (such as sky-courts, sky-terraces and sky-roofs), which allow for users a freedom of movement, social interaction, and the opportunity to observe skylines and panoramic views. In her research “Improving the social sustainability of high-rises”, Surchi Modi (2014) outlines many advantages for inserting such social spaces in residential buildings (Table 2.2). These include: offering opportunities for unplanned participation, creating a pleasurable and exciting environment, enabling adaptability of spaces to be extended, and reaching a level of hierarchy between spaces. However, different challenges need to be addressed while designing these spaces. Firstly, mixing residential units with other functions would promote social interaction, connect buildings with the context, and generate more value for the property. Secondly, distributing social spaces through the height of the building rather than concentrating only on one level, and providing alternative paths and routes for the residents, could encourage social interaction between them (Modi 2014).

Table 2.2: Advantages of social spaces in low-rise and high-rise residential buildings  
(Adapted by Researcher, after (Modi 2014))

| Advantages of Social Spaces in Low-rise Residential Buildings  | Advantages of Social Spaces in High-rise Residential Buildings  | Challenges and Solutions to the Provision of Social Spaces in High-rise Residential Buildings  |
|--|---|--|
| <ul style="list-style-type: none"> <li>- <b>Access:</b> movement along horizontal planes through a variety of social spaces offers an opportunity for both physical and visual interaction, and makes the walk more pleasurable and exciting.</li> <li>- <b>Participation:</b> front gardens create opportunities for unplanned participation.</li> <li>- <b>Adaptability:</b> the ability to expand and grow is easily enabled by providing back and front yards. This also enhances social bonds within the community, and develops a feeling of ownership.</li> </ul> | <ul style="list-style-type: none"> <li>- <b>Footprint:</b> tall buildings have smaller footprints and consume less land area. This, in principle, leaves more area for green and communal spaces.</li> <li>- <b>Views:</b> having good city views is one of the positive attributes of social spaces in high-rise buildings. This in itself is substantial enough of a reason to bring people into outdoor social environments.</li> <li>- <b>Security:</b> social spaces in contemporary tall buildings tend to be highly secure environments, which therefore reduce the fear of crime, and encourages people to use public facilities.</li> <li>- <b>Safety:</b> movement within a tall building complex is much more comfortable and safer, which can result in more social interactions.</li> <li>- <b>Pollution:</b> As one moves higher, the air gets cleaner and purer, and the noise can be reduced through open gardens.</li> </ul> | <ul style="list-style-type: none"> <li>- <b>Optimisation:</b> a mix of residential spaces with other functions would promote social interaction, and help the developer to generate more value for his property by optimising its use.</li> <li>- <b>Access:</b> most communal spaces are placed on rooftops, or they are visually and physically cut off from the daily paths of movement. Inserting alternative paths and atrium encourages visual interaction and the possibility of social exchange between residents.</li> <li>- <b>Spatial design:</b> social spaces should be well distributed through the height of the building, rather than concentrated only on one level. This helps in establishing a hierarchy of spaces that varies according to scale, proportion, number of occupants, and function. Weather-shield systems and shading devices would ensure a year-round usage.</li> </ul> |

### 2.3.2. Environmental Dimension

Previous studies indicated that high-rise buildings consume more energy than other types of dwellings, as they depend on mechanical air-conditioning and artificial lighting (Al-Kodmany 2015; Kearns *et al.* 2012; Aldawoud and Clark 2008). One approach for reducing energy consumption is inserting passive design systems that are influenced by the local climate. For example, semi-open spaces (such as roof garden, terraces, and sky-courts) could reduce urban 'heat island' effect and minimise the required energy to cool buildings in summer times

(Pomeroy 2014). Moreover, introducing setbacks, projecting cornices, awnings, and canopies, tend to mitigate the potential impact of increased wind.

Other features that could be applied in the hot-arid climate are courtyards and atriums. Aldawoud and Clark (2008) addressed that inserting a courtyard in a high-rise building is more energy-efficient until ten floors, while the atrium option (especially with a skylight) performs better after this height. Results of their experiments showed that a courtyard could reduce the energy consumption by 31% to 43%, depending on the type of glass used around it (Table 2.3).

Table 2.3: Comparing the total energy consumption of courtyards at 10<sup>th</sup>-floor level in a high-rise building (Aldawoud and Clark 2008)

| Type of Comparison  | Total Energy Consumption |
|---|--------------------------|
| A courtyard with double clear glass compared with a courtyard with single clear glass (at the 10 <sup>th</sup> -floor level). | 31% lower                |
| A courtyard with low-e glass compared with a courtyard with single clear glass (at the 10 <sup>th</sup> -floor level).        | 39% lower                |
| A courtyard with clear triple glass compared with a courtyard with single clear glass (at the 10 <sup>th</sup> -floor level). | 43% lower                |

Vegetation, internally and externally, could also improve the environmental quality of tall buildings on the local scale, as part of the shading or air cooling system of the building itself, and the city scale, through enhancing the quality of air and reducing 'heat-island' effect (Wood 2013). In addition, high-rise buildings that are associated with daylight access; visual communication between internal spaces; views toward the exterior; and a direct contact with the outdoor environment, are essential architectural and environmental qualities of sustainable developments (Goncalves 2010).

### 2.3.3. Economic Dimension

Economic sustainability concerns with maximising financial returns on every square meter of floor space, and generating replicable and flexible models (Wood 2008; Dalziel 2012). A tall building has many economic merits at both scales: the building, and the city. Firstly, it could preserve natural and green spaces in the city. Secondly, a high-rise housing could achieve higher energy efficiency; since it has less exposed wall area, low heat loss, and lower resource consumptions compared to other types of housing. Thirdly, various services could be located within a suitable walking distance from units.

However, developers of high-rise buildings tend to support their marketing campaigns through incorporating diverse recreational facilities and mixed-use schemes to harmonise the indoor environment, where a sense of community could be developed, and the satisfaction of residents could be improved (Pomeroy 2014; Wood 2008).

Table (2.4) illustrates a detailed review of previous studies concerned with investigating aspects of sustainability in tall buildings, and the suggested future studies.

Table 2.4: A review of studies concerning sustainability in tall buildings

| Study  | Location, Climate, Year               | Objectives  | Main Findings  | Suggested Future Studies  |
|--|---------------------------------------|---|--|---|
| “Residents’ experiences of privacy and comfort in multi-storey apartment dwellings in subtropical Brisbane”.<br>(Kennedy <i>et al.</i> 2015) | Australia, subtropical climate, 2015. | Explore private residents’ experiences of privacy and comfort, and their perceptions of how will their apartment dwelling modulated the external environment in subtropical conditions.     | <ul style="list-style-type: none"> <li>- Comfort parameters comprise both quantifiable factors (for example, thermal comfort, acoustics, air quality and illumination); and qualitative considerations (for example, perception of privacy and personal control over the comfort of one’s private space)</li> <li>- The availability of natural ventilation and outdoor private living spaces (balconies) play an essential role in the perception of liveability in the subtropical areas.</li> </ul>   | Future design research to be undertaken that perform better socially, economically and environmentally, to assist residents to interact positively with the subtropical climate and urban environment, and to control the intensity of their interaction with neighbours. |
| “The impact of private and shared open spaces on liveability in subtropical apartment buildings”.<br>(Kennedy and Buys 2015)                 | Australia, subtropical climate, 2015. | Study the effect of the balcony as an extension of the home, and how private outdoor spaces such as balconies affect liveability of apartment buildings in subtropical cities in Australia. | <ul style="list-style-type: none"> <li>- Resident satisfaction would be enhanced by the accommodation of open spaces to apartment liveability as a climate-responsive design element to enhance privacy, and to counter the ever-increasing extent of external glazing used in apartment buildings’ materiality.</li> <li>- Most residents (87%) considered the physical and spatial design of the balcony to be an ‘important’ to ‘significant’ influence on their experiences of everyday living functions, spaciousness, privacy and control of indoor environmental comfort.</li> <li>- They used the balcony for a wide variety of social and non-social domestic activities.</li> <li>- Lack of a balcony was considered to be an omission in good apartment design; otherwise, residents want a townhouse and a (private) courtyard where they could go and sit out.</li> </ul> | Future research could focus on materials and spatial characteristics of private open spaces.  |

|   |   |  |   |   |
|---|---|--|---|---|
|   |   |  | <ul style="list-style-type: none"> <li>- A private balcony allowed residents to move to an outdoor space without leaving the apartment.</li> <li>- Visual privacy was considered very important. Residents did not like ‘overlooking’ their neighbours, nor to be ‘overlooked’, and expressed a preference for balconies located on the more ‘anonymous’ street side rather than balconies overlooking communal spaces.</li> </ul>  |   |
| “Improving the social sustainability of high-rise buildings”. (Modi 2014)   | Different locations and climates, 2014. | Study the social benefits of horizontal neighbourhood communities and explores the challenges and rewards of transferring those features to a vertical format.   | <ul style="list-style-type: none"> <li>- Advantages of social spaces in low-rise residential developments: access, participation, hierarchy of spaces, adaptability, and individuality.</li> <li>- Typical advantages of social spaces in high-rise developments: footprint, views, security, pollution, and safety.</li> <li>- Challenges and solutions to the provision of social spaces in residential high-rises: optimization, access, and space design.</li> </ul>  |   |
| “Liveability of high-rise housing estates – case studies in the inner city of Tianjin, China”. (Li 2013)  | Tianjin, China, temperate climate, 2013 | Explore features of high-rise residential buildings and residents’ experience of high-rise living; which reveals the liveability strengths and weaknesses of current high-rise housing developments, and discover the measurement, indicators and dimensions of the liveability of high-rise housing estates, to provide implications for both theoretical research and practical development. | <ul style="list-style-type: none"> <li>- Lack of private and public outdoor activity spaces for children and the elderly was considered one of the main weaknesses of current high-rise housing.</li> <li>- Poor acoustic environment (noise of urban neighbourhood, external and internal sound-proof of dwelling units).</li> <li>- Harsh wind environment in high-rise housing estates.</li> <li>- Lack of public places and facilities within housing estates,</li> <li>- The poor identity of dwelling buildings.</li> </ul> | Traditional housing forms such as multi-level housing projects and courtyard houses are rapidly being demolished and replaced by high-rise housing. It is necessary to carry out a study on the comparison of the liveability between high-rise housing and other housing forms to provide suggestions for urban development. |
| “Liveability of high-rise housing estates: a resident-centered high-rise residential environment evaluation in Tianjin, China”. (Li <i>et al.</i> 2012) | Tianjin, China, temperate climate, 2012 |  |   |   |

|  |   |   |   |
|--|---|---|---|
| <p>“Living the high life’? Residential, social and psychosocial outcomes for high-rise occupants in a deprived context”. (Kearns <i>et al.</i> 2012)</p> | <p>Glasgow, mild climate with no dry season, 2012</p> | <p>Examine the impacts of living in a high-rise in comparison to other dwelling types.</p>  | <ul style="list-style-type: none"> <li>- Many residential outcomes are worse for people in high-rise buildings, primarily related to noise and security issues.</li> <li>- Social and psychosocial outcomes are worse in a high-rise, a particular frequency of contact with neighbours and some aspects of control and recuperation at home.</li> <li>- Negative impacts of high-rise buildings were most wide-ranging among adult-only households rather than families, with older persons least affected by adverse social outcomes in a high-rise.</li> </ul>   |
| <p>“Guidelines for tall buildings development”. (Al-Kodmany 2012)</p>  | <p>Different locations and climates. 2012</p>         | <p>To provide extensive urban and architectural guidelines for the design and layout of tall buildings and open spaces, to manage cityscape and to ensure a safe and healthy living, to enhance the visual experience, to improve the microclimate conditions, and to foster active social life. These guidelines help in providing enjoyable urban experiences through the examination of spatial relationships, human scale, genius loci, perceptual characteristics, local identity, built heritage, economic activities, and social life.</p> | <p>Issues that should be considered while designing a tall building:</p> <ul style="list-style-type: none"> <li>- Urban context: The built heritage, view corridors and skyline, figure, gateways, landmarks, social issues.</li> <li>- Spatial clusters design guidelines: Focal points, visual relief, transition, varying building heights and massing, design diversity, visual coherence, ventilation.</li> <li>- Block considerations: Spacing of towers, transitioning, corridor views and visual privacy, functional connectivity, alignment, sense of enclosure, height-to-width ratio of street, daylight and shadow, weather protection, wind impact.</li> <li>- Tall buildings design guidelines: <ul style="list-style-type: none"> <li>o Base/podium: It should not exceed 5-6 stories in order not to block views to the shaft. A colonnaded base also has the advantage of alleviating the wind uplift around the building and providing extra shelter and protection from the weather for pedestrians.</li> <li>o Stairs: the walking distance to an exit staircase must not exceed 30 m.</li> </ul> </li> </ul> |

|   |  |   |   |
|---|--|---|---|
|   |  |   | <ul style="list-style-type: none"> <li>○ Refuge floors for super-tall buildings are designed mainly as firebreaks where people can take shelter while waiting for evacuation.</li> </ul>  |
| <p>“Environmental issues in high-rise residential building design in urban areas”. (Niu 2004)</p> | <p>Hong Kong, subtropical climate, 2004.</p> | <p>Achieving comfortable and healthy indoor environment, and minimising energy consumption for residential high-rise buildings become a challenging engineering and societal issue. With the typical tower design, an individual apartment is likely to face merely one single direction. Also, to provide a view to the occupants, large, convex-shaped windows have become very popular as additional market value. Consequently, solar heat gains are becoming dominant air-conditioning load.</p> | <ul style="list-style-type: none"> <li>- The balcony is not only an architectural feature for residential buildings, but also significantly affects the indoor air pollutant exposure of residents, as well as the energy use.</li> </ul>   |
| <p>“Tower buildings in Dubai: Are they sustainable”. (Al-Sallal 2004)</p>                         | <p>Dubai, hot-arid climate, 2004.</p>        | <p>Several issues are investigated such as energy consumption, thermal performance, lighting design, and the potential use of renewable energy resources. The focus is to study how these issues are affected by the building form, envelope, and systems.</p>  | <ul style="list-style-type: none"> <li>- The optimum built-form configuration should be a rectangle within an aspect ratio of 1:2 and 1:3, with long sides oriented to north-south.</li> <li>- To maximise the use of daylight, the fitting room height-to-depth ratio is 1:2 with window glazing that is 20% of the external wall area.</li> </ul> |

## 2.4. Spatial Principles of Vernacular Neighbourhoods and Houses in the Middle East and North Africa

The design of a residential environment, compared with other types of buildings, needs a sensitive approach to reflect values and socio-economic conditions of people. Ragette (2003) claimed that the architecture of dwellings and houses is an attempt to think more critically about two issues: (1) the physical requirements and psychological needs, such as protection, health, security, privacy, identity, and self-expression; and (2) the environmental conditions, such as sufficient heating, cooling and ventilation.

Throughout history, people in any culture have their particular methods for constructing dwellings and domestic spaces according to their needs and values. Oliver (2003) expressed the vernacular architecture as a 'theatre of our lives', where different scenes of daily events are played out. Rather than materials or process of construction, a vernacular artefact, which could be varied within a specific order, has been derived from the locality, and organised by the community (Rapaport 1969b; Ragette 2003). It is a reflection of beliefs, social patterns, cultural values, and behaviours (Bianca 2000; Oliver 2003). In this manner, houses were seen as sheltered spaces that respect other people, and reflect the local needs and living conditions. Over generations, these dwellings became a 'tradition' and a 'philosophy of life' that has a shared image of life and an acceptable living pattern (Rapaport 1969b).

### 2.4.1. The Vernacular Model of Neighbourhoods

Modern and contemporary towns in MENA region are normally characterised by a rational and a rigid grid of streets and open plazas. On the other hand, a vernacular neighbourhood, or *hara* in Arabic, has an irregular pattern and more than one focal centre. Yet, this organic configuration, which was determined by specific social and religious principles, have been the preferred environment for families (Modi 2014; Bianca 2000).

The traditional public square, or *saha* and *maidan* in Arabic, allows for a high degree of social interaction between people, and reflects their cultural identity and sense of community (Al-Masri 2010). Moreover, the access from public areas to residential quarters is usually broken into hierarchical sections to increase degrees of privacy, and at the same time maintain a balance between isolation and interaction (Crouch and Johnson 2001). This circulation pattern is controlled by different intermediate tools, such as dead-end alleys and gradual sequence of

gateways, to protect the private family domain, and prevent conflicts with the public realm (Bianca 2000), (Figure 2.3). One example of such layouts is “the Village of New Gourna” near Luxor in Upper Egypt, designed in 1945 by Hassan Fathy, a notable Egyptian architect, in which he derived his concepts from the traditional built environment of Egypt (Figure 2.4). He used the concept of narrow and zigzagged streets, and a hierarchical system of planted open spaces, to enhance the social interaction between residents, and to encourage the air circulation (Mortada 2003).

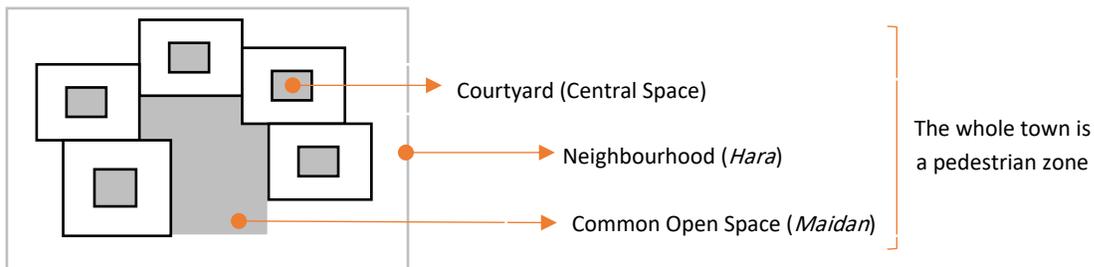


Figure 2.3: A diagram showing the different components of a traditional town in MENA region (Researcher)

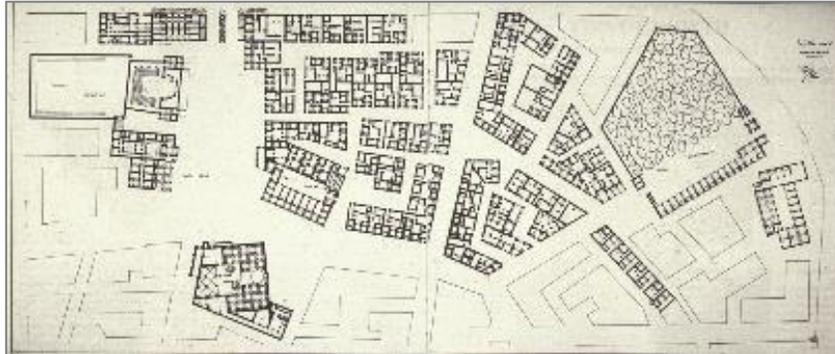


Figure 2.4: The Village of New Gourna, Egypt (<http://web.mit.edu/>, accessed on 4/2/2016)

Another example, is the core of old Tunisia, which has a compacted layout. Hakim (1986), in his book: *Arabic-Islamic Cities*, evaluated the urban and the architectural language of this quarter, and concluded that open spaces and private courtyards play a major role in reducing crowding and increasing interaction between neighbours. Such a dense grouping of courtyard houses has many advantages. It eliminates the left-over spaces between buildings, reduces external heat gain or loss, and blocks excessive air movement (Ragette 2003; Crouch and Johnson 2001). Moreover, security and privacy of the family could be maintained (Bianca

2000). After a careful investigation of spatial qualities of traditional quarters in different cities in MENA region, including Tunisia, Algeria, Cairo, Aleppo, Medina, Fez, Marrakech, and Yazd, the following illustrates the main findings (Figures 2.5, 2.6, 2.7, 2.8, 2.9, and 2.10):

- Most residential quarters are characterised by a dense and compacted fabric, where buildings seem like a single roof with holes representing courtyards. This solution offers a protection against the harsh weather.
- The use of introverted courtyards, so families are protected against visual intrusion.
- The use of covered pathways as a transitional area between inside and the outside.
- The irregularity of forms, which does not mean that there is a lack of order, but a harmonious integration of spatial elements to make a whole (Aina *et al.* 2013).
- The staggered pattern of entrances of houses, which maintains the private life of families.
- Corners of buildings are cut at 45 degrees at the street level to ease people movement.
- Most residential units are similar in its form and spatial arrangement. No special treatments on the solid exterior facades could be noticed, which could indicate the absence of social or status celebrations in the physical aspect of dwellings (Mortada 2003).
- The use of high walls between residential units, and avoiding windows open towards adjacent roofs could protect neighbours' rights against views.

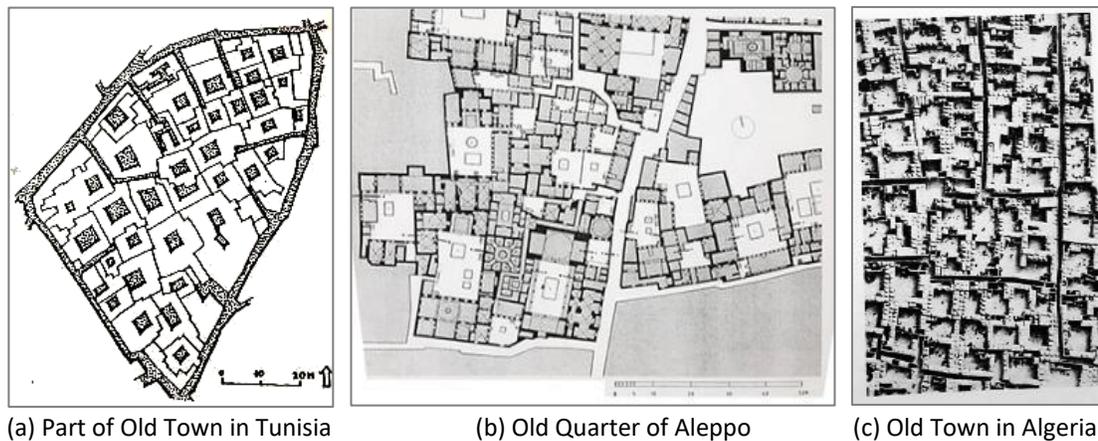


Figure 2.5: Different traditional residential quarters in the study area  
((a)+(b): (Ragette 2003); (c): (Mortada 2003))

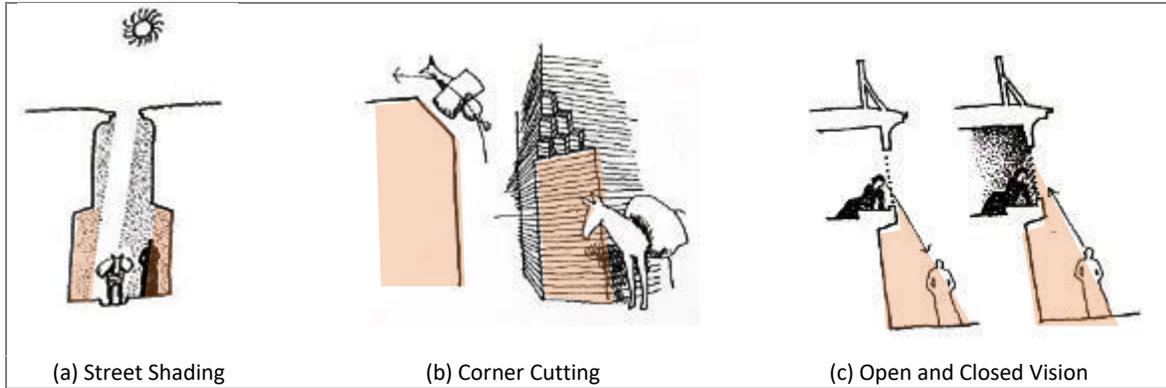


Figure 2.6: Rules and principles of spatial arrangements in traditional quarters (Ragette 2003)

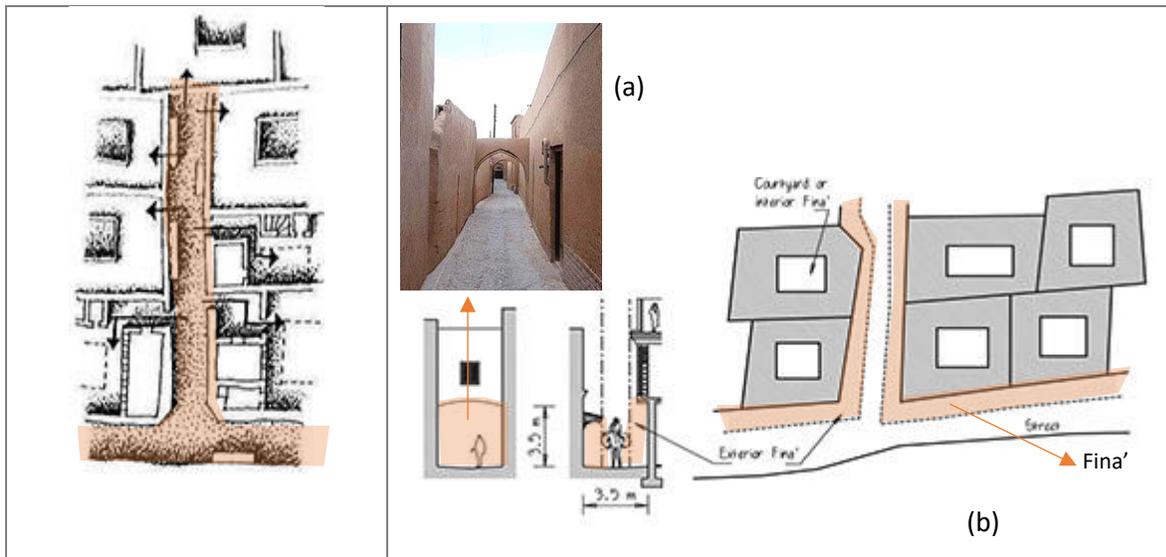


Figure 2.7: The principle of staggered entrances (Ragette 2003)

Figure 2.8: Rules for alleys in a traditional residential quarter ((a) Moossavi 2014; (b) Steyn 2012)

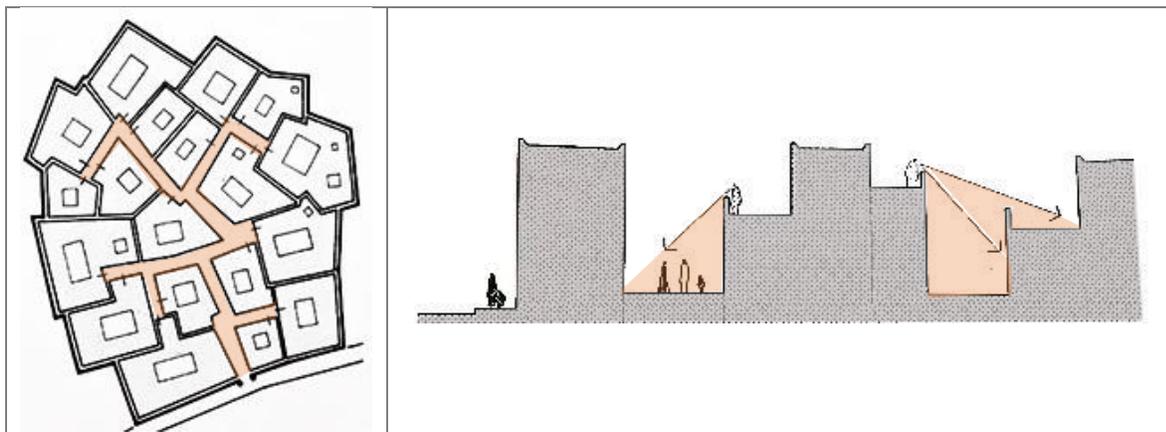


Figure 2.9: Cluster of courtyard houses around dead-end alleys (Bianca 2000)

Figure 2.10: A section through adjoining houses showing how setbacks are used to maintain privacy between neighbours (Bahammam 2006)

However, the layout of traditional neighbourhoods could have several impacts on residents and the built environment:

- Footprint and land needs: the vernacular model of residential quarter is usually occupies a much larger ground area than modern clusters, which affects the area of green and communal spaces (Modi 2014).
- Security and safety: the compact design of neighbourhood, the spatial arrangement of public spaces and narrow alleys, the absent of doors between common areas, and the availability of more than one gate, could have negative impacts on families, as it could increase fear and crime in the neighbourhood (Al-Thahab *et al.* 2014; Al-Kodmany 1999).
- Viewing the outside: the introverted layout of traditional neighbourhoods, the use of solid exterior walls with small windows, and the absent of front garden, reduce the opportunity to see and interact with the outside public areas (Al-Kodmany 1999).
- Acoustical privacy: the location of public spaces between houses, which are used by families as gathering areas and by children as playgrounds, can cause noise, especially for elderly people (Modi 2014).

Table (2.5) summarises the main spatial features of traditional neighbourhoods, social and environmental rewards, and negative impacts on residents and the built environment.

Table 2.5: Spatial elements of traditional neighbourhoods in MENA region, classified according to social/environmental rewards, and negative impacts

| Spatial Elements of Traditional Neighbourhoods  | Social Rewards   | Environmental Rewards  | Negative Impacts   |
|---|--|--|--|
| <ul style="list-style-type: none"> <li>- A large irregular courtyard (or group of courtyards are interconnected sequentially).</li> <li>- Covered pathways (irregular and narrow passages).</li> <li>- Surrounded walls in public and private spaces.</li> <li>- Dense fabric.</li> <li>- Limiting the size of neighbourhoods and reducing distances between houses.</li> </ul> | <ul style="list-style-type: none"> <li>- The courtyard serves as the village square, where people can celebrate and meet.</li> <li>- Eliminate wasted spaces between buildings.</li> <li>- Appreciate the cultural identity and nostalgia.</li> <li>- Create protected outdoor spaces that enhance interaction between families and children.</li> <li>- A visual barrier to maintain privacy, avoid disputes with neighbours, and increase the sense of community.</li> </ul> | <ul style="list-style-type: none"> <li>- Eliminate external heat gain or loss.</li> <li>- Provide shade.</li> <li>- Block excessive air movement which carries sand and dust.</li> </ul> | <ul style="list-style-type: none"> <li>- Occupy a much larger ground area than modern clusters, which affects the area of green and communal spaces.</li> <li>- Limiting views to the outside</li> <li>- The spatial arrangement of public spaces and narrow alleys, the absent of doors between common areas, and the availability of more than one gate, could have negative impacts on families, as it could increase fear and crime in the neighbourhood.</li> </ul> |
| <ul style="list-style-type: none"> <li>- Corner Cutting: Corners of buildings are cut at 45 degrees up to shoulder height</li> <li>- <i>Al-fina'</i>: which is the exterior space immediately adjacent to the exterior walls of the house.</li> <li>- <i>'Sabat'</i>: building a room over a street joining two structures owned by the same person.</li> </ul>                 | <ul style="list-style-type: none"> <li>- To ease people walk and movement.</li> <li>- To allow for loading and unloading.</li> </ul>   | <ul style="list-style-type: none"> <li>- Provide shade for pedestrian.</li> </ul>  | <ul style="list-style-type: none"> <li>- The problem of ownership when upper floors of houses are extended over streets.</li> </ul>  |
| <ul style="list-style-type: none"> <li>- Avoid entrances facing each other (the principle of staggered entrances).</li> <li>- Windows of neighbours are not supposed to allow a view into adjacent yards.</li> <li>- Houses are built wall-to-wall with introverted courtyards (dense grouping of courtyard houses), and sometimes there are setbacks.</li> </ul>               | <ul style="list-style-type: none"> <li>- To maintain privacy between neighbours.</li> <li>- To block the direct view and access.</li> </ul>  | <ul style="list-style-type: none"> <li>- Eliminate external heat gain or loss.</li> <li>- Provide shade.</li> </ul>  | <ul style="list-style-type: none"> <li>- Reduce the opportunity to see and interact with the outside public areas.</li> <li>- Cause noise, especially for elderly people.</li> </ul>   |

### **2.4.2. The Vernacular Model of Houses**

Broadly, traditional dwellings in hot-arid regions have special characteristics that consider the climate. Most houses are inward-looking with living spaces organised around a central space (courtyard) that is opened to the sky. This favoured prototype of houses could be found in rural areas as well as urban zones of the study area (Bianca 2000; Taylor 1985; Al-Masri 2010). It is widely used to maintain a shaded area in summer, and to receive solar radiation in winter. It also provides security, privacy, and a comfort zone within the house (Moossavi 2014).

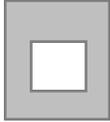
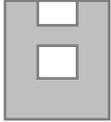
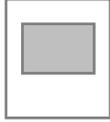
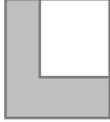
Courtyard houses were used widely throughout the history. In ancient Egypt and Mesopotamian civilisations (Sumerians, Babylonians and the Assyrians), houses were built around one or more courtyards. Later, in Roman and Greek architecture, most of houses have courtyards surrounded by rooms (Islam and Al-Sanafi 2006). In the Middle East and North Africa, the courtyard house has been adopted in the 7<sup>th</sup> and 8<sup>th</sup> century as a basic form of design, and remained the dominant type with some variations in terms of location and treatments to respond to the local context, traditions, climate and available materials (Mitchel 2010; Samizay 2010; Bianca 2000).

In terms of spatial configuration, different possibilities for zoning and placement of rooms could be noticed in courtyard houses, where rooms could be located on one side or more of the open-to-sky space (Ebadi *et al.* 2014). In hot-arid regions, there are two typologies of traditional houses: atrium house, and patio house (Table 2.6). In the first type, the courtyard is the spatial centre of the house. It serves as a circulation zone, recreational space and access to the adjacent rooms. In patio house, several small courtyards are cut out of the building volume to capture natural light and create a spatial experience between rooms (Pfeifer and Brauneck 2008).

#### **a. The Morphology of Vernacular Houses**

Dwelling layouts may be varied in different periods, regions and cultures (Mustafa 2010). Physical features of houses, in general, reflect the identity of the family, their social and cultural needs, and the different requirements of each space. Thus, there is a reason behind every space in the house (Goethert 2010). However, a mixed-function space was a dominant feature in vernacular architecture (Mortada 2003).

Table 2.6: Schematic layout of traditional houses in different climatic zones  
(Adapted by Researcher, after (Ebadi *et al.* 2014))

| Climate                                | Hot-Arid  |   | Cold  | Humid-Moderate  | Hot-Humid   |
|--|---|---|---|---|---|
| Type                                   | Atrium-Type House   | Patio House   | Garden Courtyard House  | Four-Sided Garden House   | L-shaped House Type   |
| Schematic Layout of Traditional Houses |    |    |    |                             |  |
| Characteristics                        | The courtyard is the spatial centre of the house. It serves as a circulation zone, recreational space and access to adjacent rooms. | It utilises several small courtyards cut out of the building volume, to naturally light the floor space and create interesting spatial relationships. | It is organised around an enclosed garden courtyard. The open space has an intimate character as it is surrounded by the four sides. It is ideally suitable for dense urban housing developments. | It is ideally suitable for townhouses to offer daylight exposure and air circulation between adjacent houses. | It offers maximum daylight exposure and economical use of space.                    |

In the hot-arid regions of the Middle East and North Africa, spaces in most traditional houses are dynamic through using different techniques, such as changes in levels and directions (Figure 2.11), various degrees of openness, and the contrast of wide and narrow (Ragette 2003). These dwellings could have one courtyard, and sometimes more. The main courtyard is usually the central space of the house (family courtyard) and located on the ground floor. The other one acts as an entry open-space with a staircase leads to upper floors. This entry hall has a special treatment where visibility from one courtyard towards the other is restricted.

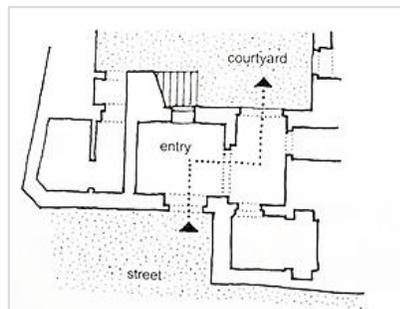


Figure 2.11: The concept of indirect entry to the courtyard  
(Ragette 2003)

On the ground level, main rooms and services (kitchen, storage and staircase) surround the courtyard, while on the first floor rooms around each courtyard are not linked together (Figure 2.12). Dwellings could have porches, galleries and balconies which connect spatially the indoor environment with the outside while preserving their purposes as extensions of the domestic living space. This relationship between indoor and outdoor spaces, and the use of transitional zones between public and private areas are key qualities in the spatial arrangement of the house to maintain the privacy as a social need, and to offer environmental rewards (Oliver 2003).

After careful analysis of different traditional houses and vernacular dwellings in the study area, most physical components remained relatively unchanged in their formal properties and function, with slight variations. Tables (2.7) and (2.8) illustrate the main spatial elements of these houses in the different regions within the study area, with their common terms in Arabic, functions, spatial characteristics, and symbolic meanings.

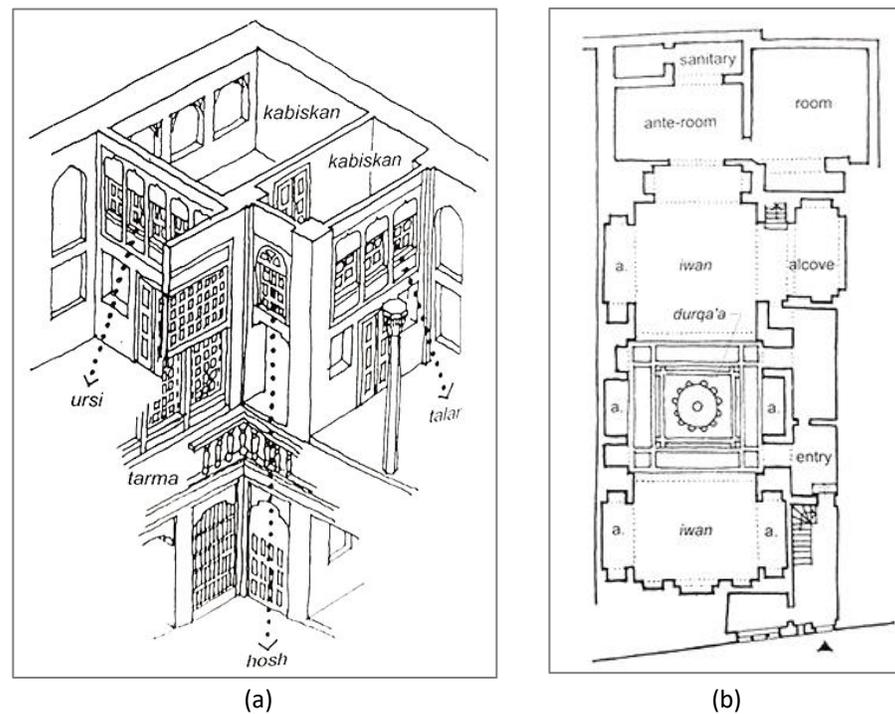


Figure 2.12: Part of traditional houses in (a) Iraq, (b) Cairo, showing main spatial features (Ragette 2003)

Table 2.7: Main spatial elements of different traditional houses in the study area

| Spatial Elements  | Common Terms (in Arabic)   | Descriptions and Functions   |
|---|--|--|
| The main (family) courtyard   | <i>Hosh</i>  | It is an open space (a window to the sky) for performing the functions of daily living while ensuring visual and spatial privacy.  |
| Entrance passageway and the entry courtyard   | <i>Majaz</i>   | It is a circulation space connecting the entry hall with the main courtyard. It is a mediator between inside the house and the outside world. The courtyard acts as an entrance open-space with a staircase leads to upper floors.   |
| Reception room (for male visitors)  | <i>Salamlik</i> or <i>Diwaniya</i>   | It is used for male visitors, suited off the entry courtyard.  |
| Portico (Gallery or Balcony) overlooking the courtyard                              | <i>Burtal</i> in North Africa, <i>Riwaq</i> in Syria, and <i>Tarma</i> in Iraq | It is a horizontal linear structure with a back wall, and a row of columns supporting the front edge of the roof. It offers important protection from harsh weather conditions, and a circulation space connecting a series of rooms. It is usually attached to the courtyard.                 |
| A single open space in front of the courtyard with a pair of columns in front of it | <i>Iwan</i> in Syria, and <i>Talar</i> in Iraq                                 | It is an open central part, with a back wall, affording access and creating a sheltered space (with beams resting on transverse arches or a tunnel vault) to the horizon. It is an extended space in front of the courtyard, and a transitional area from the outside to the inside.           |
| A large room of the house closed by screens or windows and entered from the sides   | <i>Ursi</i>  | It is a specific version of ' <i>talar</i> '.  |
| Gallery carried with columns all around a courtyard                                 | <i>Peristyle</i>   | It is an extended space in front of the courtyard, and a transitional area from the outside to the inside.   |
| Reception room for female visitors (screened mezzanine)                             | <i>Majlis</i> or <i>Kabishkan</i>  | A room suspended halfway between upper and lower floors, which is a reception space ( <i>majlis</i> ) for women, and a retreat for the elders ( <i>kabishkan</i> ).  |
| A room with a raised floor and a side open to the courtyard                         | <i>Takhtaboush</i>   | It is a covered outdoor sitting area, located between two courtyards: one is unshaded and large –paved courtyard, and the other is planted. The main function is to ensure a steady flow of air.   |
| Main reception (covered courtyard)  | <i>Qa'ah</i>   | It is the main reception hall in the house, consisting of the <i>durqa'ah</i> (a central part of the <i>qa'ah</i> with a high ceiling covered by the <i>shukhshakhah</i> (wooden lantern on the top) and two <i>iwans</i> (sitting areas) at a higher level on both the north and south sides. |

Table 2.8: Typologies of traditional houses in the hot-arid regions of the Middle East and North Africa

| Typology according to Geographic Location                    | Distinctive Features   | Main Spaces and Architectural Vocabularies | Spatial Characteristics  | Functions and Symbolic Meanings   |  |
|--|--|--|--|---|--|
| <b>Type (1):<br/>Maghrebi type<br/>(Morocco and Tunisia)</b> | <ul style="list-style-type: none"> <li>- Features the most consistent and formalised typology</li> <li>- Shows an interesting architectural dialectic between the mostly irregular contours of the plot and the perfect geometric form of the courtyard</li> <li>- The size of the house varies with dimensions and proportions of the courtyard</li> <li>- Usually extends over 2 or 3 floors</li> <li>- Height of each main floor is 4 to 5 meters</li> <li>- Tight outer enclosure wall, which creates a total introversion while allowing for lateral attachment of neighbourhood houses.</li> <li>- Materials of walls are sun-dried or baked bricks</li> </ul> | Main Courtyard                             | <ul style="list-style-type: none"> <li>- Absolute centrality of the courtyard '<i>wust ad-dar</i>' (centre of the house), which shaped the building</li> <li>- Symmetrical and balanced order</li> <li>- Length of courtyard walls = 6 to 10 meters</li> </ul>   | <ul style="list-style-type: none"> <li>- Can be interpreted as the timeless centre of gravity of the house.</li> <li>- The shape of the courtyard established a strong vertical ambition toward the sky.</li> </ul>   |  |
|  |  | Main rooms ' <i>bait</i> s'                | <ul style="list-style-type: none"> <li>- An ideally symmetrical layout of the main rooms around the courtyard</li> <li>- Follow the geometric pattern of the courtyard</li> <li>- They usually face each other and are accessible from the courtyard or the gallery.</li> <li>- Their main dimensions are defined by the length of the courtyard, while the depth, irrespective of the length, rarely exceeds about 3 meters, due to the practical limitation of beam lengths.</li> <li>- The very long space allowed for a convenient subdivision into a central access zone and two lateral bays.</li> </ul> | <ul style="list-style-type: none"> <li>- To receive a large number of people during festive, continuous benches were placed along the whole sides of the room, allowing people to lean on the wall and to face each other (producing a sense of centrality within the room).</li> <li>- A depth of around 3 meters provided the right distance to feel comfortable</li> <li>- They had 'door within door', which allow inhabitants of the house to adjust the opening according to different occasions and climate conditions.</li> </ul> |  |
|  |  | Ancillary (secondary) facilities           | <ul style="list-style-type: none"> <li>- They were relegated to the periphery of the building</li> </ul>   | <ul style="list-style-type: none"> <li>- They were used as 'filling material' to absorb the change of directions of irregular plot shape</li> <li>- They can be ventilated by a separate air shaft (if needed).</li> </ul>  |  |
|  |  | Air shafts (small courtyards)              |  |   |  |
|  |  | Storage rooms                              | <ul style="list-style-type: none"> <li>- Injected between two main floors</li> <li>- Height = 2 meters</li> </ul>  |   |  |
|  |  | Gallery                                    | <ul style="list-style-type: none"> <li>- Located on the first floor running around the courtyard</li> </ul>  | <ul style="list-style-type: none"> <li>- It is a horizontal linear structure with a back wall, and a row of columns supporting the front edge of the roof. It offers important protection from the weather, and a circulation space connecting a series of rooms. It is usually attached to the courtyard.</li> </ul>   |  |
|  |  |  |  |   |  |

|   |  |                                |   |  |
|---|--|--------------------------------|---|--|
|   |  | Staircases                     | <ul style="list-style-type: none"> <li>- Staircases are more than one, placed in strategic corners of the building without being exposed</li> </ul>   |  |
|   |  | Balcony                        | <ul style="list-style-type: none"> <li>- Used as replacement of colonnaded galleries in the case of narrow courtyards</li> <li>- Connecting opposite rooms on the first floor</li> </ul>  |  |
| <p><u>Type (2):</u><br/><b>Syrian Type</b><br/><b>(Syria, Jordan, Palestine and Lebanon)</b></p> <ul style="list-style-type: none"> <li>- Has a more complex and less regular structure, especially with regards to the courtyard shape and the interior elevations of the house.</li> <li>- Tight outer enclosure wall, which creates a total introversion while allowing for lateral attachment of neighbourhood houses.</li> </ul> |  | Courtyard                      | <ul style="list-style-type: none"> <li>- Less formal in shape</li> <li>- Less concern for symmetry in the facades facing the open space</li> </ul>  | <ul style="list-style-type: none"> <li>- Takes the character of a shared family square</li> <li>- Providing the intermediate connection between the various components and sub-units of the house</li> </ul>   |
|   |  | Main rooms                     | <ul style="list-style-type: none"> <li>- Symmetric layouts were applied, but not extended to the central courtyard.</li> <li>- There is a lower (sunken) circulation space (as an entrance) for every room.</li> </ul>  | <ul style="list-style-type: none"> <li>- The lower (sunken) circulation space (<i>ataba</i>) was used for cleaning check (to take off one's shoes), while the higher space is used as living and sitting area.</li> </ul>  |
|   |  | Reception room ' <i>qa'a</i> ' | <ul style="list-style-type: none"> <li>- High-domed central space of square shape, which could be entered from one side (through a door from the courtyard)</li> <li>- In modest houses, it was adapted in incomplete form with only one bay and a small anteroom, directly accessible from the main courtyard.</li> </ul>  | <ul style="list-style-type: none"> <li>- A fully developed reception, which constitutes a house within the house</li> <li>- The central space of the reception room acts as the 'courtyard'</li> <li>- The front elevation faces the central courtyard and contains small windows, emphasising the dominant vertical orientation and the self-contained character of the central space</li> <li>- Equipped with an interior fountain</li> <li>- Light and air could be entered through openings in the polygonal or circular drum</li> </ul> |
|   |  | <i>Iwan</i>                    | <ul style="list-style-type: none"> <li>- In big houses, three <i>iwans</i> are located adjacent to the reception room, two facing each other and one facing the entry door</li> <li>- The front of each <i>iwan</i> is marked by a wide arch.</li> <li>- In most cases, the floor of the <i>iwan</i> is raised by one or two steps from the lower circulation space</li> <li>- Surrounded walls are mostly solid.</li> <li>- The single <i>iwan</i> was open and attached directly to the courtyard.</li> </ul> | <ul style="list-style-type: none"> <li>- Lower circulation space to take off one's shoes, and higher living and sitting area.</li> <li>- Open <i>iwan</i> could serve as a family sitting area or an open-air reception space.</li> <li>- The open <i>iwan</i> was usually oriented northwards to avoid direct sun radiation, and to catch the cool breeze during hot summer days.</li> </ul>  |

|                                    |  |   |  |   |
|------------------------------------|--|---|--|---|
|                                    |  |   | <ul style="list-style-type: none"> <li>- The single <i>iwan</i> could be edged by two lateral rooms, which are accessible via the <i>iwan</i>, and form another sub-unit of the house.</li> </ul>  |   |
|                                    |  | <p>Separate (independent / individual) living room (“<i>murabba</i>” or “square”)</p>   | <ul style="list-style-type: none"> <li>- Intermediate sections between 6 to 8 meters high, which include <i>qa’a</i> and open <i>iwan</i>.</li> <li>- It could be located either at the ground level, which is directly accessible from the courtyard, or at the first level (which is serviced by an individual open staircase).</li> </ul> | <ul style="list-style-type: none"> <li>- Provide separate quarters for family members or guests (for privacy).</li> </ul>   |
| <b>Type (3):<br/>Egyptian Type</b> | <ul style="list-style-type: none"> <li>- More complex houses than <i>Syrian</i> and <i>Maghribi</i> types</li> </ul> | <p>Central open courtyard</p>   | <ul style="list-style-type: none"> <li>- Regular central space with relatively symmetric introverted rooms.</li> </ul>   | <ul style="list-style-type: none"> <li>- Open to the sky</li> </ul>   |
|                                    |  | <p>Single <i>iwan</i></p>   | <ul style="list-style-type: none"> <li>- The single <i>iwan</i> was open and attached directly to the courtyard (located at the end of the central open courtyard).</li> </ul>   | <ul style="list-style-type: none"> <li>- Informal covered reception room</li> </ul>   |
|                                    |  | <p>Bent entrance</p>  | <ul style="list-style-type: none"> <li>- A corridor connected with a small anteroom and a bench “<i>mastaba</i>” for doorkeeper.</li> </ul>  | <ul style="list-style-type: none"> <li>- It is a circulation space connecting the entry hall with the main courtyard. It is a mediator between inside the house and the outside world. The courtyard acts as an entrance open-space with a staircase leads to upper floors.</li> </ul>              |
|                                    |  | <p>Formal male reception room (“<i>qa’a</i>” or “<i>mandara</i>”), which consists of:</p> <p>a. Two deep <i>iwans</i></p> <p>b. Covered / sunken central space (<i>durqa’a</i>)</p> | <ul style="list-style-type: none"> <li>- Formal layouts</li> <li>- Located on the ground floor</li> <li>- It is a roofed over courtyard-<i>iwan</i> combination (Ragette 2003)</li> <li>- Sometimes it was T-shape space</li> <li>- Could take monumental proportions, with the central part extending through three floors</li> </ul>       | <ul style="list-style-type: none"> <li>- Usually used by male visitors</li> <li>- There was a greater degree of transparency since the rooms could have <i>mashrabiyya</i> openings to both sides (to the courtyard and surrounding family rooms, and to the street)</li> </ul>                     |
|                                    |  | <p>Two deep <i>iwans</i></p>  | <ul style="list-style-type: none"> <li>- Two deep <i>iwans</i> facing each other across a sunken central space (<i>durqa’a</i>)</li> </ul>   | <ul style="list-style-type: none"> <li>- One of them supplied with fresh air from a <i>malqaf</i></li> </ul>  |
|                                    |  | <p>Private living room</p>  | <ul style="list-style-type: none"> <li>- Located on the upper floor overlooking the central space of the <i>qa’a</i></li> <li>- Located above the <i>iwans</i> or around the vertical shaft of the <i>durqa’a</i></li> </ul>   | <ul style="list-style-type: none"> <li>- Permitted the female group to watch activities in the male reception room</li> <li>- Densely screened windows (timber lattice screens – “<i>mashrabiyyas</i>” or “<i>rowshans</i>”) to achieve privacy, to project into the street, and to form</li> </ul> |
|                                    |  |   |  |   |

|                                 |   |  |  |
|---------------------------------|---|--|--|
|                                 |   |  | protected bay windows with integrated benches, which allows for glimpses from the outside world.   |
|                                 |   |  | <ul style="list-style-type: none"> <li>- "Porosity" of large portions of the external walls and internal partitions, to maximise cross ventilation and adequate air circulation.</li> <li>- The principle of "<i>mashrabiyyas</i>" depends on keeping water jars of unburned clay close to the screen, to benefit from the natural cooling effect of the draft.</li> </ul> |
|                                 |   | Wind catchers<br>" <i>malqa'</i> "                   | - Directed cool breezes from the roof into the lower rooms.  |
|                                 |   | Family loggia<br>" <i>maq'ad</i> "                   | - A covered room located on the upper floor, and overlooked the courtyard  |
|                                 |   | smaller scale <i>qa'a</i>                            | <ul style="list-style-type: none"> <li>- Located on the upper floor</li> <li>- In the case of multi <i>qa'as</i>, these small rooms were connected by corridors, staircases, services, and open terraces.</li> </ul>   |
|                                 |   | Covered / sunken central space<br>( <i>durqa'a</i> ) | <ul style="list-style-type: none"> <li>- An entry space, which allows for an access to the raised <i>iwans</i></li> <li>- Extended vertically across the surrounding vertical volumes of the house (a central void, which is usually covered by a pyramidal roof on a pierced polygonal drum).</li> </ul>  |
|                                 |   |  | <ul style="list-style-type: none"> <li>- It contains a central fountain.</li> <li>- The polygonal drum allows for the natural light and air to penetrate.</li> </ul>   |
| <b>Type (4):<br/>Iraqi Type</b> | <ul style="list-style-type: none"> <li>- Ancient Iranian influences</li> <li>- The ground floor contained only service rooms, a shaded recess which was used for open-air sitting area and an informal reception at the level of the courtyard.</li> <li>- The upper floor was 5 meters high, which allowed the inclusion of split levels in the corners on both sides of an "<i>ursi</i>" and a "<i>talar</i>".</li> </ul> | Courtyard  | - Regular layout of the courtyard without insisting on bi-axial symmetries.  |
|                                 |   | Elevated colonnade<br>" <i>tarma</i> "               | <ul style="list-style-type: none"> <li>- It is used predominantly on the first floor running around one or several sides of the courtyard</li> <li>- Combined with the iwan-like recesses of the "<i>talar</i>"</li> </ul>   |
|                                 |   | " <i>talar</i> "                                     | - Recessed bay with two front columns which is used on the first floor.  |
|                                 |   | Closed reception room " <i>ursi</i> "                | - It is located on the first floor   |
|                                 |   | Shaded recess  | <ul style="list-style-type: none"> <li>- It is located at the level of the courtyard.</li> <li>- Open-air sitting area and an informal reception.</li> </ul>   |
|                                 |   | Living room " <i>nim</i> "                           | - High living room located at basement level.  |

|   |   |  |  |  |
|---|---|--|--|--|
|   | <ul style="list-style-type: none"> <li>- The first floor rooms had front windows to project into the air-space of the street.</li> </ul>  | <p>Low mezzanine rooms<br/>"kabishkan"</p> | <ul style="list-style-type: none"> <li>- It is located on the mezzanine of the first floor (above corner rooms "ursi" and "talar").</li> </ul>   | <ul style="list-style-type: none"> <li>- Used by women if the main first floor was used for a male reception.</li> <li>- Used by women to ensure their privacy.</li> <li>- It had strategically located windows through which the women could look into the "ursi" or the "tarma" and watch the lower courtyard level across the open colonnade.</li> </ul>              |
|   |   | <p>Basement<br/>"sirdab"</p>               | <ul style="list-style-type: none"> <li>- It is a single shaft-ventilated subterranean room.</li> <li>- Rooms around the courtyard called "neem", are dropped down by one meter and have a high window (Ragette 2003).</li> </ul>   | <ul style="list-style-type: none"> <li>- Used in cold and wet northern climates, since it provides a space of even temperature, hardly freezing in winter and never too hot in summer.</li> <li>- It also keeps the ground floor slab warm and dry.</li> <li>- It collects the fresh morning air and preserves it for the hot afternoon hours (Ragette 2003).</li> </ul> |
| <p><u>Type (5):</u><br/><b>Anatolian Type (Turkish Style)</b></p> | <ul style="list-style-type: none"> <li>- The courtyard element may be absent, and replaced by covered halls.</li> <li>- The house formed a pavilion-like structure within an enclosed plot.</li> <li>- The need for protection against the cold and heavy rainfalls produced: <ul style="list-style-type: none"> <li>▪ The inclined roof, which contrasts with the roof of North African style and Middle-Eastern houses.</li> <li>▪ Limited vertical windows.</li> </ul> </li> </ul> | <p>Covered entrance hall<br/>"hayat"</p>   | <ul style="list-style-type: none"> <li>- It was raised above the ground floor and was accessible by an open staircase from the garden.</li> </ul>  | <ul style="list-style-type: none"> <li>- The layout is controlled to ensure their mutual independence.</li> </ul>  |
|   |   | <p>Type (1)</p>                            | <p>Main reception rooms</p> <ul style="list-style-type: none"> <li>- Centrality played a major role in the layout and interior design of the main reception rooms.</li> <li>- The front rooms were preceded and connected by a covered hall "hayat".</li> <li>- The front rooms oriented towards an enclosed garden space.</li> </ul>  |  |
|   |   | <p>Type (2)</p>                            | <p>Central hall<br/>"sofa"</p> <ul style="list-style-type: none"> <li>- In large houses, the entrance hall was pulled into the centre of the building, called "sofa", and symmetrically surrounded by a series of living rooms "oda".</li> <li>- In some cases, the sofa was enlarged into a cross-shaped core structure, with four lateral bays (as iwans), reaching out to the periphery of the building.</li> </ul> | <ul style="list-style-type: none"> <li>- It performed the function of the courtyard (but being covered)</li> </ul>   |
|   |   |  | <p>Living rooms<br/>"oda"</p> <ul style="list-style-type: none"> <li>- Four main rooms were located at the corners of the building, which produced an incredibly formal layout.</li> </ul>   |  |

|   |  |                                 |  |  |
|---|--|---------------------------------|--|--|
| <b>Type (6):<br/>South Arabian<br/>Tower House<br/>(Sana'a in<br/>Yemen) and<br/>Red-Sea Type<br/>(e.g. Jeddah,<br/>Mecca, Soakin<br/>in KSA)</b> | <ul style="list-style-type: none"> <li>- The courtyard element may be absent, and replaced by covered halls.</li> </ul>  | Central covered hall            | <ul style="list-style-type: none"> <li>- It was functioned as a covered courtyard.</li> </ul>  |  |
|   | <ul style="list-style-type: none"> <li>- Centrality played a significant role in the layout and interior design of the main reception rooms.</li> </ul>                              | Staircase                       | <ul style="list-style-type: none"> <li>- A vertical access corridor entered by the main gate of the house.</li> <li>- There is no direct access or visual connection from the staircase into the rooms.</li> </ul> | <ul style="list-style-type: none"> <li>- The staircase was separated from the hall by a door, which emphasised the independent "apartment" character of each floor, and allowed for natural division between male and female social activities.</li> </ul>   |
|   | <ul style="list-style-type: none"> <li>- Adopted the "roshen" system (wooden lattice screens) to protect interior spaces.</li> </ul>   | Foyer hall (enclosed forecourt) | <ul style="list-style-type: none"> <li>- It was located in front of the main gate.</li> </ul>  | <ul style="list-style-type: none"> <li>- It was provided as a buffer between the house and the street.</li> </ul>  |
|   | <ul style="list-style-type: none"> <li>- Attached from one or two sides.</li> </ul>  | Male reception space "mafraj"   | <ul style="list-style-type: none"> <li>- Located at the top of the house</li> </ul>  | <ul style="list-style-type: none"> <li>- Windows offer generous views of the city skyline.</li> <li>- It was considered the preferred place for the men's social ceremonies.</li> </ul>  |
|   | <ul style="list-style-type: none"> <li>- It was conceived as a solution to protect the family on upper floors, and livestock/agricultural products on the (ground floor).</li> </ul> | Roof terraces                   | <ul style="list-style-type: none"> <li>- A recessed space in front of the "mafraj"</li> <li>- Enclosed by 2 meters high brick walls</li> </ul>   | <ul style="list-style-type: none"> <li>- Made up for the lack of an open courtyard</li> <li>- It could be used by the women for all domestic activities.</li> </ul>  |
|   | <ul style="list-style-type: none"> <li>- Windows were tiny (except in the "mafraj") to ensure privacy.</li> </ul>  | Rooms on different levels       | <ul style="list-style-type: none"> <li>- Entered from the central covered hall</li> </ul>  | <ul style="list-style-type: none"> <li>- Small windows to ensure privacy and protect the female body of the house. People sitting on the floor could look out by opening the shutters, or by manipulating minuscule hatch built into the shutter.</li> <li>- A flexible 'individual daylight regulation' system which consists of a small window (just above floor level) with double shutters.</li> <li>- A fixed light source (2 to 3 meters above the small window) consisting of two circular eyes, with two layers of stained glass mosaic "oculi", which exclude any visual intrusion, while permitting the sun to penetrate and maintain dim daylight in the room, even with closed window shutters.</li> </ul> |

It is important to mention that in the Anatolian type (Turkish style), and dwellings in Lebanon, the house formed a pavilion-like structure within an enclosed plot, which contrasts with the roof of North African style and the Middle-Eastern type. Moreover, the courtyard may be absent, and replaced by covered hall. Yet, this hall has the same function of the courtyard as a transitional area and gathering space. Such variations are due to the need for protection against the cold weather and the heavy rainfalls produced.

Another issue that was observed in the South Arabian tower house in Yemen, and the Red-Sea type in Saudi Arabia (e.g. Jeddah, and Mecca), is that the courtyard in most houses may be absent due to the vertical expansion of houses.

*i. The Main (Family) Courtyard: A Space for Daily-Living Activities*

In hot-arid regions, the courtyard is one of the most successful architectural forms for performing the different activities of the daily living in a balanced and protected atmosphere (Al-Masri 2010; Rabbat 2010). This central open space meets both environmental and social needs of residents, mainly when it is located in a crowded urban fabric. The spatial configuration of traditional houses, with rooms and shaded terraces facing the courtyard, increases the potential for air circulation and daylight to be penetrated to the interior of the house while ensuring the visual privacy of the family (Rabbat 2010). Such an arrangement provides a buffer zone against heat entering the surrounded spaces (Crouch and Johnson 2001).

Throughout the history, courtyards in rural houses, as well as in city dwellings, have many functions (Table 2.9). Spatially, it separates the different functions attached to its sides, and splits the inside life from the outside world (Tuan 1977). Socially, it is the central area for interaction and viewing the outside world through extending the four elevations of a typical compact house to eight elevations (Al-Masri 2010). Moreover, women prefer such an outdoor space for preparing food and drying clothes. As a result, the courtyard is a multi-functional family space in the house, and an active architectural element for gathering, eating, playing and even sleeping during hot summer nights. Bianca (2000) claimed that this unique spatial feature could be defined as a 'self-contained unit' which "creates a 'house' within the house".

Table 2.9: Functions of courtyard in 'rural houses' and 'city dwellings'  
(Adapted by Researcher, after (Rabbat 2010))

| Courtyards in Rural Houses          | Courtyards in City Dwellings                        |
|-------------------------------------|---|
| - Space for most everyday functions | - Protected garden                                  |
| - Food preparation                  | - Open reception space screened from view           |
| - Storage of supplies               | - Connector between rooms                           |
| - Extension of the liveable space   | - Service area where cooking and washing take place |

The concept of 'contrast' is an essential ingredient of courtyard houses. As this research is an attempt to generate a pleasant domestic environment for families in crowded cities, the courtyard is one of the most successful architectural elements that could be useful for achieving the transition from the harsh atmosphere (heat, noise and glare) of the street to more appealing spaces and cool zones (Reynolds 2002). Moreover, houses that have these outdoor spaces are dynamic as they are mediating between inside and outside; public space and private life; social constraints and environmental requirements; and soft plants and hard structures (Mustafa 2010; Rabbat 2010; Rapaport 1969a).

Many sociologists described the importance and the meaning of introducing the courtyard as a core of the house. Reynolds (2002) in his book (Courtyards: Aesthetic, Social and Thermal Delight) pointed out that such an element represents many issues for residents:

- It is *an oasis in the desert of city streets*.
- *A fragment of nature as a reminder of natural landscapes beyond the city*.
- *A centre of interest for the building*.
- *A concentration of light, sound, and water*.
- *A life-sustaining refuge of safety and privacy*.

Moreover, Reynolds (2002) introduced a metaphoric link between the courtyard and the environment. Table (2.10) explains some of these correlations and their meanings. These relationships show that most people prefer to live in residential units that combine the relationship between the indoor and the outdoor spaces. The courtyard house has such a dynamic relationship.

Table 2.10: Metaphoric relationships between courtyards and cosmos  
(Adapted by Researcher, from (Reynolds 2002))

| Courtyards and Cosmos                 | Meanings   |
|---------------------------------------|--|
| Earth,<br>Water, Air<br>and Fire      | <ul style="list-style-type: none"> <li>- Earth: as the base surface,</li> <li>- Water and Air: as a resting place,</li> <li>- Fire: as a ceremony (cooking facilities) to symbolise the end of something.</li> </ul>   |
| Animal,<br>Vegetable<br>and Mineral   | <ul style="list-style-type: none"> <li>- Animals: birds, cats, dogs (as a safe place),</li> <li>- Vegetation and plants (as a sign of maturity, health, age, and changes),</li> <li>- Pavements (stone, marble).</li> </ul>  |
| Below, On,<br>and Above<br>the Ground | <ul style="list-style-type: none"> <li>- Below the ground: environment of darkness, thermal stability, and privacy, domain of wells and cold water, roots of plants (where food might be stored and protected against the summer heat),</li> <li>- On the ground (floor level): maximum interchange of people and nature (variety of foliage, furniture that invites relaxation and even sleeps, safe and varied play area for children),</li> <li>- Above the ground: (participation and observation), through balcony and roof.</li> </ul> |
| Cycle of Life<br>and Death            | <ul style="list-style-type: none"> <li>- Seasonal variations in plants (blooming, fruiting harvest and dormancy),</li> <li>- The courtyard sees the cycle of generations as well as seasons (a place that celebrates the family's rites of passage).</li> </ul>  |

### ii. *The 'Iwan'*

A second important feature in traditional houses is '*iwan*'. It is a sheltered space inside the residential unit, connected directly with the courtyard, as an extended semi-open living area. This space conveys residents from an outside semi-private area (which is the courtyard) to private indoor spaces (rooms). It has a combined feature of welcoming, by affording seating space, and formality, through using columns and arches (Ragette 2003).

### iii. *The Portico (Gallery Space)*

A third distinctive element in courtyard houses is the 'gallery space' or 'portico'. It is a projected circulation area with a back wall and row of columns supporting the front edge of the roof. It overlooks the courtyard, and connects series of rooms that have a limited depth of roof (Figure 2.13). This spatial feature has a vital role in achieving privacy between the courtyard and surrounded rooms. Moreover, it offers protection from the weather and produces a rich architectural experience through introducing an exciting contrast between the sunny environment and dark spaces (Mortada 2003; Crouch and Johnson 2001).

There are many variations of the gallery. In North Africa, it is called '*burtal*', in Syria '*riwaq*', and in Iraq '*tarma*'. However, it is rarely found in Egypt. Ragette (2003) observed different interpretations of this element:

- The Iraqi '*tarma*' is a short gallery with two columns, and serves as a reception to further rooms behind. Such rooms could be closed '*odas*' or open '*iwans*'.
- A specific Iraqi version is '*talar*', which is a single open space in front of the courtyard with a pair of columns in front.
- If the '*talar*' is closed by screens or windows and entered from the sides, it becomes an '*ursi*'.
- If a gallery is carried with columns all around a courtyard, it is called '*peristyle*'.
- In the hillside of Lebanon, and as a consideration of the sudden drop of topography and the moderate climate, closing the large opening with a series of arches, and adding a balcony was a logical development of the gallery.

#### iv. Vertical Circulation Elements and Roof Terraces

One stair, at least, is included in most traditional houses, even if only one floor. The stair might be arrayed along an entire wall or extroverted within the courtyard's space (Reynolds 2002). Such houses have extensive roof terraces which are common in hot-arid regions all year (Figure 2.14). They are used for drying of grains, fruits and clothes, as well as playgrounds for children, sitting areas for male guests, or sleeping spaces during the summer (Samizay 2010; Zako 2006).



Figure 2.13: The concept of '*iwan*' and '*gallery*' spaces in traditional houses (Ragette 2003)

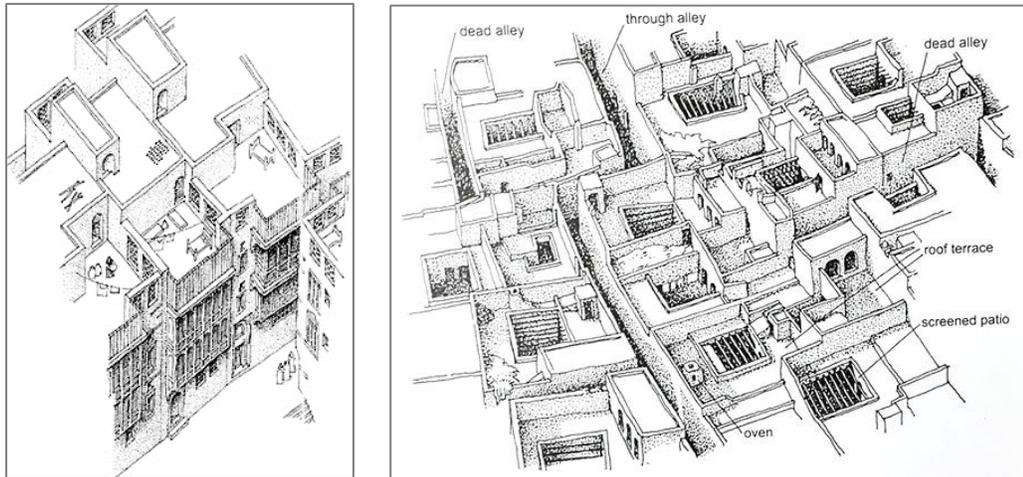


Figure 2.14: Roof terraces in traditional residential buildings in:  
 (a) Mecca, KSA; (b) Algeria  
 (Ragette 2003)

### b. The Vertical Model of Vernacular Houses

Historically, the need for preserving lands in the city, achieving security for the residents, and showing off prestigious status, are primary factors shaping the trend of residential buildings with more than three to four stories, and sometimes ten floors. One of the most notable old vertical residential buildings in the world is found in *Shibam* in Yemen, South-Arabian Mountains, *Hijaz*, and Morocco (Ragette 2003). *Shibam* is often called 'the oldest skyscraper city in the world' with more than 500 vertical houses, originate from the 16<sup>th</sup> century, and are made out of mud-brick<sup>2</sup>. The whole building is called a 'multi-floor family tower' as one family occupies it. Each tower has a small yard at lower levels, and a vertical separation of functions. Storage areas and stables are located on the ground level with small windows, then a vertical sequence of kitchen and toilet on the first or second floors, then living spaces for the family, reaching to zones for men and guests (Abu Bakar and Abdul Razaq 2012; Ragette 2003). On each floor, there is one or two rooms with a semi-public stairway that segregates social and functional zones of the house. The roof contains a reception hall for men (*mafraj* or *majlis*), and an open terrace, which is usually used for wedding ceremonies. These multi-storey buildings either share green areas or have their inward courtyards, with L-shape form to achieve privacy (Figure 2.15).

<sup>2</sup> <http://whc.unesco.org/en/list/192> (accessed on 3/5/2018)



Figure 2.15: Vernacular tall residential buildings in *Shibam*, Yemen  
(Photo credit: Jialiang Gao<sup>3</sup>)

### c. Potentials and Impacts of the Vernacular Model of Houses

Many benefits could be noticed in vernacular houses in hot-arid regions. On the other hand, there are several impacts for applying such a model. The following discussion illustrates these potentials and impacts according to the three dimensions of sustainability: social-cultural, environmental, and economic aspects.

#### i. Social-Cultural Dimension

*'The social, cultural, and behavioural life of people are key factors in giving the architecture its identity and character'* (Bahammam 2006). In that sense, several studies, conducted by architects, planners and sociologists, outlined different social rewards for traditional houses. Yet, these dwellings could have negative influences on residents (Othman *et al.* 2015; Sobh and Belk 2011; Goethert 2010; Mitchel 2010; Sözen and Gedik 2007; Zako 2006; Bahammam 2006; Mortada 2003; Ragette 2003; Crouch and Johnson 2001; Bianca 2000; Al-Kodmany 1999; Hakim 1986; Taylor 1985). According to the 13 indicators of social sustainability, mentioned in Section 2.2.1 in this chapter, the following is a summary of the advantages and the impacts of vernacular houses on these indicators. However, aspects that have effects on social indicator (4) - human comfort, are illustrated in the environmental dimension, after this section on (page 63).

<sup>3</sup> [www.peace-on-earth.org](http://www.peace-on-earth.org) (accessed on 9/2/2016)

- *Social Indicator (1): Population Density and Crowding*

Vernacular architecture has been derived from the needs of the community as they know what spaces are required in their homes. As a result, there is a reason behind every space in the house (Goethert 2010). Based on that issue, and due to the small plot area, spaces inside houses are modest in their sizes related to their actual use. Area of each space neither small nor exaggerated. However, mixed-functions of space is the main feature in traditional houses. Spaces, such as living and dining rooms, served different purposes at different times of day and night. Thus, these areas could be crowded, especially in winter.

- *Social Indicator (2): Hierarchy of Spaces*

A clear hierarchy of spaces from public to semi-public/private to private and intimate domains could be noticed. Such an arrangement could offer privacy for the family, which is one of the most significant social requirements for the community. However, these characteristics give an expression of social power for the family (Ragette 2003). The public domain includes 'shallow' reception spaces for male guests next to the entry hall with no visual connections between this space and the private domain, such as the kitchen, the living room, and bedrooms (Zako 2006). However, the reception hall of male visitors could be attached to the courtyard, so the entry side of the courtyard is a semi-public space. The courtyard, as a semi-private space is placed at the centre of the house to provide a total protection and flexibility for the family.

- *Social Indicator (3): Social Inetration and Area of Living Spaces*

In traditional houses, there are several spaces, such as courtyards, *iwans*, covered living areas, and alleys surrounding the house, that facilitate social communication. In large houses, sharing a room between two or three families is common in the city, and the courtyard could provide such social support (Goethert 2010). However, there are some cultural constraints that control this interaction between guests and family members, and sometimes, between the same family members (male and female), especially in the extended-family house (Ragette 2003) (Table 2.11). Achieving such a cultural constraint requires large plot areas, special considerations in the arrangement of spaces, or a vertical separation between functions.

Table 2.11: Communication system with a typical grouping of family members  
(Adapted by Researcher, after (Ragette 2003))

| Types of Family   | Sleeping Arrangements                    | Food Preparation                             | Eating Arrangements                                 | Eating Arrangements in Presence of a Guest | External Social Communication |
|---|--|--|---|--|-------------------------------|
| <b>Nuclear Family:</b><br>Father, Mother, 2 Sons, 1 Daughter                |  |  |   |  |                               |
| <b>Extended Family:</b><br>Father, Mother, 1 Son, 1 Daughter, 1 Married Son |  |  |   |  |                               |
| <b>Extended Family:</b><br>Father, Mother, 1 Daughter, 2 Married Son        |  |  |   |  |                               |
| <b>Key</b>  | ▲ Father<br>● Mother<br>△ Son, unmarried | ▲ Son, married<br>○ Daughter<br>● Son's wife | G Guest, Male<br>□ Fix Bound<br>□ Feasibility Bound |  |                               |

- *Social Indicator (5): Accessibility*

Private spaces in traditional houses could be accessed through the courtyard, or the covered central hall when the courtyard is not exist. Such a spatial distribution could offer an accessible pattern of movement for the family. Moreover, roof terraces could be accessed using stair that is located alongside the courtyard.

However, elderly people and children could face some difficulties in their movement, as most spaces inside the house are separated from the courtyard by thresholds. Moreover, living spaces and bedroom in vernacular tall buildings and multi-floor houses are located on upper floors.

- *Social Indicator (6): Visual Privacy*

Privacy is an important factor influencing the design of the house (Bahammam 2006). In the study area of this research, the term 'house' is called '*maskan*'. It is an Arabic term derived from *sakina* (peaceful), which emphasises on security and privacy. Elements such as courtyards, arrangement of transitional spaces and internal circulation, the bent entrance passageway from the street, topological relationships between rooms, and the hierarchical transition from public to private zones, and from formal to less formal spaces, are essential considerations to attain a high degree of privacy for the family (Taylor 1985; Mitchel 2010).

On the street level, the external walls of dwellings are high, and a proper distribution of openings, have been realised. Such treatments are useful to ensure that neighbours or strangers could not overlook the domestic interior from the street. Moreover, few and small windows are placed above eye-level (175 cm above the ground), and sometimes are screened with wooden latticework (which called '*qbu*' in Maghreb, '*mashrabiyya*' in Saudi Arabia, and '*rawshan*' in Iraq) to provide protection, rather than seclusion, and allow the occupants to view the outside world without being seen (Mortada 2003; Ragette 2003). To ensure more privacy, large houses have two separate entrances: one for guests, and the other for the family. The entry halls are positioned off-centre with angular corridors or screen walls in front of the door (the bent-entrance principle) to obstruct the view of inner spaces of the house (Zako 2006; Bianca 2000; Ragette 2003) (Figures 2.16, and 2.17).

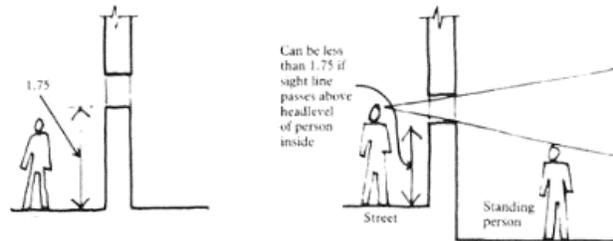


Figure 2.16: Treatments for windows in traditional houses (Hakim 1986)

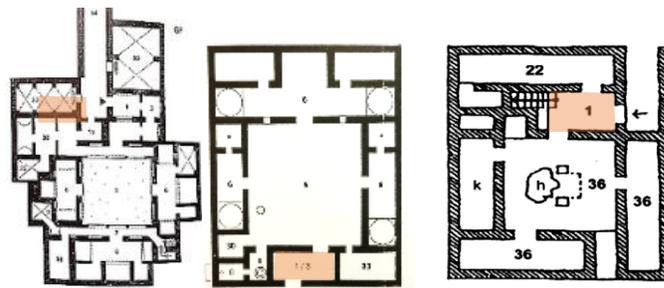


Figure 2.17: The bent-entrance principle in different traditional houses (Ragette 2003)

Women, female guests, and children use more 'deeply' private quarters (or '*hareem* area' as called in Arabic) (Crouch and Johnson 2001). However, special treatment for openings for that zone allows women to see both public and semi-public domains of their houses without being seen by guests. When houses get larger, its spatial configuration tends to provide women with more flexibility of movement and control within the house as they can observe whatever happening in any part of the house without being noticed or observed (Zako 2006). Transitional spaces, multiple courtyards, introducing a second

entrance, and allocating private spaces (such as a family room and bedrooms) on the first floor of large houses are different solutions that could be used for gender separation and for preserving the visual privacy, or what is called in Arabic '*aura*' (Mortada 2003; Bianca 2000).

- *Social Indicator (7): Acoustical Privacy*

Different zones of the house: male, female, and service areas are linked through the central courtyard, and separated by circulation spaces, semi-open spaces, and corridors to ensure acoustical protection from the outside or adjacent areas (Sobh and Belk 2011; Al-Kodmany 1999). Moreover, treatments for walls and floors using dense materials (stone, or mud brick) and thick solid walls are essential to avoid the penetration of residents' voices or sound reflections to the outside streets and their neighbours (Sözen and Gedik 2007; Mortada 2003). However, such treatments could affect the size of spaces, penetration of natural light and ventilation, and the connection with the outside streets and alleys. In addition, the compact form of clusters with no setback between adjacent houses could have adverse effects on acoustical privacy between neighbours.

- *Social Indicator (8): Olfactory Privacy*

Introducing a courtyard, and the orientation of services in traditional houses play an important role in controlling smells produced in kitchens to spread out to other spaces, primarily the zone for guests (Othman *et al.* 2015).

- *Social Indicator (9): Spirituality*

Sometimes, the orientation of spaces inside dwellings could have a symbolic and specific meaning of spiritual focus. Moreover, green areas and fountains in courtyards have a symbolic meaning, as a paradise, which affect positively on residents (Reynolds 2002).

- *Social Indicator (10): Security and Safety*

Although the courtyard is considered as a secure space for the daily-living activities, and for children to play, it could have an adverse effect on the family. Such an open space, and the dense fabric of houses, could increase fear and crime (Al-Thahab *et al.* 2014; Al-Kodmany 1999).

- *Social Indicator (11): Views to the Exterior*

One of the distinctive features of traditional houses is the availability of open areas, courtyards, roof terraces and balconies. These spaces, which are open to the sky, create a link with the outside environment, and therefore, offer the penetration of the natural light and ventilation.

However, the location of the courtyard as a central space, and the small size of windows overlooking the street or the alley, could limit the visual access to the outside context, and the direct interaction between the family and public spaces surrounding the house (Al-Kodmany 1999).

- *Social Indicator (12): Availability of Services*

Storage areas are important features in the layout of traditional houses. Typically, this zone is connected with a secondary entrance, and separated from living areas and bedrooms. In multi-floor houses, sanitary services, kitchen, and storage areas are located mostly on the ground floor. However, such a vertical separation between zones, and the limited number of toilets on upper floors, could have impacts on the satisfaction of the family.

- *Social Indicator (13): Hygiene*

Residents in the Middle East and North Africa achieved the requirements of hygiene inside their houses through several treatments. Residential units are defined by gates and thresholds where visitors take off their shoes. Inside the house, steps that separate cleaned sitting areas from services, and from the entrance of the room, where shoes and tools are put, is also a response to that requirement. However, such aspects could affect the movement inside the house.

*ii. Environmental Dimension*

In this section, aspects that are related to *Social Indicator (4) – Human Comfort* – are presented. Generally, houses are built to serve different functions that are acceptable to the occupants, and at the same time respond to climate conditions. Different issues, such as construction materials, forms, volumes, spatial arrangement, and orientation could contribute to the ‘micro-climate’ and the comfort conditions of the house.

Residents in hot-arid regions, where there is a harsh environment, high temperature, and scarcity of water, prefer to close their dwellings to the outside through introducing a courtyard, which embodied most of the missing aspects (Noor 1986). By this treatment, a balance between the human body and the environment could be achieved to satisfy a thermal comfort inside the house. However, such a comfort depends also on personal involvement of the occupants and their actions such as watering the courtyard, and the use of shading devices (Reynolds 2002). Many scholars showed that there are many potentials in the courtyard house that could attain the human comfort and solve problems of the climate (Mohamed 2010; Aldawoud 2008; Almasri 2010; Reynolds 2002; Ragette 2003; Sözen and Gedik 2007; Crouch and Johnson 2001; Al-Masri and Abu-Hijleh 2012; Almhafdy *et al.* 2013; Edwards *et al.* 2005; Foruzanmehr and Vellinga 2011; Safarzadeh and Bahadori 2005; Pfeifer and Brauneck 2008; Oliver 2003; Noor 1986; Bianca 2000; Islam and Al-Sanafi 2006; Samizay 2010; Sarkis 2010). The following illustrates the main strategies adopted in the study area.

- *Orientation and Spatial Arrangement of Spaces*

The interior plan has a unique arrangement as a response to the climate condition. Usually, the orientation of spaces depends upon surrounding streets, function of rooms, and whether winter heating or summer cooling is the most appropriate for the context (Reynolds 2002). Most spaces are located on the southern and the northern parts of the courtyard, while the western part is the least used direction. This solution is used to protect these spaces from solar radiation and heat absorption (Foruzanmehr and Vellinga 2011), and acts as a barrier to the north wind to reduce heat losses for the northern part of the house, where rooms for winter use are placed to trap the sun and to capture solar radiation from the south direction (Ragette 2003). Moreover, spaces for spring and autumn seasonal use are located on both east and west sides of the court (Figure 2.18).

For the rectangular courtyard, Reynolds (2002) evaluated two alternatives for the orientation of courtyard walls that could be implemented. The first situation is when the introverted court is elongated in the east-west direction. In this case, the direct solar radiation in summer could be prevented from entering the longer sides of the house through using shallow overhangs, and leaving windows available for the wind to be entered. However, the shorter sides get strong direct sun in the morning or evening of summer, while in winter, these walls are fully shaded.

The second alternative is when the courtyard is elongated in the north-south direction. In contrast to the first option, there are difficulties in this case with summer sun to be entered in morning or afternoon. The shorter sides get direct sun around noon in summer, and the winter sun is welcome near noon, so walls receive its warmth (Figure 2.19).

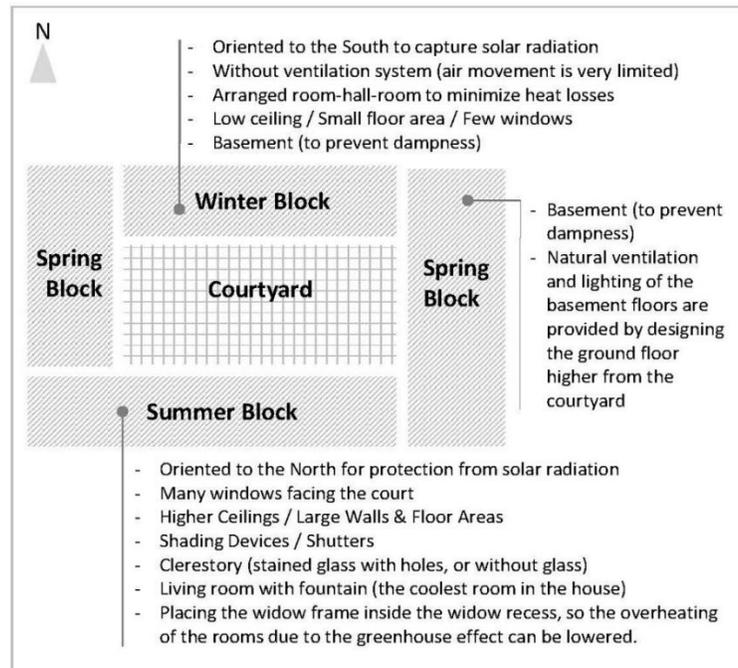


Figure 2.18: Zoning for a typical traditional courtyard house in hot-arid regions (Researcher)

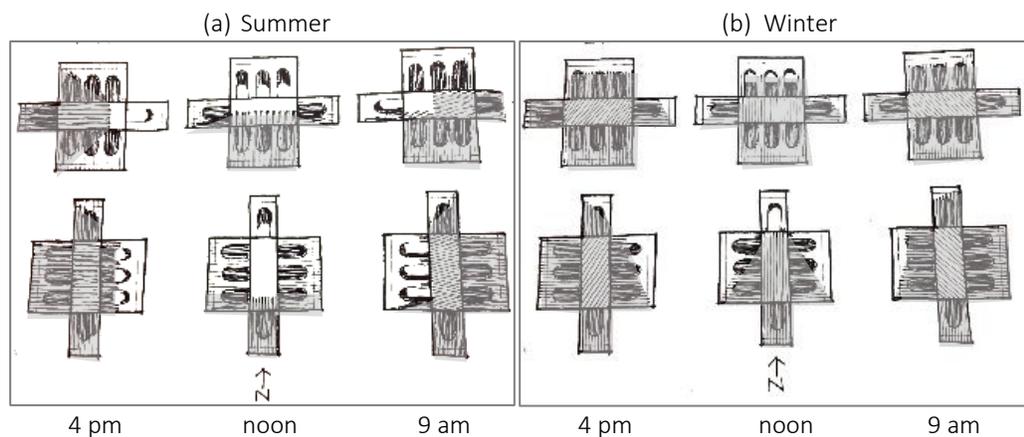


Figure 2.19: Effects of different orientations of courtyard walls (Reynolds 2002a)

- *Strategies for Achieving Summer Comfort*

Dry climates have less water vapour rates, hot air at daytime, much colder air by night, and higher radiation losses to the cold sky (Reynolds 2002). To solve these issues, and to achieve human comfort during the summer season, different approaches for cooling and humidifying the dry air, encouraging wind movement, minimising solar radiation and reducing direct glare and sunlight could be observed widely in traditional houses in the study area.

- *Cooling and Humidify the Dry Air*

To enjoy an appropriate atmosphere during the summer season, residents introduced various methods to cool and humidify the dry air. Water features, such as fountains (*nafora*); water jugs at the lowest part of the house or sometimes below the ground level; cooling plates (*salsabil*), which allow the water to drop on a marble surface; and the use of soft and hard landscaping (such as trees, pavements and high walls) in courtyards, play an essential role in cooling both the building and human skin surface, and increasing evaporation rates quickly, which maintain a lower and more comfortable temperature (Oliver 2003; Sözen and Gedik 2007; Crouch and Johnson 2001). Moreover, a semi-open room (*iwan*), with front open surface oriented to the north and the courtyard, was used as a coolness room in the house.

In multi-storey houses, the activity patterns by spending nights on the roof as an outdoor sleeping area, mornings on lower floors, and the afternoon time in a basement oriented to the northern part of the courtyard, help residents in avoiding excessive heat atmosphere.

- *Encouraging Air Movement*

Special treatments were used extensively in traditional houses to enhance the movement of air inside dwellings using passive design features instead of air-conditioning devices. Courtyards and semi-open spaces, such as galleries, *iwans* and arcades, are excellent modifiers that aid the flow of cooling breezes through the house. Opening windows on both sides of rooms that separate the outside from the courtyard, and using proper plants to guide the airflow into the building, create different speeds in the air movement and, in turn, cause a wind tunnel and cross ventilation (Ragette 2003; Reynolds 2002). However, in some regions, such as the Gulf

area, this could permit dust and noise to be entered. To solve this issue, residents adopted another ventilation device in their traditional houses. They used wind towers (*malqaf* or *badgir*), which encourage the air movement, and at the same time prevent the dust from passing into the house. These ventilation shafts catch a fresh and clean air, and transmit it to the lower living rooms, and then pass into the courtyard (Bianca 2000; Oliver 2003). Such cooling process could be improved by the evaporation effect of wet canvas or water jars being placed in the path of the wind (Ragette 2003). During the winter season, the wind tower is closed at the bottom.

A further feature advocated by Baruch Givoni (1998) is to raise the height of the courtyard wall downwind, so a draft of fresh air can be enhanced through an outlet at the bottom (Reynolds 2002).

- *Minimising Solar Radiation*

A proper orientation and the use of plants, local materials, awnings and shading devices could minimise the direct play of sunlight and solar gain (Ragette 2003). The following represents some remarks and benefits of passive design elements and design decisions that were implemented in traditional houses, and have the potential to reduce glare and solar radiation:

- North-facing rooms with large windows are preferred in summer to provide coolness (Samizay 2010).
- Protected east and west walls with small windows to reduce heat transfer effects.
- The use of south-facing high-level windows and recessed openings screened with awnings.
- The use of vegetation and plants to shield roofs and walls.
- The use of balconies and gallery spaces (*iwan*), which provide shaded buffer zones between the hot open spaces of the courtyard, and the cold rooms surrounding it (Islam and Al-Sanafi 2006).
- The use of sunscreens and shading devices.
- High ceilings and large windows with exterior movable shutters facing the courtyard for summer rooms ( Sözen and Gedik 2007).
- Thick outer walls are preferred (between 50 cm and 80 cm), which maximise the transmission time of the outside temperature to enter spaces.

- *Strategies for Winter Warmth*

The primary strategy for achieving warm winter in hot-arid climates is to minimise exposure to the cold air at night and maximise the heat gain during day-time. Residents in hot-arid climates oriented the winter part of their houses, usually, to the south direction, and arranged it as room-hall-room, with low height ceiling, small floor area, and high windows placed outside opening recess. These treatments could minimise heat losses and utilise the maximum daylight (Sözen and Gedík 2007).

Moreover, residents in many arid regions closed the long south-east facades of semi-open spaces, such as arcades, with glass to obtain the maximum amount of daylight. Pfeifer and Brauneck (2008) described these glazed zones as an 'energy garden' that creates comfortable and 'transparent living spaces'. Reynolds (2002a) argued that these arcades are adequate if the depth of adjacent spaces does not exceed 2.5 times of the opening's height above the floor. Furthermore, he claimed that the preferred proportion of rooms next to the courtyard is 3:1.

In some cases, such as Lebanon, the courtyard was roofed and developed, in a high degree of formality, to the 'central hall' house, where access to all rooms is via the hall, which is a multi-purpose space for reception, dining and living housework.

*iii. Economic Dimension*

Courtyard houses provide many financial rewards for occupants. For instance, it allows for a dense development on the plot area. It could be linked to adjacent houses with shared walls from three sides, as there are no surrounding back or side yards. Based on this compact structure, the cost of construction and infrastructure is significantly reduced, as well as the annual operating costs for energy and water (Pfeifer and Brauneck 2008; Tabesh and Sertyesilisik 2015). Yet, such a large ground area could affect the area of green and communal spaces at the urban scale (Modi 2014).

Moreover, some Traditional houses were expanded horizontally through adding rooms on the sides of the courtyard, or vertically by adding floors, or using the roof to create an additional living or sleeping spaces. However, this vertical expansion was limited by the structural system and the construction materials.

## 2.5. Research Gaps

After reviewing different studies about sustainability in residential buildings, it was noticed that physical applications of how spatial features that promote social sustainability in high-rise developments were neither fully explored nor widely recognised (Table 2.12).

Table 2.12: Current literature studies about sustainability in high-rise residential buildings

| Dimensions of Sustainability | Current Literature   |
|------------------------------|--|
| Social-Cultural Dimension    | <ul style="list-style-type: none"> <li>- Many studies present theoretical guidelines about aspects of social sustainability in residential buildings. However, there are limited applications of how these aspects could be addressed in the spatial design of high-rise buildings.</li> <li>- Limited investigations about how the local context, and the cultural values of the community, could be addressed in the design of high-rise residential buildings.</li> </ul> |
| Environmental Dimension      | <ul style="list-style-type: none"> <li>- Many studies show the impact of mechanical heating/cooling systems on energy consumption in high-rise buildings.</li> <li>- Limited studies show how passive design elements could be adopted in the design of high-rise residential buildings.</li> </ul>  |
| Economic Dimension           | <ul style="list-style-type: none"> <li>- Limited studies about the financial impact of inserting social gathering spaces in high-rise residential buildings.</li> </ul>  |

In a recent study “Roadmap on the future research needs of tall buildings”, published in 2014 by the “Council on Tall Buildings and Urban Habitat, Chicago”, shows that there is a significant priority for studies that focus on social sustainability and the social impact of tall buildings, at both urban and building scales (Oldfield et al. 2014). The study identifies the highest-scoring topics in the field of ‘Architecture and Interior Design’ that are related to the liveability and the social experience of occupants. These topics (Figure 2.20) are ranked as the following (Oldfield et al. 2014, p.36):

1. *The impact living in tall buildings has on families with children, and strategies to make high-rise living more appropriate for families with children.*
2. *Experience, happiness and satisfaction of those who live and work in tall buildings.*
3. *Needs of the elderly and disabled, with respect to high-rise living.*
4. *Improve the social-communal experience of occupants in tall buildings.*

**Top-Five Priority Index Scores**

| Topic   | Priority Index |
|---|----------------|
| 1 Research on the impact living in tall buildings has on families with children, and strategies to make high-rise living more appropriate for families with children                                      | 7.9            |
| 2 Research on the experience, happiness and satisfaction of those who live and work in tall buildings   | 7.6            |
| 3 Research on the needs of the elderly and disabled with respect to high-rise living  | 7.6            |
| 4 Research to improve the social-communal experience of occupants in tall buildings (including appropriate mix of functions, humanizing tall building environments, strategies to foster community, etc.) | 7.5            |
| 5 Research on architectural strategies to improve tall buildings' integration and relationship with the surrounding urban context   | 7.4            |

**Occupant Impact and Need**

|   |     |
|---|-----|
| → 1 ... Research on the impact living in tall buildings has on families with children, and strategies to make high-rise living more appropriate for families with children                                      | 7.9 |
| → 2 ... Research on the experience, happiness and satisfaction of those who live and work in tall buildings   | 7.6 |
| → 3 ... Research on the needs of the elderly and disabled with respect to high-rise living  | 7.6 |
| → 4 ... Research to improve the social-communal experience of occupants in tall buildings (including appropriate mix of functions, humanizing tall building environments, strategies to foster community, etc.) | 7.5 |
| → 6 ... Research on the impact sky gardens and sky courts have on occupants' social behavior in tall buildings  | 7.3 |
| → 14 ... Research on the services and functions that would satisfy tenants in mixed-use tall building   | 7.1 |

Figure 2.20: Priorities of required future research to improve the social impact of tall buildings  
(Oldfield *et al.* 2014, p.36)

This study aims to contribute to this growing area of research and fill the research gap through developing strategies and tools for designers that maximise the connection of vertical residential developments with the social life of residents, and at the same time reflect the context, and the social/cultural values of the society.

## 2.6. Towards Socially Sustainable High-rise Developments

Modern developments are a globalised phenomenon that might not be differentiated from one city to another, and has challenged the spatial-cultural identity of the city and destroyed the cultural practices and traditions of local people (Pomeroy, 2014). In their research, “Traditional solutions in low energy buildings of hot-arid regions of Iran”, Mitra Khalili and Sanaz Amindeldar (2014) compared the architectural concepts of traditional houses with the layout of contemporary residential buildings in hot-arid regions (Table 2.13). They reported that there is lack of flexibility and hierarchy in the spatial organisation of contemporary houses. Moreover, the existence of nature and the use of passive design elements are marginal and limited, and

the residents depend dominantly on mechanical systems for heating, cooling, and ventilation (Khalili and Amindeldar 2014).

Table 2.13: A comparison between architectural concepts in traditional houses and contemporary buildings in hot-arid regions

(Adapted by Researcher, after (Khalili and Amindeldar 2014))

| <b>Traditional Houses</b>  | <b>Contemporary Houses</b>  |
|--|---|
| The spatial organisation depends on the use of open, semi-open and closed spaces.  | There is no hierarchy of spaces in most contemporary houses.                                |
| Houses take advantage from wind flow, solar radiation, and water for providing comfort. Elements such as wind catcher, basement, shades, fountains and courtyard are integrated inside the spatial organisation.   | The dominant use of cooling and heating mechanical devices in different spaces.             |
| Houses are not separated from nature, and the existence of some natural representatives was mandatory in the internal spatial organisation of a house. In semi-open spaces (such as porches), there is a direct connection with nature, and these spaces not only play an essential role in the adjustment of indoor temperature, but are also a reflection of comfort besides the concept of outlook. | The existence of nature in contemporary houses is limited and marginal.                     |
| Space flexibility for life-style dynamism, as it could be adapted to the modern living requirements and the mixed-use activities.  | Domination of objects in the spatial organization causes space inflexibility.               |
| There is a wide range of open spaces from yard surface to the roof, which had a seasonal role in providing comfort facility.   | Lack of open spaces in the spatial organization of houses reduces the relation with nature. |

The built environment could be viewed in three different perspectives. The first one is a 'traditional perspective' where they feel with the loss of cultural values and the traditions of old generations. The second view, 'modernisers', which declares the importance of change and narrowing of traditions. The third perspective is a 'synthesis view', which addresses the process of creating a balance between traditional values of living in parallel with the progress and development (Ragette 2003). This balanced view refers to the concept of 'regionalism'. Ken Yeang, for example, who is a Malaysian architect and considered the father of the sustainable and bioclimatic skyscraper, bases his works on the adaptation of 'regionalism', through understanding traditional values, as well as the importance of progress, without the direct use of traditional forms and materials (Pomeroy 2014). Moreover, Dean Hawkes (2006) in his research "The selective environment: environmental design and cultural identity" (cited in (Bay

and Ong 2006)) outlined the importance of creating a balance between historical architectural cases, and the contemporary practice, which therefore, respects the cultural identity of the place. However, a 'contemporary building', which represents the current time, requires architects to think holistically with all aspects affecting the output, and at the same time, consider the latest issues of technological developments (Dalziel 2012).

Such a combination could generate a 'contemporary vernacular' building that has symbolic identities. A 'contemporary vernacular' is described as a "commitment to uncover a particular tradition's unique responses to spatial arrangements, place and climate and after that exteriorise these established and symbolic identities into creative forms" (Lim 2004, p.19, as cited in (AlHaroun 2015)).

As the courtyard in traditional houses represents the concept of a space that relates the interior to the exterior, designers in developing economies have appropriated this feature and built on its advantages (Samizay 2010; Goethert 2010). The courtyard has been adopted at different scales: the housing unit, and the cluster. Each scale maintains the concept of the courtyard as many social and cultural advantages to families could be achieved, in addition to economic and environmental benefits to the city could be added.

In some contemporary apartment developments, and due to space limitations, the courtyard has been replaced by a central atrium as a controlled space. However, this space is not exposed to the daily living activities of the house, so it seems to be lifeless. Moreover, the atrium does not fit the definition of a courtyard, which must be surrounded by rooms and living spaces on three sides at least, while being directly exposed to the environment (Al-Masri 2010).

At the scale of neighbourhoods, most of the contemporary models encourage the extensive use of spaces and the fragmentation of functions. This issue is the contrast of the traditional model that depends on a dense fabric that respects the human scale, and the existence of a common space, which includes a diversity of functions (Aina et al. 2013). However, planners who promote 'green' concepts in their new designs, refer to the traditional and vernacular experience, especially of the Middle East and North Africa (Table 2.14). One of these concepts was suggested by Ragette (2003) through inserting L-shape courtyard in a multi-storey attached buildings (Figure 2.20). Such a proposal offers residents to enjoy the views to the outside, interact with each other, and the same time protect their privacy.

Table 2.14: Modern concepts and traditional principles of community organization in the Middle East and North Africa  
(Adopted by Researcher, after (Ragette 2003))

| Modern Concepts  | Regional/Vernacular Experiences  | “Green” Concepts based on Traditional Principles  |
|--|--|---|
| <ul style="list-style-type: none"> <li>- The dominance of technology.</li> <li>- Intensive use of energy.</li> <li>- Centrally controlled.</li> <li>- Concentration of population.</li> <li>- Loss of social equilibrium.</li> <li>- Lack of human scale.</li> <li>- Pollution (noise, fumes, water).</li> </ul> | <ul style="list-style-type: none"> <li>- Low technology (passive design elements).</li> <li>- Energy efficient.</li> <li>- Locally controlled.</li> <li>- Protection from heat, cold and dust.</li> <li>- Crowding behind common walls.</li> <li>- Narrow streets (shade and pedestrian zones).</li> <li>- Internal zoning for privacy.</li> <li>- Organic structure.</li> </ul> | <ul style="list-style-type: none"> <li>- The notion of unity.</li> <li>- Attune architecture to climate with low energy technology.</li> <li>- Live in harmony with nature (the use of local materials).</li> <li>- Create balanced community (elderly and young, poor and wealthy).</li> <li>- Promote the neighbourhood concept, clusters, and integrated services.</li> <li>- Introduce pedestrian zones and avoid grid concepts.</li> <li>- Establish mutual responsibility for common spaces.</li> <li>- Design for privacy without segregation, and carefully zoned into public / semi-public / semi-private / private areas, and design from inside to outside.</li> </ul> |

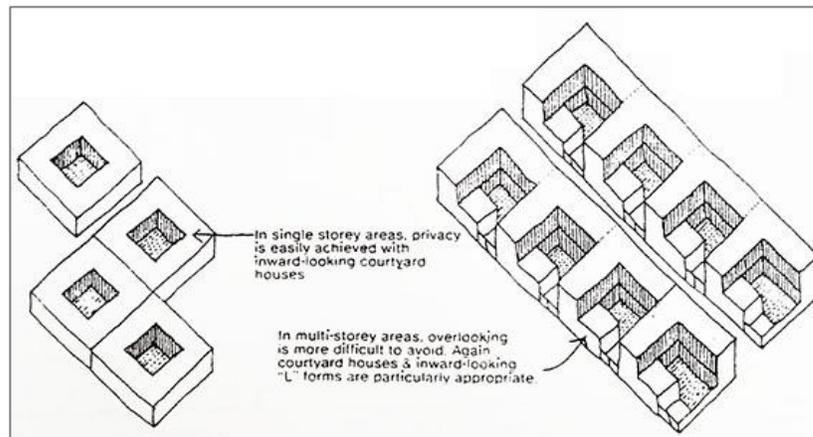


Figure 2.21: A proposal for inserting L-shape courtyard in a multi-storey building (Ragette 2003)

The design of socially sustainable residential buildings that concern with enhancing the social life inside buildings, and reflecting the context and the cultural values of the society, needs a smart and sensitive approach that deals with the context, preferences of users, and requirements of the modern and future time (Kennedy *et al.* 2015; Mehrpoya *et al.* 2015). In a study that focuses on the design of sustainable contemporary houses and low-rise developments in Saudi Arabia, May Al-Jamea (2014) recommended eight principles for achieving social and cultural sustainability. Some of these aspects relate directly to the indicators of social sustainability that are listed in this chapter (Section 2.2.1, page 23). The eight recommendations according to (Al-Jamea 2014) are illustrated in (Table 2.15).

Table 2.15: Recommendations for achieving social and cultural sustainability in contemporary houses and low-rise developments

| <b>Recommendations<br/>(according to (Al-Jamea 2014))</b>   | <b>How these recommendations are related to<br/>social indicators proposed by the researcher</b>                                  |
|---|---|
| 1. Privacy: designers should define three main zones inside the house (guest's part, family part, and services part). Moreover, the design should embrace the idea of inner courtyards. | This aspect relates to two indicators:<br>- Social Indicator (2): Hierarchy of Spaces.<br>- Social Indicator (6): Visual Privacy. |
| 2. Social needs: providing a suitable area for family gatherings.   | This aspect relates to:<br>Social Indicator (3): Social Interaction and Area of Living Spaces.                                    |
| 3. Accessibility: easy and clear access to all family members (children, the elderly, or the handicapped).  | This aspect relates to:<br>Social Indicator (5): Accessibility.   |
| 4. Security: high visual control over the family hall, children's activity areas, and outdoor spaces.   | This aspect relates to:<br>Social Indicator (10): Security and Safety.  |
| 5. Cultural values: the design should reflect the valuable Saudi cultural identity, such as façades.  |   |
| 6. Quality of life: providing natural light and ventilation.  | This aspect relates to:<br>Social Indicator (4): Human Comfort.   |
| 7. Adaptability: It is the flexibility of the house design that enables it to be adapted to any future changes.   |   |
| 8. Participation: involve the users in the design process.  |   |

## Part (B): Computational and Parametric Design Models

Inspiring from historical cases for the design of contemporary and socially sustainable buildings requires designers a sensitive approach that considers the existing realities, the particular design requirements, human needs, preferences of users, and at the same time, leads to innovative solutions. Such a complicated process, which includes many design parameters, needs a systematic procedure for the generation and evaluation of the outcomes in terms of social and spatial qualities. Therefore, it is efficient to be manipulated by computers using computational analysis and design models.

This part seeks to review the different design models and processes to select the most appropriate approach for achieving the goal of the study. Moreover, an overview of the different analytical and generative systems that are useful for understanding the social logic of spaces, and its relation to the spatial arrangement of design elements, are presented.

### **2.7. Reviewing Design Models and Processes**

The term 'design' has many levels of meanings. In his book 'Design: A Very Short Introduction', John Heskett (2005, p.3) pointed out that "*Design is to design a design to produce a design*". In other words, it is the field that includes actions and processes that need to be manipulated to produce a conceptual idea, and then develop it to reach a final output.

Many architects suggest that the design process is a decision-making procedure which includes data collection, synthesis, analysis, design, creation, testing, and evaluation. However, this process requires the designer to explore multiple solutions and then choose the optimum alternative (Krish 2011). This definition is supported by Lawson (2005, p.32), who claimed in his book: *How Designers Think*, that the "*design activity is the optimum solution to the sum of the true needs of a particular set of circumstances*".

This process of architectural design could be summarized in six phases<sup>4</sup> (Figure 2.22):

- Phase (1): defining the design problem to find a solution.
- Phase (2): gathering data and information as a procedure for understanding the context.

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<sup>4</sup> <http://www.discoverdesign.org/design/process> (accessed on 20/3/2016)

- Phase (3): analysing all gathered data through conducting a brainstorming process by sketches and diagrams.
- Phase (4): developing solutions and schematic drawings.
- Phase (5): discussing the different alternatives with the client to know their feedback.
- Phase (6): improving the final solution to be implemented.

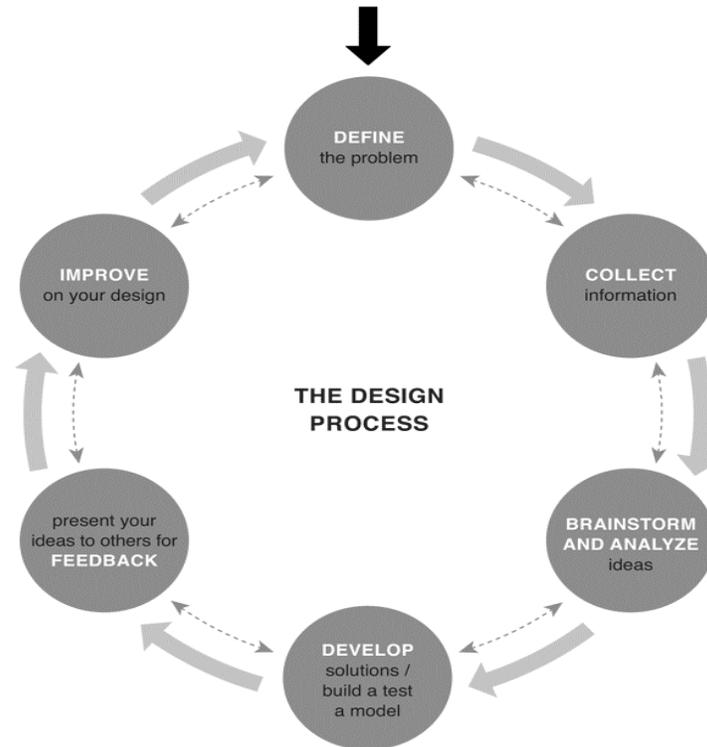


Figure 2.22: The process of architectural design  
(<http://www.discoverdesign.org/design/process>, accessed on 6/4/2016)

Prior understanding the philosophical logic of the design, three different paradigms and models could be adopted to process the design requirements and achieve the required target. These design models are: (a) the analysis-synthesis model; (b) the conjecture-analysis model; and (c) the abduction model. Each model has its unique processes for thinking and exploring solutions with creativity.

### 2.7.1. Design as a Problem Solving Process: The Analysis-Synthesis Model

'Design' is the activity of solving problems (Stojcevski 2008; Peponis et al. 2002). David Jonassen (2004, p.3), in his book: *Learning to Solve Problems*, described the 'problem' as "*an unknown entity in some context ... that must have social, cultural, or intellectual value ... moreover, its worth for someone to find the unknown*". To find solutions to these complications, different

scholars proposed models that help designers solving problems systematically and logically. The first attempt was proposed by Christopher Jones and Christopher Alexander, during the first 'Conference on Design Methods' in London in 1962. They suggested a model that divides the design process into two major phases: analysis and synthesis. They defined the process of design as a "*process of inventing physical things which display new physical order, organization and form, in response to function*" (Alexander 1964, p.1).

This model starts with observing the problem and listing all requirements. The 'analytical phase' of this process consists of three steps:

1. Decomposing a problem into components 'minor subsystems' that are independent as much as possible, through some mathematical routines.
2. Establishing a hierarchy among them and combine the different components into major subsystems.
3. Finding 'patterns' from the surrounding environment that meet the requirement of each component of the problem.

The second phase is to synthesise all of these parts into a whole. This process offers designers to shape the different components of the new structures through a hierarchal decomposition of the problem in a rational method (Cross 2001).

This method, which was adopted later by different scholars, such as Simon (1977), attempts to leave the designer's mind as free as possible for random and creative ideas, by keeping the sorted random input for later evaluation, and delaying the choice of the final solution until the problem is entirely explored, and the potential solutions are evaluated (Peponis et al. 2002; Cross 1984). Moreover, Simon introduced the use of charts and diagrams as visual elements for the analysis, which facilitate the design process in the later stages (Mahmoodi 2001).

In the same manner, Christopher Jones (1984) proposed a method for organising the design process with logical analysis and creative thought through a three-phase model (analysis-synthesis-evaluation) of rational decision making (Jones 1984):

1. The first phase 'analysis' is about breaking the problem into relatively small pieces and self-contained components.
2. The second phase 'synthesis' concerns with a design solution, and how the different pieces that are mostly informed by precedents 'typologies', habit, convention, memory or environment 'pattern', should be re-arranged to respond to the problem.

- The final phase 'evaluation' considers the consequences of translating these arrangements into practice to know if the objectives of the study were achieved.

Another attempt to solve design problems systematically was introduced by Bruce Archer in 1963. He argued that solving a design activity is based on a model that represents the intention to create a product with some creative steps without an automatic process (Cross 1984). This process is a sequence of three interrelated realms: external representation, the process of activities, and the problem solver (Mahmoodi 2001). It includes six stages which are overlapped with many feedback loops: programming, data collection, analysis, synthesis, development, and communication (Cross 1984) (Figure 2.23).

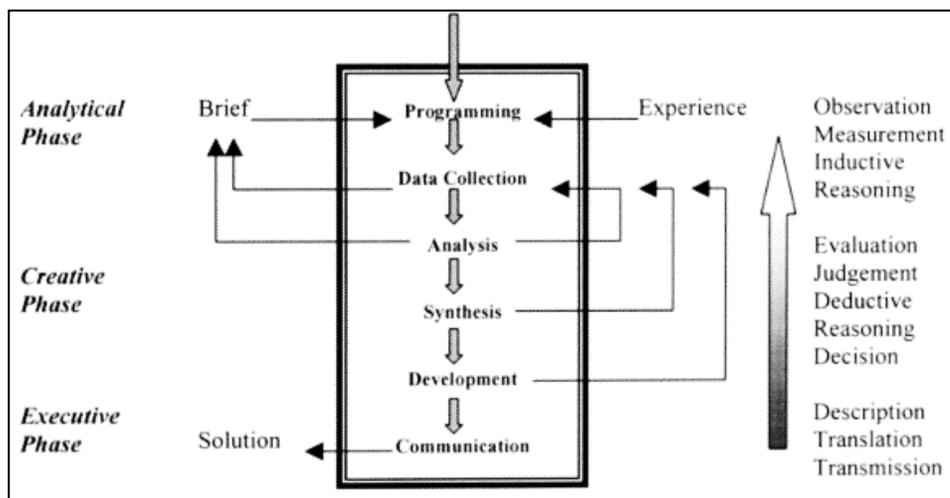


Figure 2.23: Archer's model showing stages of the design process (Mahmoodi 2001)

Archer recognised that perfect and complete information is rarely available in the real world, and it is not possible for the designer to wait until an analysis has been conducted (Archer 1984). Therefore, the previous experience of the designer and the knowledge from historical cases are essential as evidence, which reduce the efforts of problem-solving process and allow for a sensible decision (Cross 1984). In the analytical phase, the designer needs to identify the design goals, the constraints, and a list of sub-problems which are ranked according to the importance of the problem. The result of this stage is a statement of the problem, not of the answer. In the synthesis stage, creativity is an essential process in formulating the design ideas. Archer claimed that *"if the solution to a problem arises automatically and inevitably from the interaction of the data, then the problem is not, by definition, a design problem"* (Cross 1984,

p.4). This model of design is very efficient for solving well-defined problems, without considering a single unique or the best solution. However, the architectural design is not just a problem-solving process, and it is assumed that the architect should be more innovative in finding the best and optimum solution (Maani 2014).

### **2.7.2. Design as a Scientific Knowledge: The Conjecture-Analysis Model**

The second model of how designs could be managed is based on the philosophy that science cannot be progressed without conjectures. This idea has been firstly initiated by Karl Popper in 1963, and adopted by other scholars such as Bill Hillier and his colleagues in 1972.

In the fifth edition of his book 'Conjectures and Refutations: the growth of scientific knowledge', Popper (1989) pointed out that scientists can learn from their mistakes, and they should test the hypothesis and destruct it rather than trying to prove it. If the scientist cannot refute the hypothesis or predict something from it, then it is considered a theory (Popper 1989). The refutation of the theory is about giving criticism of conjectures to understand the difficulties of the problem, and this is a step that takes the scientist nearer the truth.

In the early 1970s, Bill Hillier and his colleagues followed Popper's model of scientific method. They believed that pre-structuring of the design process is necessary to any conceptual stage, but it is not sufficient in itself. Therefore, they proposed the 'Conjecture-Analysis Model' instead of the old 'Analysis-Synthesis Model'. This new model is based on conjecturing solutions in the early stages of the design to understand the problem. Conjectures come from anywhere, such as personal experience and professional knowledge (Hegeman 2008, cited in (Maani 2014)), but are not derived from data by induction (Hillier et al. 1972).

In the design realm, for instance, a project, which is the problem, starts with an unlimited number of solutions. According to Hillier's Model, this variety of possibilities is already reduced by two sets of limiting factors, before the actual design process starts (see Figure 2.24). The first set is external to the designer, 'external variety reducing constraints', such as preferences of the clients, norms of appearance, availability of technological means, costs, and standards. This type of constraints could be deterministic of the design. The second set is the 'internal variety reducers', such as the expressions of the designer's cognitive map and his understanding of solutions (Hillier et al. 1972). Jane Darke (1979), as cited in (Groat & Wang 2013), adopted the same ideas and proposed a 'Primary Generator Model', which composed

of three stages: (Generator → Conjecture → Analysis). The model enables the designer to provide a narrow focus and limit the problem to be more manageable. This serves as the basis of initial assumptions that need to be evaluated to meet the detailed requirements of the project.

This model of design process differs from the analysis-synthesis model in several aspects. Firstly, the purpose of the analysis is to test conjectures rather than to optimise information. Secondly, solutions are allowed to exist at earlier stages of design in this model. Thirdly, this model is equivalent to the situation in science as both information, and conjectured solutions are inherently incomplete, where a stop has to be called somewhere. Finally, the conjecture-analysis model is an interactive process of design rather than systematic or linear methods (Mahmoodi 2001), and it is emphasising on how the designer pre-structures the problem (Hillier et al. 1972).

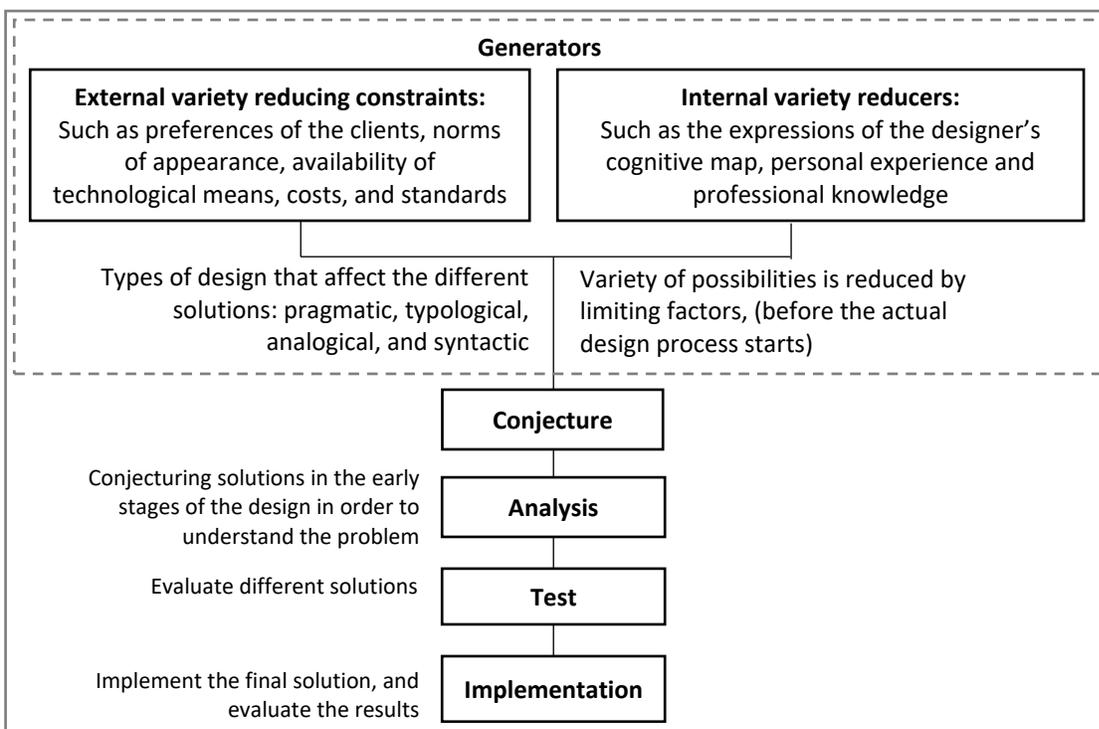


Figure 2.24: Design as a scientific knowledge: The conjecture-analysis-test model  
(Adapted by Researcher, after (Maani 2014))

Another scholar who adopted Popper's Model was Geoffrey Broadbent (1973) in his book '*Design in Architecture: Architecture and the Human Sciences*' (Mahmoodi 2001). He defined four types of 'design conjectures' that affect the different solutions of the design: (1) pragmatic, (2) typological, (3) analogical, and (4) syntactic. For instance, conjectures could be brought by an analogy, metaphor, or an inspiration (Hillier et al. 1972). Then, by refutation, the designer examined the fit of these conjectures (spaces) to different attributes: fit of spaces to activities, environmental filtering, cultural symbolism, economic performance and environmental impact (Broadbent 1973, as cited in (Mahmoodi 2001; Maani 2014)).

Using this scientific model, Jon Lang (1987) in his book '*Creating Architectural Theory: The Role of the Behavioural Sciences in Environmental Design*' sees the design process as an argumentative process involving conjectures, and the evaluation of these conjectures (Mahmoodi 2001). Moreover, Lang claimed that this process is an adaptation of previous experiences of designers to the current situation, through adopting five phases (Mahmoodi 2001; Kheiri et al. 2013):

- An *intelligence* phase: to understand the overall purpose.
- A *design* phase: where possible solutions are generated.
- A *choice* phase: to evaluate the different solutions.
- An *implementation* phase: in which the final solution is implemented.
- A *post-implementation evaluation* phase: in which results are evaluated.

### 2.7.3. Design as a Hypothesis that can be tested: The Abduction Model

Philosophically, abduction is a kind of reasoning that can be used to develop a hypothesis, which can be tested by additional data (Johansson 2003). It may lead to true or false conclusions as it depends on interpretations. The concept of *abduction* was devised by the American pragmatist philosopher Charles Sanders Peirce (1901), in his book: *On the Logic of Drawing History from Ancient Documents especially from Testimonies* (Johansson 2003). He first introduced the term as 'guessing'. Peirce claimed that *abduction* is the first step of scientific reasoning, and 'induction' is the concluding step, and the 'deduction' leads to a '*result based on a rule and a case*' (Peponis et al. 2002, p.81). In other words, to *abduce* a hypothetical explanation '*a*' from an observed circumstance '*b*' is to suppose that '*a*' may be true but not necessary for '*b*' as it is a matter of course.

In the field of architectural research, Nigel Cross (2011) in his book: *Design Thinking* (cited in (Groat & Wang 2013, p.35)), observed that an abduction is a useful approach used by design researchers for transferring thoughts between the required functions and appropriate forms to satisfy that purpose. Using this approach, the designer comes up with a basic idea for a solution. Then the architect creates a form and introduces new ideas through the logic of conjectures. Conjectures could be selected via induction by the testable consequences obtained by deduction. After that, new forms are tested against design requirements, objectives and constraints. This approach of thinking offers designers an understanding of the problem, and therefore, develop solutions in parallel lines. In other words, it is difficult to formulate a design problem without considering a solution (Cross 1984). Kees Dorst (2011) introduced an 'open form' of abductive approach that is suitable for the conceptual design phase. In that model, "What (thing), and How (working principle)" leads to "Value", designers know the value that they want to achieve, but they need to figure out the start of the problem-solving process (what), and the working principle (how) which leads to the required value.

In general, this model differs from the 'conjecture-analysis model' in two issues. Firstly, the conjecture-analysis model is based on the previous knowledge and the professional experience of the designer, which is called 'Heuristic Method' (Hudson 2010), while the abduction model is based on logical and mathematical thinking. Secondly, designers can create new solutions using the abduction model. However, the conjecture model addresses known solution types (Reichertz 2004, as cited in (Maani 2014)).

As the abductive model starts with collecting database, and ends with creating initial assumptions and alternatives that could be evaluated to meet the required result, the researcher sees that this model is the most suitable for the current study (Figure 2.25). However, the final product, which is derived from the analytical process, could be a new solution that is not expected. These designs are a response to a complicated set of social and spatial requirements, in addition to aesthetic needs that reflect the local identity of the community.

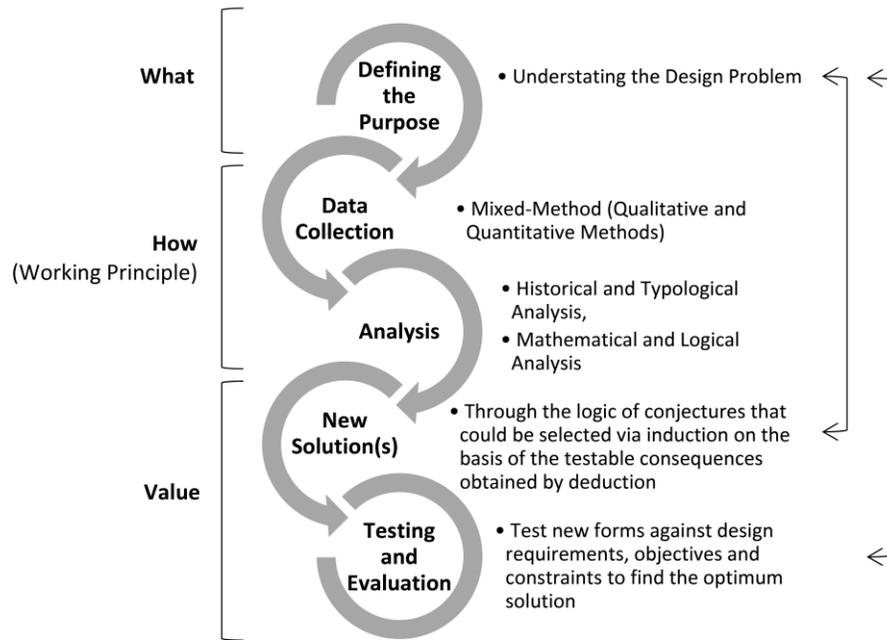


Figure 2.25: The open-form of the abductive model (Researcher)

The conventional manual manipulation of spaces could not be the perfect procedure for the researcher to address such a complexity, and to find the optimum solution. Thus, processes manipulated by computers that consider diverse parameters and constraints could be a useful approach to adopt. The following section reviews the concept of the computational design process, and the different analytical and generative methods that could offer the researcher the ability to convert the complex requirements of high-rise buildings into feasible solutions that attain the required target.

## 2.8. Computational Design Process

Computational design is about manipulating ideas, concepts and interactions between design elements by computer (Terzidis 1994). Computation is a logical and dynamic design process that is similar to the human mind, but within a mathematical and abstracted framework (Hall & Kibler 1985). It starts with defining design properties and a finite number of generative rules, and ends with an infinite number of solutions that are unpredictable (Narahara & Terzidis 2000; Terzidis 2005). Thus, creative designs could be conceived. This approach is different from 'computerisation', which is the act of entering, processing, or sorting data in a computer.

A computational system that could be used for the design of a building, has four main elements: (1) inputs, which are conditions and geometric properties of shapes (parameters); (2) rules and algorithms, which are mechanisms for generating solutions; (3) outputs, which are the design solutions; and (4) the selection process of the best alternative (Dino 2012). To execute this system, it requires from the architect to think with the design problem mathematically and algorithmically (Woodbury 2010).

### 2.8.1. Thinking Mathematically: A Parametric Design Approach

Parametric architecture is about using mathematical expressions and operations to offer variations that generate multiple solutions (Lee *et al.* 2014; Woodbury 2010). In mathematics, a parameter is defined as '*a quantity constant in the case considered, but varying in different cases*' (Hudson 2010, p.19). For instance, a particular circle can be described with two equations where there is one parameter (the angle  $\Theta$ ), and one constant (the radius  $r$ ): ( $x = r \cos \Theta$ ); ( $y = r \sin \Theta$ ). However, if ( $r$ ) is a parameter, there is a potential family of circles with different radii. Another example is when defining a spatial point grid (volume) with four lines drawn from each point to the lower corner of the volume. Properties of these lines, such as lengths and coordinates of the points, are then used to define other geometric properties for the volume.

Parametric design can offer variations that extend the exploration process to reach to creative solutions. This process is associated with the concept of abstraction, which means converting the complex ideas into basic shapes to know the fundamental structure of things (Jumelet 2013) (Figure 2.26). Robert Woodbury and his colleagues (2006) claimed that this process in parametric design is called a 'propagation-based system', which computes from specific and known knowledge, to unknown results, using a data-flow model. In other words, it is about making the abstracted model applicable in new situations. The data-flow consists of nodes representing objects, and arrows representing relationships.

Different types of arrows represent various relationships between objects (Figure 2.27). The process usually flows from independent to dependent nodes. For example, a plan that consists of three rooms (room #0, room #1, and room #2) could be represented by circles (nodes) with different geometric relationships between the width and the height of each room. Figure (2.28) shows that the overall width of the layout ( $w(t)$ ), the width of room #0 ( $w(0)$ ), the overall height of the layout ( $h(t)$ ), and the height of room #1 ( $h(1)$ ) are independent variables, while  $w(1)$ ,  $w(2)$ ,  $h(0)$ , and  $h(2)$  are dependent.

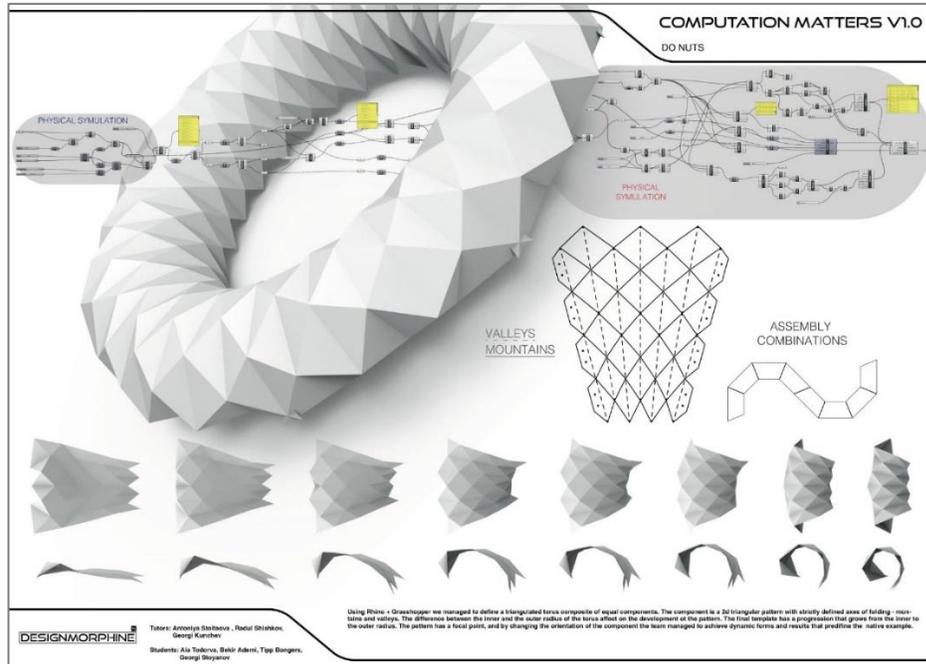


Figure 2.26: Converting a complex structure into basic shapes and components (Source: Computation Matters V1.0, DesignMorphine, [www.arch2o.com](http://www.arch2o.com) (accessed on 3/5/2018))

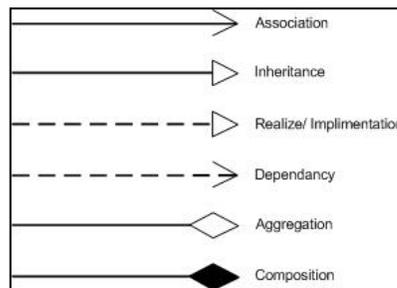


Figure 2.27: Different types of representations in data-flow diagrams (Nirosh 2015)

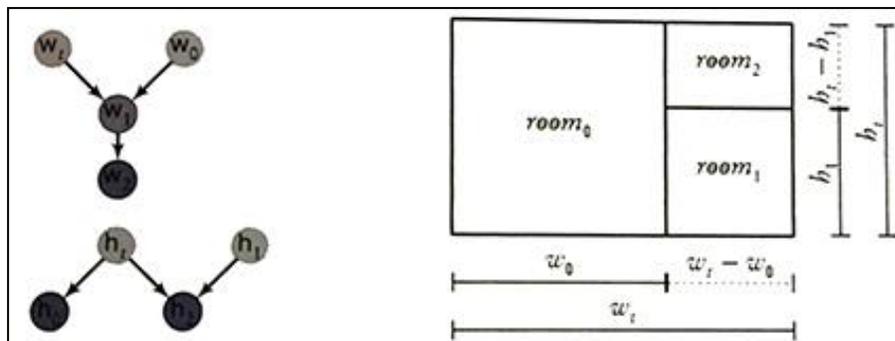


Figure 2.28: An example of the 'propagation-based system'. (Woodbury 2010)

Such a process could be used in both analytical and generative processes, to validate the logic of the problem, and to generate new forms and different alternatives that could have many interpretations (Nirosh 2015).

In comparison to traditional computer modelling, where designers need to study the problem with its all constraints to design a single solution, parametric models offer designers the ability to embed all design objectives and relationships between objects as a set of rules and algorithms. The model can respond and manipulate the design geometry, and then, generate different alternatives and prototype solutions with a minimum amount of time needed (Jabi 2013; D'Ino 2012). Moreover, this interactive process of form-finding allows for the user to revise parameters and rules, at any stage, to make custom adaptations and generate unique and un-repeatable solutions (Oxman and Gu 2015; Jabi 2013; Fernandes 2013; Soddu 2012; Correia 2013).

The most important solutions for the architect are related to the optimal design based on specific parameters and criteria, such as performance (Kheiri et al. 2013). This could be achieved through utilising the potentials of other external simulation tools, or tasking computer with exploring different solutions, and then reporting back to the user which alternatives are suitable. This automated process of 'generative design' requires designers to extend the parametric model by including pre-defined performance metrics that describe explicitly to the computer how to determine which designs perform better (Villaggi et al. 2017). These criteria, which are called fitness factors, should be selected sufficiently to capture the priorities of the design problem. However, current systems accept only numeric quantities as performance factors. Therefore, thinking with methods for quantifying other qualitative aspects of design is needed.

### **2.8.2. Thinking Algorithmically: an Object-Oriented Programming (OOP) Approach**

An algorithm is "*a finite set of instructions that aim to fulfil a clearly defined purpose in a finite number of steps*" (D'Ino 2012, p.210). This means that a designer executes, in an intelligence and precise procedure, a finite series of specified computational steps and rules for addressing a problem through converting inputs into different solutions and outputs (D'Ino 2012; Woodbury 2010).

This process involves deduction, induction, abstraction, generalisation, and structured logic through utilising the arithmetic and logical capabilities of computers, and searching for repetitive patterns and universal principles (Terzidis 2006). However, algorithms are not limited to well-defined problems with specific solutions (Yüksel 2014). Terzidis (2006) states that there are some problems whose solutions are unknown or ill-defined. In this case, algorithms become the appropriate approach for exploring potential solutions, especially when using computers. This algorithmic computational process is based on 'object-oriented programming (OOP)' approach, which is a programming paradigm that can create and modify objects stored in a database (Jabi 2013). An 'object' contains (a) data, in the form of fields, often known as 'attributes', such as length of edges, centre of a circle, or name that identifies the object; and (b) code, in the form of procedures and algorithms that can act on an object by modifying its attributes, often known as 'methods'. When objects share certain attributes or characteristics, it could be organised as members of a 'class' or 'family of objects' (Jabi 2013). A class is composed of three things: a name, attributes, and operations (Nirosh 2015).

Robert Woodbury (2010), in his book: *Elements of Parametric Design*, claimed that parametric systems (algorithms) are realised as 'programs' where designers accomplished their work through writing a precise and prescribed programming language. Each language has different components (Jabi 2013; Terzidis 2006):

- *Values*: each object has values that determine its attribute. A 'value' could be *constant*; an integer, a real number, a character, a string, or a boolean. However, in many cases, values could be *functions*, where it can derive its value from the values of other attributes which can belong to other objects.
- *Variables*: which are the symbolic representation of containers that hold a changing value. In parametric design, these variables are called *parameters*, which are opposite to constants, and have a range of possible values. It could determine another measure or values as it is the variable in a function that determines the specific form of a function but not its general nature.
- *Operations or Expressions*: which combine values, variables, operators and functions that return values.
- *Statements*: which are codes that to be executed in a given order. For instance, a repetition statement is referred to as a loop, which consists of three parts: an initial condition; a termination condition; and a piece of repetition.

- *Control Statements*: such as 'if' or 'switch' statements that change the flow of control, or provide a list of possible actions given the value of a variable, respectively. Another example is the 'for-loop' which calls an initialiser for a control variable and repeats a block code until its loop conditions fail.

The process of parametric modelling involves the use of multiple representations such as geometry, symbols and script (Hudson 2010). Writing a 'script', or a 'code', means to translate a design into a program through abstracting the design ideas and turns them into precise and logical instructions in an object-oriented programming language, such as Python, C++, and JAVA, that adopted a procedural methodology. This gives the opportunity for the designer to understand the problem by decomposing it into parts and objects (Figure 2.29), and then to assign algorithms (data and functions) for these parts (Woodbury 2010). Mark Burry (2011) in his book 'Scripting Cultures: Architectural Design and Programming' suggested several motivations for scripting in design: it enables the designer to customise the software and to become the new tool maker, which provides opportunities for innovation; and it increases the productivity through automating many routine aspects and repetitive activities of the design process. This gives the designer more time to be spent on design thinking.

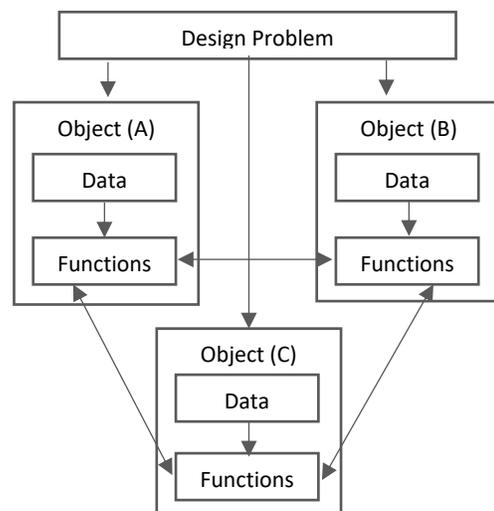


Figure 2.229: Decomposing the design problem into parts (objects)  
(Researcher)

However, architects find difficulty in applying this algorithmic process, as it needs a good knowledge of scripting and programming languages. Recently, Grasshopper, developed in 2011 by David Rutten at Robert McNeel & Associates, and runs within the Rhinoceros 3D

computer-aided design (CAD), offers new ways to control the generation process of complex geometries, in a high degree of flexibility, through mathematical functions. Grasshopper is a visual scripting tool that requires no programming or scripting knowledge. Data is always stored in parameters, and the tool allows input data to be passed from one component to another via connecting wires (Figure 2.30).

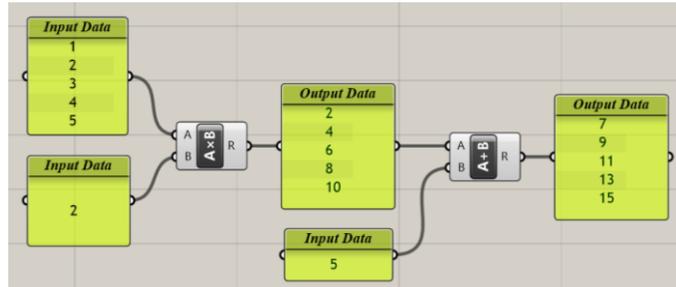


Figure 2.30: A sample of mathematical functions processed by Grasshopper (Researcher)

### 2.8.3. Applying a Computational Approach in the Design Process: The ‘Structured Systems Analysis and Design Method’ (SSADM)

In computing sciences, the formal methodology is mostly used to develop a mathematical technique and algorithms that generate logical solutions automatically (Nelson 2011), (Figure 2.31). It is based on inductive reasoning to verify the quality of these possibilities and alternatives and to capture the essence of the problem (Anay 2005; Burgess 1995). Terzidis (2009) argued that this inductive strategy could be used to simulate a complex problem or to execute a process that generates logical solutions.

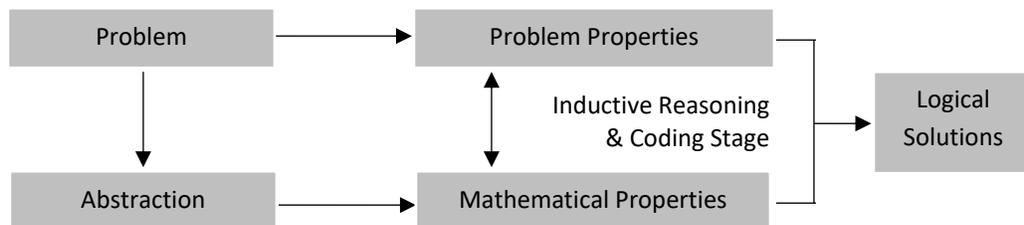


Figure 2.31: The general structure of ‘formal methodology’ within the computational world (Adapted by Researcher from (Burgess 1995))

To understand processes and techniques of formal methodology in computational models about the architectural design process, it is useful to shed light on how developers, in the field of computer science, analyse and convert the requirements of their clients (users) into

programs and software. One of the earliest systematic and computational models is the 'Structured Systems Analysis and Design Method' (SSADM), developed by Larry Constantine in the late 1960s, and then refined and published by different scholars and computer scientists, such as Edward Yourdon, Wayne Stevens, and Douglas Ross. Using this model, the designer identifies inputs, controls, mechanisms and outputs as related to the activities in two major phases: 'structured analysis phase' and 'structured design phase' (UK Office of Government Commerce 1994).

The structured analysis phase consists of four stages: (1) conducting a feasibility study; (2) investigating the current environment; (3) defining all requirements of users; and (4) analysing and interpreting the concept (or real-world situations) into different options represented by flow charts.

The design phase is about developing and processing all requirements to produce physical design activities. It consists of three stages: (1) narrowing down the large number of options to two or three, and then presenting the selected options to the user to select the most appropriate development that meets the technical needs; (2) the logical design stage which concentrates on the requirements for the human-computer interface; and finally (3) the physical design stage which converts all logical data structure, and specifies the exact structure of all functions and how they are implemented (Table 2.16).

Table 2.16: Stages of 'Structured Systems Analysis and Design' Method  
(Adapted by Researcher, from (UK Office of Government Commerce 1994))

| Stage  | Aim(s)   | Steps   |
|--|--|---|
| <b>Stage 0:<br/>Feasibility<br/>study</b>                                | <ul style="list-style-type: none"> <li>- Technical: is the project technically possible?</li> <li>- Financial: can the business afford to carry out the project?</li> <li>- Organizational: will the new system be compatible with existing practices?</li> <li>- Ethical: is the impact of the new system socially acceptable?</li> </ul> | <ul style="list-style-type: none"> <li>- Define the problem.</li> <li>- Investigate goals and implications of the project.</li> </ul>   |
| <b>Stage 1:<br/>Investigation<br/>of the<br/>current<br/>environment</b> | <ul style="list-style-type: none"> <li>- To look at the existing services and requirements and produce a logical view of the processing requirements.</li> </ul>   | <ul style="list-style-type: none"> <li>- Establish analysis framework.</li> <li>- Investigate and define projects' requirements, and the current processing and data through a combination of interviewing employees, circulating questionnaires, observations, and existing documentation.</li> <li>- Analyse the current system and process.</li> </ul> |

|  |  |   |
|--|--|---|
| <b>Stage 2:<br/>Business system options</b>    | <ul style="list-style-type: none"> <li>- To decide the most appropriate development that meets the business needs.</li> </ul>  | <ul style="list-style-type: none"> <li>- Define business system options in which the new system could be produced, through a brainstorming session to know all possibilities.</li> <li>- Select business system options.</li> </ul>   |
| <b>Stage 3:<br/>Definition of requirements</b> | <ul style="list-style-type: none"> <li>- To take the analysis of requirements and produce the requirements' specification.</li> <li>- It is not about how the system will be implemented, but instead describes what the system will do.</li> </ul>  | <ul style="list-style-type: none"> <li>- Develop required data mode and system functions.</li> <li>- Enhance required data model.</li> <li>- Develop specification prototypes.</li> <li>- Develop processing specification.</li> <li>- Confirm system objectives.</li> <li>- Develop three types of diagrams: <ul style="list-style-type: none"> <li>i. 'Entity Relationship Diagrams' showing full description of the data and its relationships.</li> <li>ii. 'Entity Life-Histories Diagrams' which describe all events through the life of an entity.</li> <li>iii. 'Effect Correspondence Diagrams' which describe how each event interacts with all relevant entities.</li> </ul> </li> </ul> |
| <b>Stage 4:<br/>Technical system options</b>   | <ul style="list-style-type: none"> <li>- It is the first stage towards a physical implementation of the new system. The primary objective is to narrow down a large number of options to two or three, and then present the selected options to the user to select the most development that meets the technical needs.</li> </ul> | <ul style="list-style-type: none"> <li>- Determine the programming language that will be used, the cost and all constraints.</li> </ul>   |
| <b>Stage 5:<br/>Logical design</b>             | <ul style="list-style-type: none"> <li>- It concentrates on the requirements for the human-computer interface.</li> </ul>  | <ul style="list-style-type: none"> <li>- Define user dialogues.</li> <li>- Define inquiry processes and how the system will be implemented.</li> </ul>  |
| <b>Stage 6:<br/>Physical design</b>            | <ul style="list-style-type: none"> <li>- To convert all logical data structure and specifications to descriptions and real software.</li> <li>- To specify the exact structure of all functions and how they are implemented.</li> </ul>   | <ul style="list-style-type: none"> <li>- Create Physical Data Design.</li> <li>- Create Function Component Implementation Map.</li> <li>- Optimize Physical Data Design.</li> <li>- Complete Function Specifications.</li> <li>- Consolidate Process Data Interface.</li> </ul>   |

#### 2.8.4. Humanising the Computational Process: Integrating Parametric Models with Qualitative Dimensions

The current focus of computational models is primarily limited to building performance and optimisation, in addition to the functional and programmatic requirements of the design problem (Castellano 2011; Yüksel 2014). However, qualitative factors, such as social, cultural and contextual aspects are also essential dimensions in solving architectural design problems. Devan Castellano (2011, p.276) claimed that *"the built environment should address the user's psychological, informational, and social needs as well as the functional and programmatic requirements, environmental concerns, and optimisation"*. Yet, integrating the embedded

qualitative criteria of the architectural design problem, with the functional and environmental requirements, remains a challenge in the computational process, due to the difficulty in converting complex and abstracted issues into necessary parameters that can be algorithmically represented (Yüksel 2014; Terzidis 2006).

Therefore, feeding the parametric model with quantitative functions and qualitative data needs additional tools and approaches to be adopted. Based on that, a ‘typological analysis approach’, associated with different formal, syntactical, analytical and generative methods (such as space syntax, and shape grammar) would be used. The following section gives an overview, advantages and implications of each method, to create a base for selecting the most appropriate method, or a combination of different methods, to be adopted for achieving the objectives of the study and answering the research question.

## 2.9. Analytical and Generative Design Systems

To design a building that is in harmony with the context, the past, and the requirements of the modern and future time, designers need to analyse multiple complex variables rather than focusing on the analysis of each variable (Groat & Wang 2013). To incorporate all of these issues, it is important to understand and analyse two sets of relationships. The first set addresses space-form languages, which includes lexical (geometrical) and syntactical levels. The second set considers semantic and semiotic levels that are related to the meanings and symbols of elements and treatments.

### 2.9.1. Typological Analysis Approach

The typological analysis concentrates on studying the current and past situations. Learning from previous experiences is a suitable approach to acknowledge the role of precedents in design (Colquhoun 1969), which provides continuity to the existing world, and at the same time, it offers to design with sensitivity to the current situation (Assi 2001). Peter Lack (1995), as cited in (Pfeifer & Brauneck 2008, p.8)), defined ‘typology’ as “*an approach that isolates the attributes of the architectural coherence, identifies them as characteristics, in order to compare them with similarly abstracted attributes from other contexts and to define similarities or differences*”. The first typological approach has been developed by the French archaeologist Quatremere de Quincy in his work ‘*Encyclopedie*’ at the end of 18<sup>th</sup> century (1789). He compared between two concepts: ‘type’ and ‘model’. While the ‘model’ is a form that could be copied or

replicated, 'type' is a principle that describes the commonalities of a series of different concrete models (Pfeifer & Brauneck 2008). Henri Achten (1997) defined building types as "*classes of buildings that have major formal, functional, or procedural characteristics in common, and encompasses a significant form of declarative knowledge (the kind of building) and procedural knowledge (designing that kind of building) in design*". However, architecture is not only described by types, but it can also be produced from them (Achten et al. 1996). Rafael Moneo (1978) interpreted Quatremère de Quincy's definition as the inherent structure and formal order that allows architectural objects to be grouped, distinguished and repeated.

Typological studies are a useful tool for the architect during the design process. It helps the designer in establishing a database that organises the architectural knowledge and preserves the social and spatial order of the community. Moreover, designers could use types to understand the built environment and to generate new buildings based on these types. Therefore, it could be classified into two aspects: formal and behavioural analysis. Each aspect has multiple levels of analysis (Figure 2.32). The formal analysis means to understand the morphology and form (space-form languages) (Pfeifer & Brauneck 2008). Argan (1963) claimed that a 'type' is formed through a process of reducing a complex of formal variants to a common root form. It includes two levels: "lexical level", through adopting a 'de-compositional model' that reduces shapes to its basic geometries (vocabularies); and "syntactical level" that defines relationships and arrangements of vocabularies relating to each other. However, the syntactical level is also related to the second aspect which addresses the social life of users. The second aspect is to identify the behavioural meaning and the cultural and social values that are rooted in the history and reflect the local lifestyle of the community (Güney 2007; Petruccioli 2007). It has two levels: "*semantic level*" that defines the meanings of components and vocabularies; and the "*semiotic level*" that defines symbols for the overall language.

This study focuses on both aspects of analysis. It analyses the patterns and components of traditional houses and relationships between different spaces. In addition, it explores the meanings and symbols behind these vocabularies. This could be a powerful tool to provide continuity to the existing world, to reflect the local identity of families, and to enhance the social interaction between people in contemporary developments.

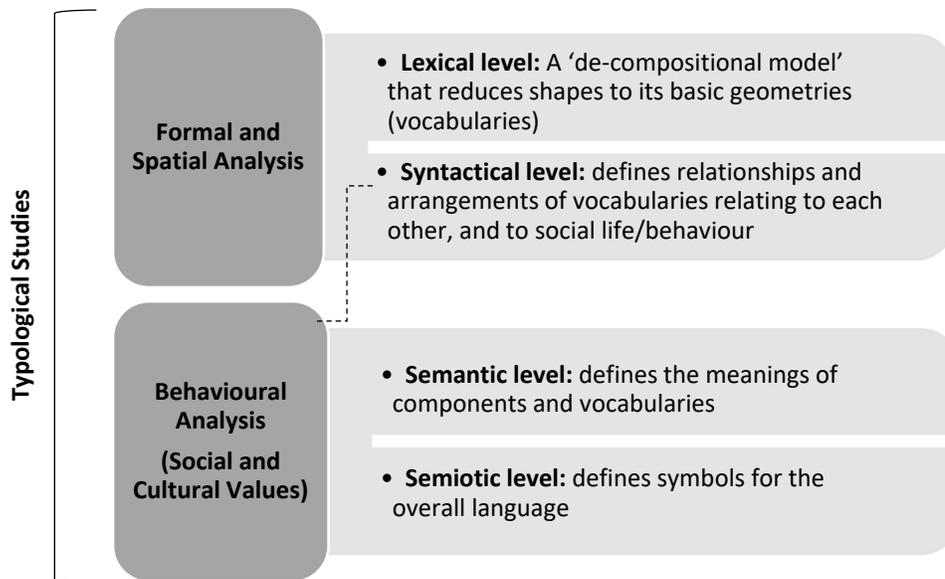


Figure 2.32: Typological analysis approach (Researcher)

### 2.9.2. Spatial Reasoning and 'Design Space Exploration'

Jerome Bruner, in his studies about the psychology of knowing, defined 'reasoning' as 'going beyond the information given' (Bruner 1973). In the field of architecture, spatial reasoning is a logical process of analysis that enables designers' understanding of the layout complexity, and the exploration of features that have social or experiential significance (Abshirini & Koch 2013). For instance, tracing the visual fields from a specific location in a building allows an explicit evaluation of spatial elements that affect the privacy of occupants. Different methods, such as space syntax and shape grammars, could be used for carrying out reasoning analyses to derive social and spatial parameters that affect the design of the built environment.

### 2.9.3. Space Syntax Approach

'Space Syntax', developed at the University College London by Bill Hillier and Julienne Hanson (1984), is a technique that could be used to describe topological relationships between the morphological/spatial structure of the man-made environment (buildings and urban fabrics) without a direct reference to the geometrical properties, and the social life or behaviour (Hillier & Hanson 1984). Social meanings that take place within the spaces of the building, and the ordering of spaces, are about the ordering of relations between people (Zako 2006). In other

words, it is the study of cognition or social meaning and the spatial configuration of spaces with its topological structure (Hillier 2014; Sayed 2012). Configuration refers to the arrangement of spaces in relation to the overall social pattern (Emo et al. 2012). Spaces in this approach are understood as voids (such as rooms) between walls, and are represented in a graph by circles (which called nodes), and lines (which called syntactic steps) representing relationships between spaces (Klarqvist 1993).

Different studies have been conducted to understand the social logic of houses using space syntax approach. Tahar Bellal (2004) in his study, “Understanding home cultures through syntactic analysis: The case of Berber housing”, aims to explore the social logic of Berber houses in Algeria through identifying a correlation between spatial patterns and the system of social relations within houses. His main methodology was space syntax as an analytical tool to explore depth, integration value, choice and movement links inside houses (Bellal 2004). Another study is “The socio-cultural facets and spatial morphology of Tangale domestic spaces”, which was conducted by Joy Maina (2013). The primary objective of her research was to explore factors, themes, and concepts that influenced the house form and residential structure in the study area. Moreover, she targeted to establish contemporary socio-cultural determinants of house form and a residential structure that could be useful in policy making and future planning of the built environment. To achieve these objectives, a field survey has been conducted to document the lifestyle of users, the use of spaces, spatial configuration, house form/residential structure and socio-cultural determinants. Furthermore, different scaled drawings have been analysed using the space syntax method to understand patterns of houses and analyse different typologies in the community (Maina 2013).

To understand how buildings could be analysed using ‘space syntax’, it is essential to review some basic concepts, representation maps and graphs, different measures that could be calculated, and some syntactic tools.

#### a. The Basic Concepts in Space Syntax Analysis

- *Convex space* is a space where no line between any two of its points crosses the perimeter. A concave space has to be divided into the least possible number of convex spaces.
- An *axial line* is a straight sight line that is possible to follow on foot.
- *Isovist space* is the total area that can be viewed from a point.

- *Depth* between two spaces is defined as the least number of syntactic steps in a graph that are needed to reach one from the other. For instance, Depth (1) means that a space is directly accessible to another, Depth (2) means that it is necessary to pass through one intervening space to move, Depth (3) means that a minimum of two spaces must be passed.
- *Mean depth*, which is the average depth (or average shortest distance) from node (n) to all other nodes (Hillier & Hanson 1984, p.108). It can be calculated by:

$$\text{Mean Depth (MD)} = \frac{TD}{k - 1}$$

where (TD) is the total depth values, and (k) is the total number of spaces.

### b. Types of Syntactic Maps

- *Convex map*, which shows the least number of convex spaces that thoroughly cover a layout, in addition to all connections between spaces.
- *Axial map*, which shows the least number of axial lines that cover all convex spaces of a layout and their connections.
- *Isovist map*, which shows areas that are visible from convex spaces or axial lines.
- *Justified graph*, which is a restructured graph showing a specific space (the root space) at the bottom, all spaces that are one syntactic step away from it are put on the first level above, and all spaces that are two syntactic steps are put on the second level. This offers a visual picture of the overall depth of a layout seen from one of its points. When most of the nodes are located near the root space, then the system is described as shallow. Figure (2.33) show a sample of the convex map and justified graph for a house.

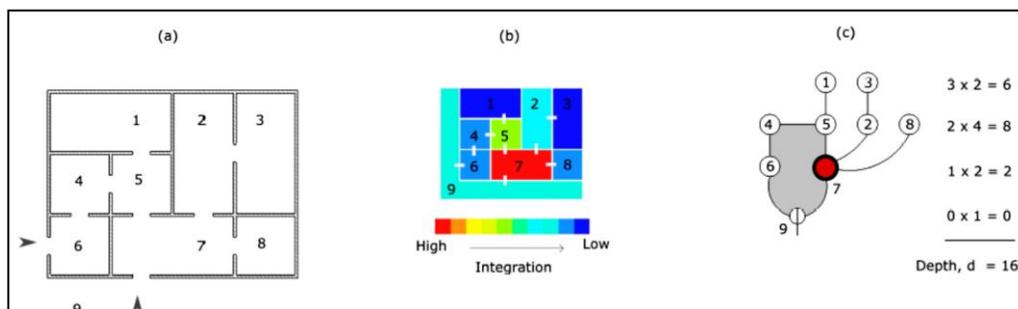


Figure 2.33: A sample of convex map and justified graph for a house (Maina 2013)

### c. Types of Measures

- *Connectivity*, which measures the number of immediate neighbours that are directly connected to space.
- *Integration value*, which describes the average depth of space to all other spaces in the system. The spaces of a system can be ranked from the most integrated to the most segregated. The highest value indicates the maximum integration. The following equation can calculate this value:  

$$\text{Integration Value} = 1 / \left( \frac{2(md-1)}{k-2} \right)$$
, where  $(md)$  is the mean depth of spaces from the space; and  $(k)$  is the total number of spaces.
- *Control value*, which measures the degree to which space controls access to its immediate neighbours, taking into account number of alternative connections that each of these neighbours has.
- *Global choice*, which measures the 'flow' through space. Space has a strong choice value when many of the shortest paths, connecting all spaces to all spaces of a system, passes through it.

### d. Computational Syntactic Tools

Space syntax software and tools, such as 'Depthmap-X'<sup>5</sup> and 'AGRAPH'<sup>6</sup>, offer an analytical tool to draw and calculate space syntax graph. *Depthmap-X* is a single software platform designed to perform a set of spatial network analyses on different scales, to understand social processes within the built environment, to derive variables which may have social or experiential significance, and to convey how social organisations occupy spaces. This software was developed by Alasdair Turner at Bartlett Space Syntax Laboratory, University College London (UCL), in 2000, and there is an ongoing development for it through an open source platform for knowledge dissemination in coordinated with Space Syntax LTD.

The second software is AGRAPH, which was developed by Bendik Manum at The Oslo School of Architecture and Design, in 2005, for drawing and calculating space syntax graphs. It is a tool for analysing layouts with the possibility of doing modelling and analyses

<sup>5</sup> <https://www.bartlett.ucl.ac.uk/space-syntax/research/projects/ucl-depthmap> (accessed on 30/3/2016)

<sup>6</sup> <https://www.ntnu.no/ab/spacesyntax> (accessed on 30/3/2016)

as well as making printable images and graphs (Manum et al. 2005; Manum 2009; Manum et al. 2009).

As a conclusion, 'space syntax approach' is a helpful tool for understanding and evaluating architectural spaces, and relationships between social constraints and spatial possibilities (Dursun 2007; Şalgamcıoğlu 2014). Therefore, using the spatial measures of 'space syntax' in this study, with other qualitative analyses, would provide a powerful tool for analysing the morphology of traditional houses in the study area. This analysis of spatial patterns and the prediction of social indicators (such as interaction, privacy, patterns of movement) would help the researcher in understanding the relationship between the spatial arrangement of spaces and the social meaning and behaviour in traditional courtyard houses (Adeokun 2007; Klarqvist 1993). Moreover, space syntax is a useful tool for analysing the current situation of contemporary tall residential developments, in comparison to traditional houses and proposed alternatives that will be produced at the end of this study.

#### **2.9.4. Semantic and Semiotic Analysis Approach**

In written languages, the 'word' results from the combination of a specific form (syntactic) with a particular meaning (semantic) (Lang 1987). The same issue is in the architectural context, as 'semantics' is the study of the relations between the meanings and the elements of the environment which they designate. The semiotic approach is the extension of semantics, as it is concerned with uncovering the hidden meanings and the signs of some aspects in the everyday life (Bryman 2016). Based on the writings of the philosopher Ferdinand de Saussure (as cited in (Lang 1987)), the semiotic approach concerned with the symbols of the overall language, as there is an associational relationship between the patterns and their meanings within a context. Thus, the context is very important since the same element might mean different things based on the place.

To design a tall building that respects the identity of the place and the society, and inspires from traditional houses, it is essential to explore the different reasons for using specific elements in these dwellings. Once the researcher identifies the meanings and the functions of the various elements, social parameters associated with spatial constraints will be specified and coded.

### 2.9.5. Grammars as a Tool of Analysis and Design

'Designing by grammar' is one of the generative processes that consider the morphology of the overall form and the components of the internal structure, relationships and processes that generate them (Eilouti & Al-Jokhadar 2007b). It emphasises on the lexical and syntactical levels of the composition rather than semiotics and semantic levels. The following section illustrates an important type of these grammars, the 'shape grammar', which allows the analysis of existing design, and the generation of new solutions through applying rules and constraints on an initial shape.

#### a. Shape Grammars

Shape grammar is one of the generative systems that allow designers to understand and generate designs through working with shapes rather than symbolic computations. Studies in the area of shape grammar started in the early 1970s by George Stiny and James Gips (1972). This systematic process generates a language of design through formulating a set of spatial relationships, parameters, rules and restrictions that can be applied to a set of vocabularies to analyse existing shapes and to generate new alternatives (Stiny & Mitchell 1978; Stiny 1980a; Knight 1980; Stiny 1985; Chan 1992; Stiny & Gips 1972).

According to (Stiny 1980a, p.347), a shape grammar is composed of four components: (1) a finite set of shapes; (2) a finite set of symbols; (3) a finite set of shape rules; and (4) an initial shape. Osman (1998) in his research "Shape grammars: simplicity to complexity" (cited in (Eilouti & Al-Jokhadar 2007b, p.9)) summarises the four stages of the shape grammar framework:

1. *Vocabulary definition*: It is about defining the basic shapes of the formal language.
2. *Spatial relationship determination*: It is about deducing the spatial relationships between the vocabularies of the design.
3. *Rule formulation*: It is about formulating the spatial relationships to be applied on the vocabularies that are identified in the first stage.
4. *Shape combination and articulation*: applying rules recursively on initial shapes to generate new shapes, and to define a language of design.

To control the process of generating design alternatives and to produce unique solutions, George Stiny (1980b, p.434; 1980a, p.345) introduced labels (such as letters, symbols or points), associated with shapes, to reduce symmetries (Figures 2.34 and 2.35). Moreover, Stiny specified parameters that could be applied to shapes. 'Parametric grammars' are a

variation of shape grammars. It consists of parametric shapes, and proportional relationships, to define a shape rule schemata (Stiny 1980b). In this way, designers can generate new solutions that belong to a language defined by the grammar, through changing values of parameters within certain limits. Thus more flexibility in the design process could be achieved.

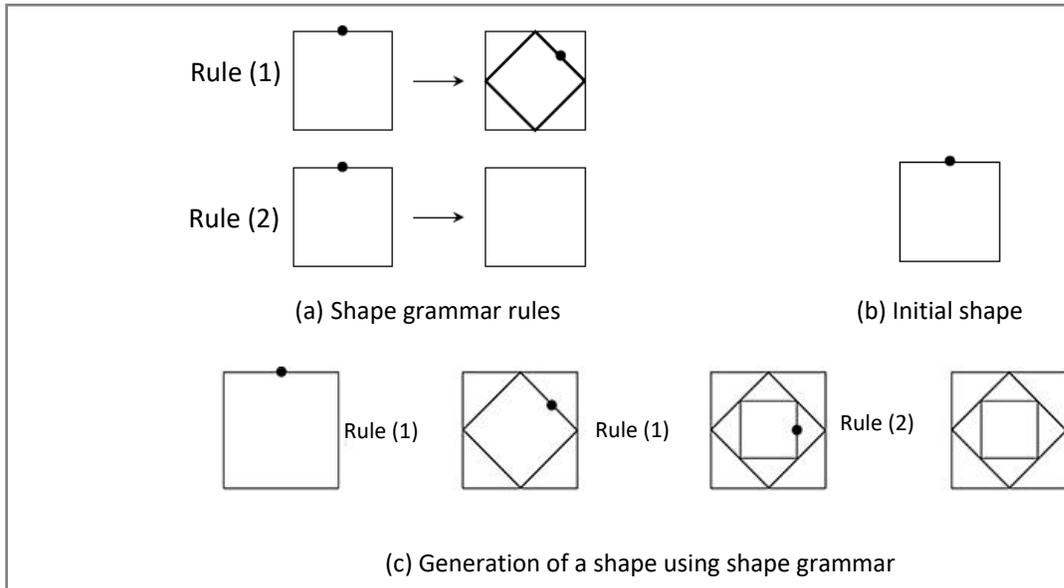


Figure 2.34: A simple shape grammar process  
(Correia 2013)

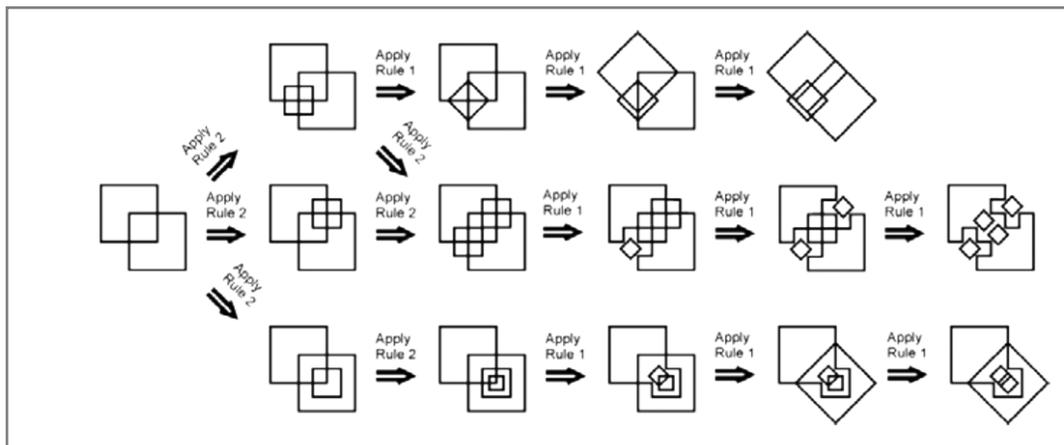


Figure 2.35: An example of shape computation  
(McKay *et al.* 2011)

Principles of shape grammar have been implemented in different fields. In 'A Pattern Language', Christopher Alexander (1977) describes the patterns of good design practices in an attempt to reconstruct the knowledge about what makes architecture vibrant and

beautiful. A pattern, which varies in the scale, addresses a problem and then recognises a good solution which is balanced within the defined context. A pattern language defines the relationship (the syntax) between the different patterns (vocabularies) in a hierarchal order.

Different studies implemented by scholars show the compelling aspect of shape grammar method in describing, analysing and generating different designs with various constraints and goals. The following are some examples: The Palladian grammar (Stiny & Mitchell 1978); The generation of Hepplewhite-style chair-back designs (Knight 1980); The bungalows of Buffalo (Downing & Flemming 1981); The grammar of Queen Anne houses (Flemming 1987); The grammar of Taiwanese traditional vernacular dwellings (Chiou & Krishnamurti 1995; Chiou & Krishnamurti 1996); The grammar of traditional Turkish houses (Cagdas 1996); The automatic generation and fabrication of designs (Wang & Duarte 2001); The interpretation and generation of vernacular Hayat houses in contemporary context (Colakoglu 2005); A grammar for customizing Siza's houses at Malagueira (Duarte 2005a); A shape grammar scheme for classification of caravanserais (Andaroodi et al. 2006); A generative system for Mamluk Madrasa form-making (Eilouti & Al-Jokhadar 2007a; Eilouti & Al-Jokhadar 2007b); The shape grammar of Rudinara Residence (Ramli & Embi 2008); The grammar of Sultanate mosques in Bengal architecture (Kabir 2009); A parametric shape grammar of the traditional Malay long-roof type houses (Embi & Said 2009); Computer-generated residential building layouts (Merrell et al. 2010); The genetic shape plan of the traditional Ottoman's style house (Alchalabi 2011); Charles Correa's housing language (Torus 2012); Shape grammars of traditional Damascene houses (Eilouti & Al Shaar 2012); and Comparing the language of Sinan and Palladio (Eilouti 2012).

However, some limitations faced the designers when they applied this formal approach. Shape grammars do not show the historical, social, cultural, environmental, economic and functional aspects of the composition as it does not go deep with semantic and semiotic levels of the layout (Colakoglu 2000; Knight 1999). Moreover, some of the design possibilities that are produced by applying shape grammar have no architectural meaning or are irrelevant. To cope with these limitations, scholars suggest different tools to be combined with shape grammars, such as descriptions, expressions, and textual information.

## b. Description Grammars

Usually, details of the design elements are provided in text and descriptions (Stiny 1981). To address this issue, George Stiny (1981) proposed the concept of adding description functions to the shape rules in the grammar to generate relevant solutions. Rudi Stouffs (2014 and 2015) in his studies reviews the concept of description grammars and gives examples of descriptions in a textual form, such as numbers, strings, lists, operators, functions, and parameters. He defined different schemes for descriptions: (1) as reflections, (2) as expressions, and (3) as design brief (Stouffs 2015).

### - *Descriptions as Reflections*

This scheme reflects the spatial vocabularies that form the design and the combination of elements (Stiny 1981). Examples of these are the four descriptions that Andrew Li (2001) has included in the shape grammar of the *Yingzao Fashi* architectural style: the depth (in rafters), the height, the disposition and character of beams (expressed in various combinations of three terms: clear span, central division, or beams), and the number of columns (Li 2001, p.29). He wrote a description rule for one of the spaces as the following: “6-rafter building, centrally divided, 1-rafter beam in front and back, with 5 columns” (Li 2001, p.30).

### - *Descriptions as Expressions*

This type is used to describe some properties such as volume, cost or manufacturing plan. For example, Agarwal (1999), as cited in (Stouffs 2015, p.140)), added cost expressions or equations to evaluate the cost of a design during the generation process. This type of descriptions gives the design feedback and guides the design by cost preferences.

### - *Descriptions as Design Brief: Programming Grammar*

This type of descriptions is based on user data, which request user input values at the rule application; or site data, such as functional zones and their adjacency relations; or adding conditional specifications to constraint rule application and limit parameter values (Stouffs 2015). The latter could be applied through an enumeration of ‘true’ and ‘false’, which may allow a parameter, such as function or rule label, to be constrained beyond a single value (Duarte 2005a; Eloy & Duarte 2011).

José Duarte (2001, 2005) applied these descriptions in the ‘programming grammar’ while he worked on the Siza's Malagueira housing program guidelines and evaluation system. It is about generating symbolic description (the housing program) from user input data to know his needs and preferences. In that study, descriptions include two types: variable and fixed descriptions (Figures 2.36, 2.37 and 2.38). Features of fixed descriptions have fixed values, and the user cannot change it. Features of variable descriptions are organized into three main groups (Duarte 2005a, p.267):

- Group (A): contextual, typological and morphological features, which are called constraints, as values are specified by the user and cannot be changed by the programmer.
  - Contextual features: plot size, urban context, and solar orientation;
  - Typological features: degree of customisation, users’ profile, number of bedrooms, and quality level;
  - Morphological features: house type, number of floors, and the existence of balconies.
- Group (B): functions and aesthetic qualities, which could be evaluated by the user to know the overall quality of the design.
  - Functional qualities, which include: spatiality (dwelling capacity, room capacity, articulation, and spaciousness); and topology, which refers to the relation between two spaces in terms of distance and communication.
  - Aesthetics, which include proportion.
- Group (c): construction cost, through specifying area, materials, thickness of walls, and number of floors (Heitor et al. 2003).

**Customized house**

**Dwellers:**

**g19: Specifying dwellers information (user), and adding required bedrooms (programmer)**

$\alpha_3 \leftarrow \alpha_3, \alpha_3 = \text{custom}$

$\alpha_4 \leftarrow \alpha_4 + < 1, (\text{name}_{n+1}, \text{age}_{n+1}, \text{gender}_{n+1}) >,$   
 $\text{age}_i \in \{ '0-1', '2-5', '6-13', '14-17', '18-23', '23-65', '> 65' \},$   
 $\text{gender}_i \in \{ \text{male}, \text{female} \}$

$\alpha_5 \leftarrow \alpha_5 + < 1, [( \text{couple}, 0 ), ( \text{double}, 0 ), ( \text{single}, 1 ) ] >$

$\alpha_6 \leftarrow \alpha_6, q_{\text{level}} = \alpha_6$

$\alpha_{13} \leftarrow \alpha_{13} + < \text{be}, \text{id}_{\text{be}}, (\text{name}_{n+1}), (\text{sleeping}), (\text{single}, 100), (q_{\text{level}}, 100), W_{\text{si}}, h_{\text{si}}, a_{\text{si}} >$   
 $\text{id}_{\text{be}} = \max(\text{id}) + 1$

$\sim \exists < ?\text{id}_{\text{be}}, ?\text{id}_{\text{t}}, \text{on}, ?W > \in \alpha_{17}$

$\Rightarrow \alpha_{14} \leftarrow \alpha_{14}, + \text{sleeping}(\text{id}_{\text{be}}, a_{\text{si}})$

$\alpha_{15} \leftarrow \alpha_{15}, + < \text{available}, (0, -a_{\text{si}}, 0, -a_{\text{si}}), (0, 0, 0, 0), (0, -a_{\text{si}}, 0, -a_{\text{si}}), 0 >$

$\alpha_{16} \leftarrow \alpha_{16}, + < \text{used}, (a_{\text{si}}, a_{\text{si}}, 0, a_{\text{si}}), (0, 0, 0, 0), (a_{\text{si}}, a_{\text{si}}, 0, a_{\text{si}}), - a_i / a_u + (a_i + a_{\text{si}} / a_u + a_{\text{si}}) >$

$\alpha_{17} \leftarrow \alpha_{17}, + < [\text{id}_{\text{be}}, \text{id}_{\text{t}}, \text{on}, 100] >$

Figure 2.36: A sample of the programming grammar (Duarte 2001)

| Variable description (program description) |                     |                           |               |   |  |
|--|---------------------|---------------------------|---------------|---|--|
| Features                                   | Groups of variables |                           | $\alpha$      | Variables   |  |
| Contexts                                   | Lot                 |                           | $\alpha_0$    | < w, l, h, a >  |  |
|  | Urban               |                           | $\alpha_1$    | <front, right, back, left>  |  |
|  | Solar orientation   |                           | $\alpha_2$    | <front, right, back, left>  |  |
| Typology                                   | Customization       |                           | $\alpha_3$    | < degree >  |  |
|  | Users               |                           | $\alpha_4$    | < number, [(name, gender, age, share),...] >  |  |
|  | Bedrooms            |                           | $\alpha_5$    | < number, [(couple, number), (double, number), (single, number)] >  |  |
|  | House quality       |                           | $\alpha_6$    | < initial quality, current quality >  |  |
| Morphology                                 | Yard location       |                           | $\alpha_7$    | < yard >  |  |
|  | Floors              |                           | $\alpha_8$    | < floors >  |  |
|  | Balconies           |                           | $\alpha_9$    | < balconies >   |  |
| Spatiality                                 | Capacity            | Minimum obligatory spaces | $\alpha_{10}$ | < [use, number, ((articulation, number)...)]... >   |  |
|  |                     | Initial obligatory spaces | $\alpha_{11}$ | < [use, articulation, weight],... >   |  |
|  |                     | Current optional spaces   | $\alpha_{12}$ | < [use, articulation, weight],... >   |  |
|  |                     | Current spaces            | $\alpha_{13}$ | < [name, id, ( users, functions, (capacity, weight), (articulation, weight), (spaciousness, weight), (insertion point, rotations, width, length, height, area)),... > |  |
|  |                     | Zones                     | $\alpha_{14}$ | < [use,rooms, area],... >   |  |
|  | Spaciousness        | Areas                     |               | $\alpha_{15}$   | < available,<br>(max interior gross, min exterior gross, 1 <sup>st</sup> Floor gross),<br>(max interior gross, min exterior gross, 2 <sup>nd</sup> Floor gross),<br>(max interior gross, min exterior gross, house gross), useful/gross>                           |
|  |                     |                           |               | $\alpha_{16}$   | < used,<br>(inhabitable, interior useful, exterior useful, 1 <sup>st</sup> Floor useful),<br>(inhabitable, interior useful, exterior useful, 2 <sup>nd</sup> Floor useful),<br>(inhabitable, interior useful, exterior useful, house useful), inhabitable/useful > |
| Topology                                   | Adjacency graph     |                           | $\alpha_{17}$ | < [ (room1, room2, relation, weight) ] ... >  |  |
| Building elements                          | Windows             |                           | $\alpha_{18}$ | < [window, (room 1, room 2), (insertion point, depth, width, height, area)],... >   |  |
|  | Doors               |                           | $\alpha_{19}$ | < [door, (room 1, room 2), (insertion point, depth, width, height, area)],... >   |  |
|  | Walls               |                           | $\alpha_{20}$ | < [wall, (room 1, room 2), (insertion point, thickness, width, height, area)],... >   |  |
|  | Pavements           |                           | $\alpha_{21}$ | < [pavement, floor, (insertion point, width, length, thickness, area)],... >  |  |
| Aesthetics                                 | Proportion          |                           | $\alpha_{22}$ | < [proportion1, weight],...>  |  |
| Quality                                    |                     |                           | $\alpha_{23}$ | < [function, weight], [spatiality, weight], [capacity, weight], [articulation, weight], [spaciousness, weight], [topology, weight], [aesthetics, weight] >            |  |
| Cost                                       | Cost                |                           | $\alpha_{24}$ | c   |  |
| History                                    | Rule                |                           | $\alpha_{25}$ | < r1, r2,..., rm >  |  |

| Fixed description    |                    |           |        |                               |
|----------------------|--------------------|-----------|--------|-------------------------------|
| Spaces dimensions    | width              | $\beta_1$ | tables | width (space, quality)        |
|                      | height             | $\beta_2$ | tables | height (space, quality)       |
|                      | area               | $\beta_3$ | tables | area (space, quality)         |
| Sectional dimensions | Pavement thickness | $\beta_4$ |        | thickness (pavement)          |
|                      | Floor height       | $\beta_5$ |        | height (floor)                |
| Cost                 |                    | $\beta_6$ | table  | unit_cost (element, material) |

Figure 2.37: A sample of housing program showing variable and fixed descriptions (Duarte 2001)

| Feature               | Feature                 | $\alpha$                       | Feature                                   | Values   |                    |
|-----------------------|-------------------------|--------------------------------|---|--|--------------------|
| Morphology            | Lot                     | $\alpha_0$                     | Width                                     | 8 m <sup>2</sup>   |                    |
|                       |                         |                                | Length                                    | 12 m <sup>2</sup>  |                    |
|                       |                         |                                | Area                                      | 96 m <sup>2</sup>  |                    |
|                       | Urban                   | $\alpha_1$                     |   | Houses on three sides (default), house on one side, house at the back, house on the side and back  |                    |
|                       | Solar orientation       | $\alpha_2$                     |   | N, NE, E, SE, S, SW, W, NW   |                    |
| Typology              | Customization           | $\alpha_3$                     |   | Custom, type (default)   |                    |
|                       | Dwellers                | $\alpha_4$                     | Number                                    | 1, 2, 3, 4, 5, 6, 7, 8, 9  |                    |
|                       |                         |                                | Name                                      | User prompted<br>Blank (default)   |                    |
|                       |                         |                                | Gender                                    | Male<br>Female<br>Blank (default)  |                    |
|                       |                         |                                | Age                                       | 0-1, 2-5, 6-13, 14-17, 18-23<br>23-65, > 65, Blank (default)   |                    |
|                       | Share                   | Room<br>Bed<br>Blank (default) |   |  |                    |
|                       | Bedrooms                | $\alpha_5$                     | Number                                    | 1, 2, 3, 4, 5  |                    |
| Quality*              | $\alpha_6$              | Initial                        | Minimum (default), medium, maximum (high) |  |                    |
|                       |                         | Current                        | Minimum (default), medium, maximum (high) |  |                    |
| Morphology            |                         | $\alpha_7$                     | Yard                                      | Front, back  |                    |
|                       |                         | $\alpha_8$                     | Floors                                    | 1, 2   |                    |
|                       |                         | $\alpha_9$                     | Balconies                                 | True, False  |                    |
| Spatiality            | Capacity (dwelling)     | $\alpha_{10}$                  | Minimum                                   | List of spaces' IDs  |                    |
|                       |                         |                                | $\alpha_{11}$                             |  | Initial obligatory |
|                       |                         |                                | $\alpha_{12}$                             |  | Optional           |
|                       |                         |                                | $\alpha_{13}$                             |  | Current            |
|                       |                         |                                | $\alpha_{14}$                             |  | Zones              |
|                       | Spaciousness (dwelling) | $\alpha_{15}$                  | Available                                 | See Tables 7.8-7.10  |                    |
|                       |                         |                                | $\alpha_{16}$                             | Used   | m <sup>2</sup>     |
|                       | Name                    |                                |   | Kitchen, laundry, pantry, living, closet, step-in-closet, stairs, patio, bedroom, bathroom, circulation, corridor, studio, balcony (terrace) |                    |
|                       | Space ID                |                                |   | Random number  |                    |
|                       | Functions               |                                |   | See table 7.7  |                    |
| Capacity (spaces)     |                         |                                | 1, 2, 3, 4, 5, 6, 7, 8, 9                 |  |                    |
| Articulation (spaces) |                         |                                | Included, delimited, isolated             |  |                    |
| Spaciousness (spaces) |                         |                                | See Tables 7.18-30                        |  |                    |
| Topology              |                         | $\alpha_{17}$                  | Relation                                  | Away, close, adjacent, window, door, passage, merged, any (default)  |                    |
| Aesthetics            |                         | $\alpha_{23}$                  | Proportion                                | 1:1, 1:√2, 1:2, 2:3, 3:4, 5:6  |                    |
| Quality               |                         | $\alpha_{22}$                  | Weights                                   | 0, 5, 10, 15, ..., 100   |                    |
| Cost                  |                         | $\alpha_{24}$                  | Construction                              | USD \$ / m <sup>2</sup>  |                    |
| History               |                         | $\alpha_{25}$                  | Sequence of rules                         | Sequence of rule numbers   |                    |

Figure 2.38: A sample of housing program features values  
(Duarte 2001)

### c. Discursive Grammars

To manipulate shapes, its descriptions and semantics to produce an optimum solution that fits with the context, José Pinto Duarte (2001) proposed a framework that combines both shape grammar and programming grammar with 'heuristics' used in a deterministic process. The framework is used in two scales: at micro-scale, to choose a rule at each step of the design generation; and at a macro-scale to reach the optimum solution that is closer to the design brief and appropriate with the context through a small number of rules (Duarte 2005b; Duarte 2005a).

Examples of this type of grammars are shown in two studies. In the first study, Duarte (2001) applied discursive grammars to the 'Portuguese Housing Program Guidelines' designed by architect Alvaro Siza at Malagueira. He called the grammar (PAHPA-Malagueira). He proposed a framework and an interactive computer system, called 'MALAG' (Figure 2.39), that transfers the requirements of users within a given style into a design brief using 'programming grammar'. The description aspect of this grammar comprises a variable dimension – constraints (such as context, typology, morphology, functional space capacity, topology, aesthetics), and also fixed aspects (such as floor and sectional dimensions). Then, the computer translates the brief, through an automated process, into solutions based on 'designing grammar' (Duarte 2005a).

In a second study, Eloy and Duarte (2011) used a discursive grammar for housing rehabilitation, through understanding the existing dwellings and the new requirements of users to adapt it according to their needs. It includes two aspects: shape, and descriptive, to guarantee that the appropriate dwelling design can be obtained from the description in the functional housing programme. Figure (2.40) shows a sample for the combination of shape rules in shape grammar with specific descriptions to be closer to the design requirements.

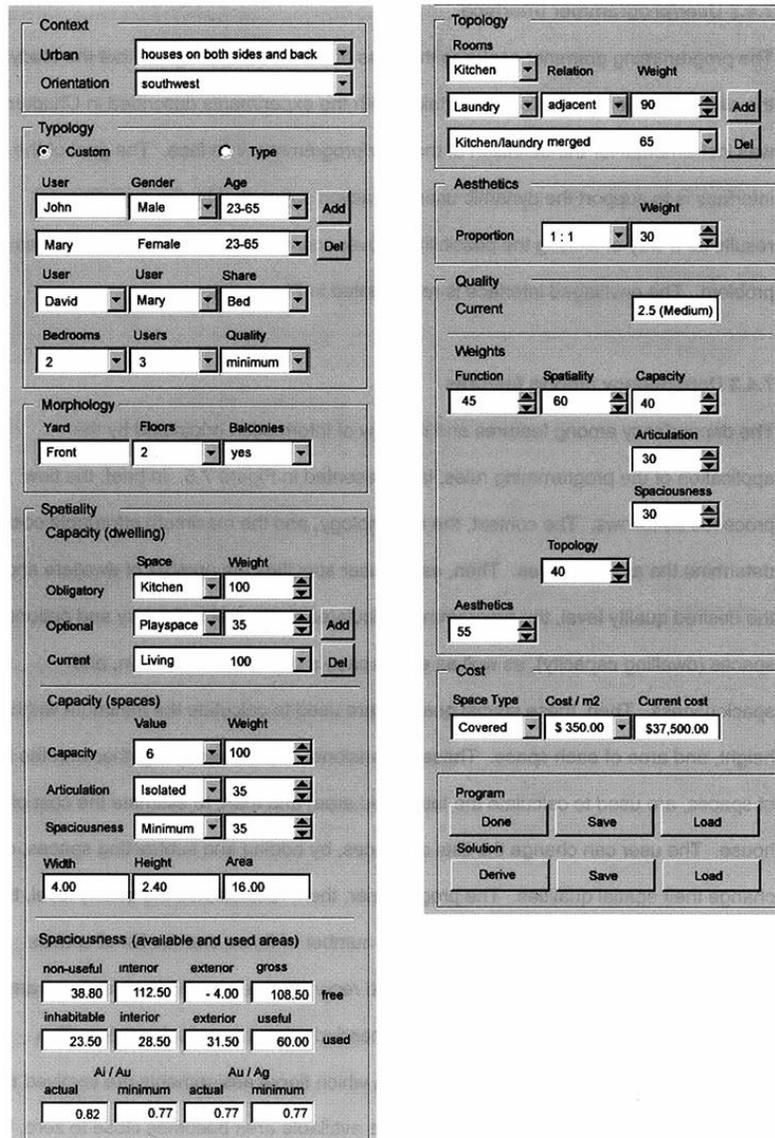


Figure 2.39: A Sample of the interface (MALAG) that translate the requirements of users into a design brief using the programming grammar (Duarte 2001)

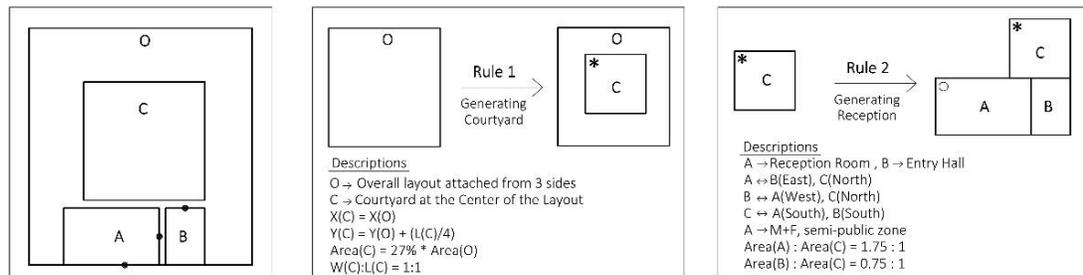


Figure 2.40: Part of a discursive grammar that generates a semi-public zone in a courtyard house (Researcher)

### 2.9.6. Combining Grammars and Qualitative Aspects

The design process could be described as a multi-disciplinary work. It needs from the designer an overall understanding of the context and the needs of users. Moreover, it requires a proper method to address the spatial, formal, social and environmental dimensions of a design (Hillier & Hanson 1984). As illustrated previously, 'space syntax' approach is used to understand spatial topologies and social relations implicit in the architectural setting. However, studies focusing on how such an approach might be used to generate or inspire new designs are limited in this area (Lee et al. 2013; Peponis et al. 2003). Shape grammars offer a different approach which addresses abstract formal topologies to understand an existing style or to generate new solutions. Yet, there is no focus on the social, cultural or symbolic aspects of the architectural compositions (Eilouti & Al-Jokhadar 2007b). Thus, making a good decision for the better design needs from the designer to understand the delicate nature of the relationship between the social dimension of the environment, and the spatial/formal aspect of the design.

Limited studies show initial attempts for combining both approaches in studying the morphological and syntactic qualities and the socio-cultural aspect of the built environment. For example, Teresa Heitor, José Duarte and Rafaela Pinto (2003) concerned with how two different computational approaches to design; shape grammars (a wide range of design solutions) and space syntax (that considers the context), could be combined into a single framework for formulating, evaluating, and generating designs. They utilised the space syntax to determine whether the formal and spatial principles applied in the design process are in the language and the contents of the grammar (Heitor et al. 2003). They constructed a 'discursive grammar' as a base for the design, in addition to variable descriptions (contextual, typological, morphological, functional, and aesthetics features) and constant descriptions (areas, materials, the thickness of walls, and the number of floors). They studied the syntactic features (topology) through identifying the following parameters:

- Depth: topological distance of one space to all other.
- Control: relationship between space and immediate neighbours.
- Contiguity: number of connections with adjacent spaces.

They concluded that syntactic analysis was able to reveal some logical spatial regularities and complex relations between functions. Moreover, it is consistent with the division of the house into functional zones as proposed in the grammar, which supports the idea that designs are in

the same language. Finally, they suggested adding the space syntax (topology) to the description grammar to control the spatial configuration of the solutions, by imposing additional restrictions on the requirements (Heitor et al. 2003).

Another study used the combination of shape grammar and space syntax as a tool for identifying and encoding principles and rules of the design in housing rehabilitation is (Eloy & Duarte 2011). In their methodology, they identified, firstly, the dweller's requirements and needs. Secondly, they identified the functional and spatial rules (through space syntax method) and constructed the grammar. Finally, they tested the grammar by applying the space syntax approach (Figure 2.41).

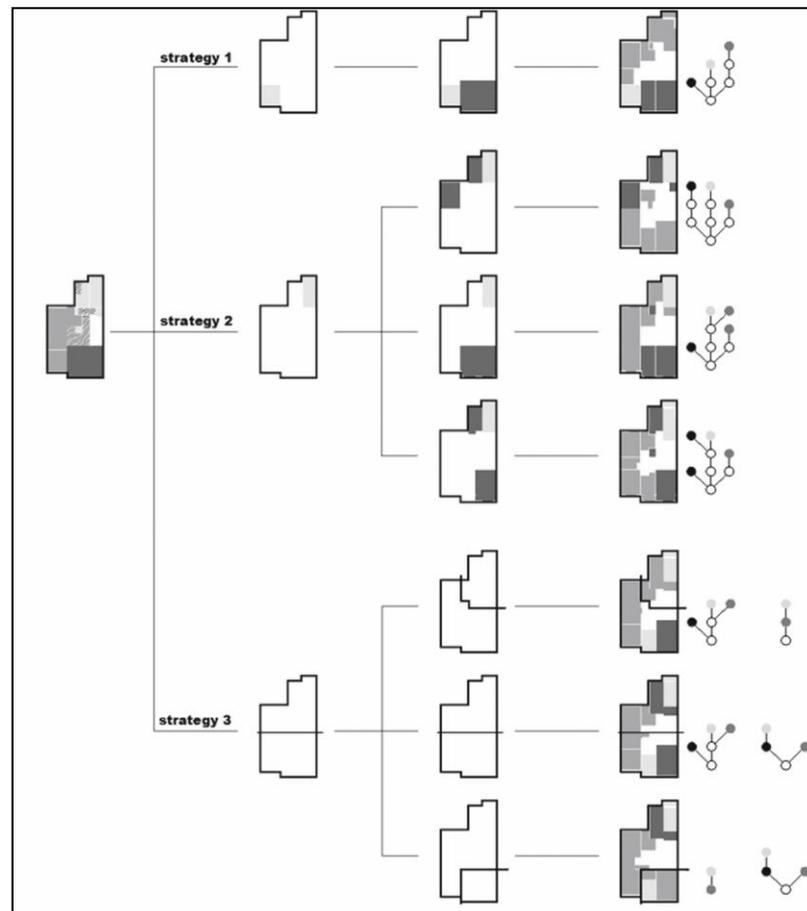


Figure 2.41: Derivation tree for the different rehabilitation strategies, using space syntax approach to test design alternatives (Eloy and Duarte 2011)

## 2.10. Conclusion

Achieving social sustainability in residential buildings, in addition to functional, formal and aesthetic needs that reflect the local identity of the community, require a holistic approach for clarifying spatial qualities that affect the social life inside houses. Thus, a clear set of actions that manipulates the decision-making process is needed. A system that starts with collecting database, creating relationships between the required functions and appropriate relationships, and ends with creating alternatives that are not expected, and could be evaluated against design constraints to meet the required result, could be an appropriate approach to be adopted in this study. This method of thinking offers designers the ability to understand the problem and develop solutions in parallel lines.

However, the conventional manual manipulation of spaces could be not the perfect procedure for the researcher to address the complexity of proposed designs, and to find the optimum solution. Therefore, a process that is manipulated by computers, and considers various parameters and constraints is adopted.

Spatial reasoning approach that defines topological relationships between spaces, and describes their formal properties, offers information about the social logic of spaces, and creates a database that acts as the input for new designs. Moreover, it can be used to improve the social qualities of future developments, and to save time and effort in generating solutions from scratch.

Shape grammars and space syntax methods are useful tools for exploring formal and spatial relationships. Yet, these approaches do not show the social, environmental and semantic levels of the composition. Thus, it is crucial to develop a system of analysis that gives the designer the ability to reveal logical spatial topologies based on social-environmental restrictions, and control the overall configuration of solutions. Moreover, combining descriptions with shape grammars and syntactic relationships to define geometric properties of spaces, addresses the qualitative aspect of the design. Furthermore, adding parameters to the definition of rules to reflect variations extracted from typological and reasoning analysis could address some of the limitations found in traditional shape grammars, and add flexibility to the generation process. The following aspects, presented in (Table 2.17), are suggested to be combined with space syntax and shape grammar approaches as a method for analysing social and spatial relationships in existing residential buildings.

Table 2.17: Combining (space syntax) and (shape grammar) approaches as a method for analysing social and spatial relationships  
(Researcher)

| Criteria of analysis                         | Space syntax method   | Shape grammar  | Suggested criteria for analysing social and spatial relations in residential buildings  |
|--|---|--|---|
| <b>Components</b>                            | <ul style="list-style-type: none"> <li>- Spaces as abstract bubbles.</li> <li>- Relationships and access between spaces (syntactic step).</li> <li>- Depth.</li> </ul>  | <ul style="list-style-type: none"> <li>- Vocabularies (main spaces) of the house.</li> <li>- Proportion.</li> <li>- Geometric relations between spaces.</li> </ul> | <ul style="list-style-type: none"> <li>- Add geometric properties for each space, and its proportion related to other spaces.</li> <li>- Add the exact location of access between spaces.</li> </ul>  |
| <b>Type of relationship</b>                  | <ul style="list-style-type: none"> <li>- Morphology and spatial configuration refers to topological relationships, interaction patterns and access between rooms rather than metric distances.</li> </ul>                     | <ul style="list-style-type: none"> <li>- Geometric properties for each space</li> </ul>  | <ul style="list-style-type: none"> <li>- Add metric distances to know spatial arrangements and patterns of movement.</li> </ul>   |
|  | <ul style="list-style-type: none"> <li>- Relations between spaces (functions) or 'Justified access graphs', which are graphs with appointed depth values for each space according to a chosen space "the carrier".</li> </ul> | <ul style="list-style-type: none"> <li>- Relations between shapes.</li> </ul>  | <ul style="list-style-type: none"> <li>- Combined shapes and functions.</li> <li>- Relationship between the core of the house and other spaces.</li> <li>- Relationship between the entrance and other spaces.</li> </ul>   |
| <b>Hierarchy of spaces (depth)</b>           | <ul style="list-style-type: none"> <li>- All spaces that have the same depth values are placed on the same line.</li> </ul>   | <ul style="list-style-type: none"> <li>- Physical relationship between spaces (wall-to-wall relation) without considering the function of the space.</li> </ul>    | <ul style="list-style-type: none"> <li>- Arrange spaces according to the following hierarchal system: public, semi-public, semi-private, private, and intimate.</li> <li>- Add 'orientation' as an environmental parameter for the distribution of spaces.</li> <li>- Add type of space as: covered, open to the sky, semi-open.</li> <li>- Study the physical-facial relationship between spaces (wall-to-wall relation).</li> </ul> |
| <b>Social interaction and visual privacy</b> | <ul style="list-style-type: none"> <li>- Relationship between spaces without considering the geometry of each space and could affect the visual interaction between spaces.</li> </ul>  | <ul style="list-style-type: none"> <li>- There is no consideration to the social dimension.</li> </ul>   | <ul style="list-style-type: none"> <li>- Study the visual privacy between spaces and how could affect the interaction between people inside each space.</li> <li>- Relationship between users through adding the dominant users (male, female, guests).</li> </ul>  |

Chapter Three

**Research Design and Methodologies**

## Chapter Three

# Research Design and Methodologies

### 3.1. Introduction

In order to find a suitable strategy for answering the research question, different theoretical paradigms and research approaches are reviewed in Section (3.2). Accordingly, a detailed framework for the study, stages, methods, and techniques are presented in Section (3.3) to ensure that all research aims and objectives have been adequately and methodically addressed.

### 3.2. Reviewing Research Paradigms and Theoretical Approaches

Academic research could be described as “a systematic inquiry directed toward the creation of knowledge” (Snyder 1984, cited in Groat & Wang 2013, p.7), or to find solutions to a particular problem (Kothari 2004). More specifically, social research is about “the use of controlled enquiries to locate, describe, understand, explain, evaluate and change patterns or regularities in social life” (Blaikie 2010, p.36). Based on that definition, social research could be classified into different categories based on the **purpose of the study**. Neuman (2007), in his book: *Basics of Social Research*, and Kumar (2014) in his book: *Research Methodology*, address four main types of such studies:

- **Exploratory:** to explore a new topic and formulate precise queries for future research. It addresses ‘what’ questions, such as ‘what is this social issue about?’, by using qualitative data. Instead of giving definite answers, it creates general mental pictures of conditions, new ideas or hypotheses, and techniques for measuring future data (Neuman 2007).
- **Descriptive:** to describe a well-defined social phenomenon, or attitudes towards an issue, through providing a detailed and highly accurate picture. This type of research focuses on ‘how’ and ‘who’ questions, such as ‘how did it happen?’, and ‘who is involved?’. It clarifies a sequence of stage, and documents a causal process, through using most data gathering techniques (surveys, content analysis, historical-comparative, field study), to report on the context of a situation, or to make a policy decision (Neuman 2007).

- **Explanatory:** to explain why something occurs, or how there is a relationship between two aspects of a social phenomenon, through testing theory's predictions and enriching theory's explanation by giving causes and reasons. This kind of research usually builds on exploratory and descriptive research. It extends a theory to new topics and links these new issues with general principles (Neuman 2007). For example, 'how the home environment affects children's level of academic achievement?', or 'why do some have a positive attitude towards an issue while others do not' (Kumar 2014).
- **Correlational:** to discover relationships between two aspects of a situation or social phenomenon. For instance, 'studying the impact of home environment on educational achievement' (Kumar 2014).

In practice, most studies are a combination of multiple purposes. This research combines many objectives. It describes the lifestyle of residents in traditional houses; explores the different 'wants' of residents in high-rise residential environments; and explains the relationship between the spatial distribution of rooms and the social meaning of such an arrangement.

### 3.2.1. Paradigms and Knowledge Claims

Philosophically, researchers start their projects with 'knowledge claims' or 'paradigms'. A *paradigm* is a 'worldview including philosophical and sociopolitical issues' (Teddlie & Tashakkori 2009, p.21), and could be defined as 'an integrated set of assumptions, beliefs, models and techniques for gathering and analysing data' (Neuman 2007, p.41). Different scholars (Blackstone 2012; Bryman 2016; Creswell 2014; Porta and Keating 2008; Kumar 2014; Groat and Wang 2013) argue that 'knowledge claims' refer to the following considerations:

- **Ontology:** what researchers want to know? It is about discovering the nature of reality whether social phenomena are external facts that have an existence, independent, singular and apart from the researcher (*objectivism*), or the phenomenon is about understanding others' view of reality, where reality is subjective, and social facts and their meanings are continually accomplished by participants that shape research questions (*constructionism*).
- **Epistemology:** how they want to know, and how to get reality? Three epistemological positions are discussed in the next section: *positivism*, *interpretivism*, and *pragmatism*.
- **Methodology:** what is the process and stages of research or 'modes of inquiry'? There are three methodological approaches that could be used for collecting data and

researching the real world: (i) ethnography and phenomenological approach, using qualitative methods; (ii) surveying approach, using quantitative methods; and (iii) mixed-method approach.

- **Interpretation:** how results should be interpreted and analysed to achieve the objectives of the study best.

### 3.2.2. Epistemological Positions: How to Get Reality

To search the social world, different paradigms and schools of thought, including positivism, interpretivism and pragmatism are discussed. The distinction between these philosophical positions does not mean that there is one approach better than the others, but each one has its perspectives.

#### a. Positivism: A Natural Science Epistemology

Historically, positivists assume that social reality is made up of objective facts which seem like natural science research. They promote that application of the methods of the natural sciences to study the social reality (Bryman 2016), as they do not accept any views beyond the capability of scientific knowledge (Uddin and Hamiduzzaman 2009). Currently, and in the context of social research, postpositivists acknowledge the fact that the experimental model used in natural sciences is often inappropriate for researching people. As a result, modifications have to be made in research practices through using correlational strategies. In spatial-architectural research, positivism is the most influential mode of research in technical issues and measured variables, such as geometry and energy conservation practices (Groat and Wang 2013). Positivists use two approaches in their research: inductive and deductive. Inductive approach is about concluding evidence, while deductive approach is about finding evidence to support or reject conclusions. In practice, many researchers are flexible and use both approaches at various levels of their studies (Neuman 2007).

#### i. Inductive Approach

In the *inductive* approach, sociologists start with assumptions or statements about the social world and collect information about the phenomena (Haralambos and Holborn 1995). All data are classified and analysed to see what patterns or meaning can be extracted, and to find correlations using empirical tools such as surveys and statistics (Ly 2012). After the analysis, researchers proceed to derive generalisations (theory-generation, or conceptualisation) about social patterns and

characteristics of people (Blaikie 2007; Johansson 2003). Then, a theory, which is 'an explanation of the observed regularities' (Bryman 2016, p.18), and 'a system of interconnected ideas or concepts', can be derived as the outcome of research (Neuman 2007). Natural science is associated with this type of reasoning (Norton 2003).

Researchers who adopt the inductive approach use 'grounded theory'. Juliet Corbin and Anselm Strauss (1990), in the first edition of their book: *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*, define 'grounded theory' as an approach that "uses a set of procedures to develop an inductively derived theory about a phenomenon" (Corbin and Strauss 1990, p.24, as cited in (Neuman 2007, p.31)). In other words, the general and abstract theory of a process is based on data and views of participants (Creswell 2014). However, this theory needs intensive, open-ended, and continuous process of data collection, coding, interpretation, and analysis, as the preliminary analysis of the first set of collected data requires further information to explore particular themes to build a theory (Groat and Wang 2013; Bryman 2016). Therefore, it needs flexible qualitative methods rather than rigid methods, such as structured interviews, questionnaires, or surveys (Hodkinson 2016).

As an example of an inductive study, Amy Blackstone (2012) summarised a research conducted by Kristin Ferguson and colleagues (2011) about "Enhancing empowerment and leadership among homeless youth in agency and community settings: A grounded theory approach", published in *Child and Adolescent Social Work Journal* 28, pp. 1-22. They analysed data from interviews with 20 young people who are homeless, to understand how best to meet the needs of young people who are homeless. A set of hypotheses has been developed from their analysis. They end their study with a set of testable recommendations for people who might wish to conduct further investigation of the topic, where most deductive investigations begin.

This theory was criticised as it offers limited explanatory power due to the emphases on details rather than the overall context (Hodkinson 2016). Moreover, depending on qualitative methods, and the coding process of data, the richness and the depth of information could be reduced.

*ii. Deductive Approach*

In the *deductive* approach, researchers start their studies with hypotheses that are deduced from theories. They work from the ‘top-down’ to add to or contradict the theory. These concepts need to be translated into researchable entities which guide the process of data collection. Then, researchers state what is happening in particular circumstances, test all findings to confirm (verify) or reject (falsify) these hypotheses (Bryman 2016; Blaikie 2007; Johansson 2003), and finally, formulate a possible explanation and an answer to the ‘why’ questions (Popper 1959). Mathematical and philosophical logic is commonly associated with this type of reasoning (Johnson-Laird and Byrne 1993).

Research entitled “Classroom learning environments and the mental health of first-grade children”, guided by Melissa Milkie and Catharine Warner (2011), and published in *Journal of Health and Social Behavior* 52, pp. 4-22 (cited in (Blackstone 2012)) is a good example of deductive studies. They studied the effects of different classroom environments on first graders’ mental health. They started their research with a hypothesis that negative classroom features, such as lack of basic supplies and heating system, would be associated with emotional and behavioural problems in children. After testing this assumption by tracking the academic outcomes of children, they demonstrated that policymakers should pay more attention to the mental health outcomes of children’s school experiences. The researchers found support from ‘The American Sociological Association’ through publishing a press release in 2011, entitled “Negative classroom environment adversely affects children’s mental health”.

After reviewing the fundamentals of the two approaches of positivism; ‘inductive’ and ‘deductive’, the following comparison summarises the main differences between them for studying the social world (Table 3.1).

Table 3.1: A comparison between deductive and inductive approaches in social studies (Adapted by Researcher from (Blaikie 2007; Porta and Keating 2008; Groat and Wang 2013))

| Criteria   | Inductive Approach   | Deductive Approach  |
|--|--|---|
| <b>Aim and focus</b>   | Focus on generating new theory, exploring phenomena, or examining previously researched phenomena from a new perspective, producing generalisations and testable hypotheses. It is appropriate for answering 'what' questions. | Focus on testing assumptions and hypotheses to know if those are true or false, and formulate a possible explanation (focus on causality). It is appropriate for answering 'why' questions. |
| <b>Source of data</b>  | Data derived from observations and overall impressions.  | Numerical information derived from statistical interpretations of data that can be manipulated and understood.  |
| <b>Forms of knowledge</b>                                      | Collecting information about phenomena that can be observed (working bottom up).   | Deducing hypotheses from theory, and then collecting the appropriate data (working top down).   |
| <b>Ontology</b>  | The reality is subjective and multiple as seen by participants.  | The reality is objective and apart from the researcher.   |
| <b>Relationship of the researcher to that being researched</b> | Researcher interacts with that being researched.   | The researcher is independent of that being researched.   |
| <b>Methodological approach</b>                                 | Qualitative approach.  | Quantitative approach.  |

#### b. Interpretivism

In contrast to positivism, which makes comparisons to develop causal relationships based on measuring variables in different settings within short periods, interpretivism, however, is about knowing the causal mechanisms and how people in a particular setting understand their own actions (Travers 2002; Porta and Keating 2008), and to grasp the subjective meaning of social action (Bryman 2016). It is a typical approach to qualitative research (Creswell 2014) that uses unstructured data collection methods through conducting in-depth ethnographies, observations, and semi-structured interviews. The goal of such research is to rely on participant's view of the situation as they can construct the meaning of their experiences (Creswell 2014; Bryman 2016). Data in this approach is presented as an interpretation of meanings, motives, people's experiences, attitudes, perceptions, and patterns of everyday actions within the context (Porta and Keating 2008; Haralambos and Holborn 1995). Interpretation deals with assigning a precise meaning to human behaviour, and building generalisations and suggestions that enhance the different aspects of social life (Packer-Muti 2009).

One example of this approach is the study of J. Foster (1995): "Informal social control and community crime prevention", published in *British Journal of Criminology* 35, pp. 563-583,

and cited in (Bryman 2016, p.28)). She conducted an ethnographic study in a housing estate in East London. The official statistics on crime indicated that this estate has a high level of crime. Through observations and semi-structured interviews, she found that residents did not perceive this high-level of crime. After reviewing the words and behaviour of residents, she concluded that this perception could be attributed to different factors. The most important reason was the 'informal social control', as residents and neighbours knew each other and looked out for each other.

### c. Pragmatism: A Mixed-Method (Combined) Approach

Pragmatism, as an epistemological position about the worldview, concerns with the research problem and solutions instead of focusing on methods. It gives the researcher freedom to choose appropriate methods, techniques, and procedures for collecting and analysing data that best meet the purpose of research and the best understanding of the problem (Creswell 2014). For example, a researcher may want to both generalise the findings and develop a detailed view of the meaning of a social phenomenon. The researcher can firstly explore what variables to study, and then apply those variables to a large sample of individuals (closed-ended quantitative data). Alternatively, researchers may first survey a large number of individuals, then follow up with few of them to obtain their specific impact (open-ended qualitative data). As a result, this triangulation of methods (mixed-method / combined approach) enables the use of multiple techniques, in sequential or parallel order, and apply it to a part of research process or the whole stages as required by the needs of the research (Saunders *et al.* 2009).

One recent example of a study that used a mixed-method approach is (AlHaroun 2015). In his research "Contemporary attitudes to vernacular elements in Kuwait's domestic architecture: A mixed-method study", AlHaroun studied people's perceptions and attitudes towards traditional domestic architecture in Kuwait. Another objective of the study was to identify the qualities and capacities of traditional/vernacular elements that designers and homeowners use in the contemporary house. To achieve these two objectives, two stages have been conducted. The first is a qualitatively driven stage, which includes workshops and group interviews with homeowners and designers, in addition to the photographic database for traditional elements. A quantitative follow-up stage has been performed to examine the findings of the first stage in more details, through distributing questionnaires and examining the cognitive maps of the participants. A notable characteristic of that research is that it uses a subsequent and interlocking study,

in which quantitative and qualitative methods provide discovery and validation for each other (AlHaroun 2015).

Another example is a study conducted by (Maina 2013), who used the mixed-method approach in the study of the socio-cultural facets and spatial morphology of tangible domestic spaces in Nigeria. An ethnographic study and field work (field notes, interviews, observing activities, photography, a collection of artefacts, translating manuscripts, sketching, and drawing) have been conducted to document the lifestyle of users, the use of spaces and its configuration, house form, residential structure, and socio-cultural determinants. In parallel to those techniques, she analysed the layout drawings using space syntax method to understand patterns and typologies of houses. All of these methods were used to answer the questions of the study: what are factors, themes and concepts that influenced house form and residential structure in the study area; and what are the contemporary socio-cultural determinants of the house form that can be useful in policy making and future planning of the built environment.

*i. Abductive Approach*

One tradition that depends on pragmatism is the 'abductive approach'. Abduction is "the process of facing an unexpected fact, applying some rules, and as a result, posting a case that may be true" (Johansson 2003, p.9). In this approach, both objectivity and subjectivity of the social life are intrinsically linked (Blaikie 2007). It is appropriate to answer 'what', 'how' and 'why' questions.

Figure (3.1) illustrates the main differences between the three approaches: inductive, deductive, and abductive. As a summary, deduction tests all findings to confirm or reject hypotheses. By induction, the researcher can conclude from facts that a rule is useful in similar cases to construct a theory. Abduction is the process of facing an unexpected fact, and it may lead to true or false conclusions (Johansson 2003).

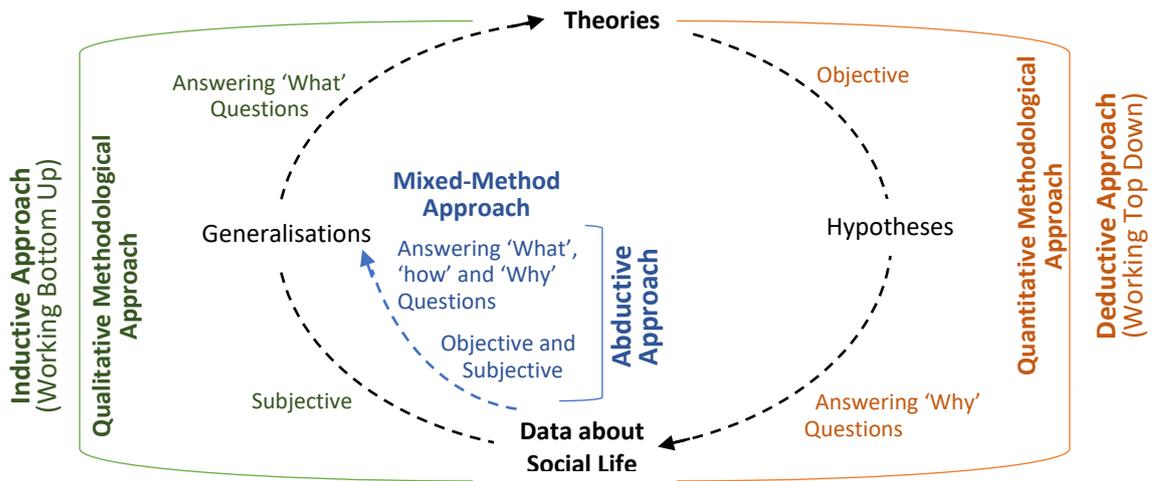


Figure 3.1: The process of inductive, deductive and abductive approaches  
(Adapted by Researcher, after (Ly 2012))

It is useful to compare the three research viewpoints (positivism, interpretivism, and pragmatism) in terms of their ontologies, epistemologies, and methodologies (as shown in Table (3.2) and Figure (3.2)), to decide which approach is appropriate to achieve the objectives of the study.

Table 3.2: A summarised comparison between different viewpoints in social studies  
(Adapted by Researcher from (Ihuah and Eaton 2013))

|  | <b>Positivism</b>   | <b>Interpretivism</b>   | <b>Pragmatism</b>   |
|--|---|---|---|
| <b>Ontology</b><br>(What researchers want to know)               | Researcher is external, objective and independent of that study.  | Things are socially constructed leading to subjective reasoning which may change with multiple realities.                     | Researcher is external, multiple, and the view is that chosen to best answer the research questions.  |
| <b>Epistemology</b><br>(How to get reality?)                     | Things are observed to prove credibility to facts, focusing on causality and generalisations through reducing phenomena to simplest elements. | Toward subjective meanings of social phenomena, looking at details and realities behind it with motivating actions.           | Either subjective or objective meanings can provide facts to a research question; focus on practical application to issues by merging views to help interpret data. |
| <b>Axiology</b><br>(Value judgements capability of a researcher) | The research is value free, independent of the data, and objective in the analysis of the data.   | The research is value bound and part of what is being studied, not isolated from the studied reality, and will be subjective. | Values play a vital role to interpret results using subjective and objective reasoning.   |
| <b>Methodological Approach</b><br>(modes of inquiry)             | Quantitative but can still use qualitative.   | Qualitative.  | Uses both qualitative and quantitative.   |

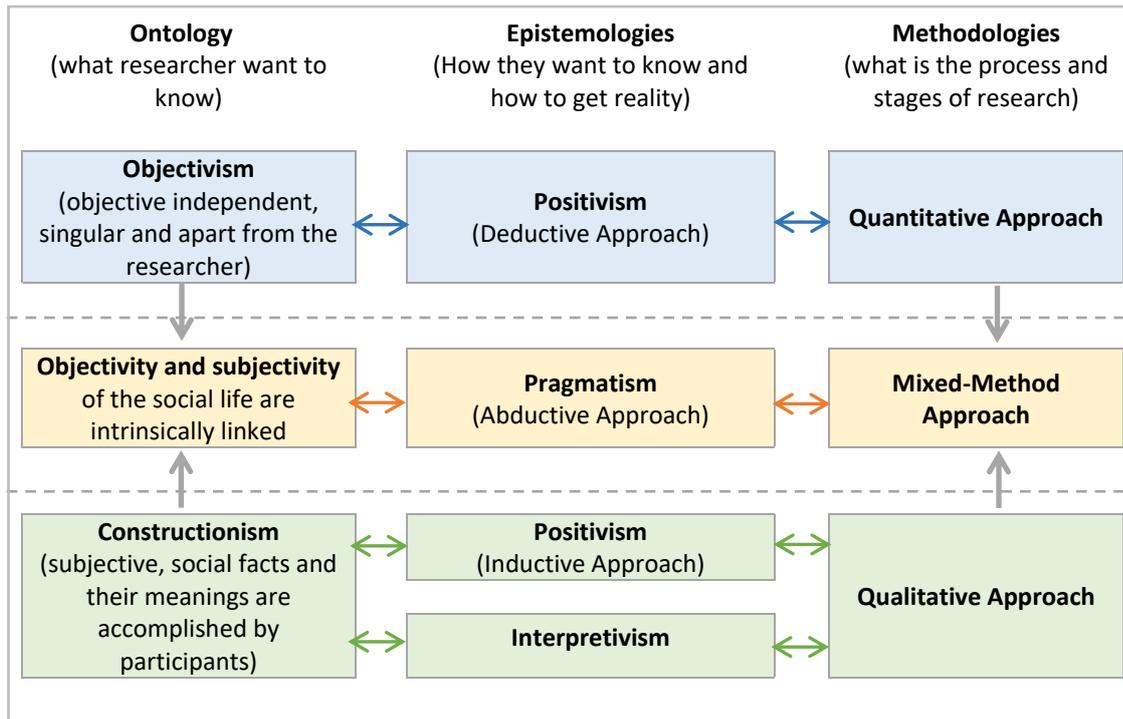


Figure 3.2: Relationships between ontology, epistemology and methodological approach for each school of thought (Researcher)

### 3.2.3. Methodological Approaches and Research Methods/Techniques

Research methodology is a systematic process to solve a research problem (Kothari 2004). Each methodology has different methods and techniques to solve the problem. Crotty (1998, p.3) defined research methods as: “The techniques or procedures used to gather and analyse data related to some research questions or hypotheses”. The following section sheds the light on three types of methodological approaches: qualitative, quantitative, and mixed-method. Moreover, different techniques and methods, associated with each approach, are outlined. At the end of this section, several related social and architectural studies will be presented to learn from previous experiences while working on the design of this study.

#### a. Qualitative Approach

Qualitative approach, known as phenomenology, is used for exploring, capturing and understanding individuals’ emotions, attitudes, thoughts, meanings, and perceptions during or after experiencing a phenomenon (Suter 2012; Groat and Wang 2013). This type of research originated in anthropology, sociology and humanities (Creswell 2014), and falling clearly under the philosophical paradigm called ‘interpretivism’. It is useful when

the researcher does not know the critical variables to be examined. Researchers who engage in this type of studies rely on their skills to receive information and uncover its meaning, through using an inductive style that is based on grounded theory, with descriptive, exploratory, or explanatory procedures (Suter 2012). The final written report has a flexible structure as it includes an interpretation of the meaning of data (Creswell 2014).

Most phenomenological studies ask 'How' or 'What' questions, (e.g., How did this happen? What is going on here?), for gathering and analysing information. However, the findings of the data collection phase affect what types of data are collected and how they are collected (Suter 2012). All gathered data are documented as notes, sketches, audios or visual records. Then, data is coded and categorised in themes to describe meanings and relationships between concepts. However, the analytical process is usually iterative as it is performed as interpretations during data collection. Conclusions and discovering connections in data, which are presented as narratives, stories, and visual models may support a theory, revise one, or generate a new one (Suter 2012).

There are different tools and techniques to conduct such studies:

*i. Ethnography, Interviews, Observations, and Narrative Stories*

In ethnographic studies, researchers engage in-depth with a group in specific settings, to observe behaviours and activities of the daily living, and collect documents about participants and settings (Silverman 2000; Groat and Wang 2013; Bryman 2016). Sources of data in this type of research are: interviews, observations, field notes, documents, records, photographs, and maps. Moreover, 'narrative stories' are useful for conducting ethnographic studies, where researchers study the life of individuals, listen to what is said, ask questions, engage in conversations, and develop understanding about the setting (Creswell 2014; Bryman 2016). Suter (2012, p.369) declared that narrative research "captures the voice of the participant and offers a collection of themes to understand the phenomenon being investigated". For instance, when we are interested in investigating human behaviour and attitudes, and discovering the underlying motives, such as why people think, do or like certain things and how they feel, qualitative research using in-depth interviews is the suitable technique (Kothari 2004). This method offers researchers to have more rich and detailed answers.

*ii. Case Study*

Another method for conducting qualitative research is 'case study'. A 'case' is a phenomenon specific to time and space, and has unique and rich information (Johansson 2003). Using this tool, researchers can develop an in-depth analysis of a selected case or action through gathering information and data over a period (Travers 2002; Creswell 2014).

In architectural research, and when it is difficult to conduct a survey or an experimental design, case studies become historical cases, where researchers look at old situations in new perspectives and explain causal links between variables to make analytical comparisons and not statistical generalisations (Suter 2012; Johansson 2003). In that case, two types of generalisations could be generated based on the process of reasoning. Firstly, when a case is created or reconstructed from historical data, generalisations occur within an 'evidential paradigm' (Ginzburg 1989, as cited in (Johansson 2003)). Secondly, operative or naturalistic generalisations, which are made from known cases, and applied to an actual problem situation by making appropriate comparisons (Johansson 2003).

However, determining theoretical ideas at earlier stages in a case study design is essential since these ideas guide types of data to be collected. Moreover, studying multiple cases would be more informative, as they give a potential to replicate findings and test if there is matching in explanations (Suter 2012).

**b. Quantitative Approach**

In quantitative studies, data are expressed in terms of quantities to make generalisations. Three types of methods could be used:

*i. Surveys and Questionnaires*

Surveys could be used for testing scientific theories, examining relationships between variables, and analysing numerical data using statistical procedures (Kothari 2004). The origin of this type of studies comes from psychology (Creswell 2014), and it is closely aligned with positivism and objective measures (Suter 2012). It is beneficial when a researcher wants to identify factors that influence an outcome, describe trends, attitudes and opinions of people, or test a theory or explanations. Social scholars who engage in this type of research test theories deductively, so they can generalise and replicate the findings. However, these surveys are a useful tool to gather broad, rather than in-depth information.

*ii. Experimental Methods*

Another type of quantitative research is experimental studies, which seeks to specify if a treatment influences an outcome. One kind of such studies is 'simulation', which involves the construction of an artificial environment and numerical model that represents the structure of a dynamic process which requires control and manipulation (Kothari 2004). When it runs, it represents the behaviour of the process over time. It is useful also in building models for understanding future conditions.

*iii. Non-Experimental Methods*

The third type of quantitative research is non-experimental studies. It shares with qualitative research a focus on naturally occurring circumstances. However, it depends on quantitative data (Johansson 2003). Causal-comparative and correlational design are two types of non-experimental methods, where researchers compare two or more groups of data in terms of a cause or an independent variable, or use correlational statistics to describe and measure the relationship between two or sets of variables (Creswell 2014).

**c. Mixed-Method Approach**

Many studies tend to be more qualitative than quantitative or vice versa. Each research method has its strengths and weaknesses. However, mixed-method research resides in the middle as it incorporates strengths and neutralises weaknesses of each method to provide a complete understanding of the research problem (Creswell 2014). Kumar (2014) claims that such an approach increases the depth, accuracy, importance, meaning and confirmation of results from both qualitative and quantitative perspectives. Moreover, he recommended the use of mixed-method approach for a study with multiple objectives, and for making a generalisation and sharing the findings with the study population.

This approach could be used in different stages of research: data collection, analysis, explanation, and dissemination. In data gathering phase, collecting information and evidence by two different methods could be used for comparing, confirming or contradicting the argument of research (Kumar 2014). For example, interviewing participants in-depth, or asking them to fill a questionnaire, might be the most appropriate method for studying the public opinion about certain facilities in their city. Yet, field surveys, observations, focus groups or community forums for that study would provide a reasonable understanding level about how people interact, move, and use these facilities. It is important to mention that collecting information from different samples

and groups of people would validate and confirm all findings, and therefore; reach a better understanding and awareness to the study issue.

*i. Benefits and Limitations of Using Mixed-Method Approach*

Different scholars (Alexander *et al.* 2016; Kumar 2014; Bryman 2016; Creswell 2014) stated several benefits and advantages of applying a mixed-method approach.

- To have a complete picture and a better understanding of the research problem. The qualitative approach explores the problem in-depth without making generalisations. On the other hand, researchers can generalise by using the quantitative approach as they gather information from many individuals with limited in-depth analysis. This triangulation and enrichment of data would enhance accuracy and validity of the findings.
- To fill gaps in researching a problem if accurate and complete information from one source is difficult to obtain.
- To enhance the quality of research through adopting a 'qualitative-quantitative-qualitative' cycle of inquiry.
- To find an explanation for research findings.
- To increase the accuracy of research findings and the level of confidence.
- To develop a useful data collection tool, and to establish validity for questions. This could be achieved in quantitative studies in consultation with potential respondents, by using qualitative methods, to ensure that they understood the questions.
- To conduct studies with multiple objectives, as each objective may need different methods. Using multiple methods can enhance the research possibilities in achieving and answering all research questions.

However, this kind of research could not be feasible as it consumes time and resources (Bryman 2016). Therefore, it is crucial for the researcher who adopted the mixed-method approach to allow more time, effort and financial resources to handle all stages. Moreover, this type of problem-solving projects needs additional and diverse skills from the researcher using different kinds of tools and software for collecting and analysing data (Kumar 2014).

*ii. Choosing a Mixed-Method Design: Combined or Integrated*

When different methods are mixed in a study, those techniques could be combined or integrated. Combining different methods means that one technique is given higher

priority than the other, and in this case, the researcher needs more methods to have a complete picture about the issue (Alexander *et al.* 2016). For example, data produced from a questionnaire could be limited to give a whole idea about the social life of people inside houses, and therefore, the researcher needs further investigations, such as conducting in-depth interviews, to complete the process of analysis and interpretations. On the other hand, integrating methods means that each method has an equal weight in the ability to produce a full interpretation of data.

Table (3.3) summarises the main differences between these three approaches: qualitative (ethnography and phenomenology); quantitative (surveys and experiments); and mixed-method, in terms of philosophical views, ontologies, methods, strategies of inquiry, in addition to the process of how researchers can apply, analyse, and interpret the results.

Table 3.3: Qualitative, quantitative and mixed-method approaches  
(Adopted by Researcher from (Creswell 2014; Kumar 2014; Bryman 2016))

|                                      | <b>Qualitative Approach</b>   | <b>Quantitative Approach</b>   | <b>Mixed-Method Approach</b>   |
|--------------------------------------|---|--|--|
| <b>Philosophical worldview</b>       | Phenomenological and inductive (grounded theory) knowledge claims (theory emergent).  | Deductive knowledge claims (theory testing)  | Pragmatic knowledge claims   |
| <b>Ontologies</b>                    | Objectivism (independent, singular and apart from the researcher), researcher interacts with participants.  | Constructionism (subjective, social facts and their meanings are accomplished by participants), the researcher is independent of what being researched.  | Objectivity and subjectivity of the social life are intrinsically linked.  |
| <b>Approach to inquiry</b>           | Unstructured, flexible, open methodology.   | Structured, rigid, and pre-determined methodology.   | Can be structured, unstructured, or both.  |
| <b>Main purpose of investigation</b> | An interactive process to describe variables in a phenomenon, situation, or issue (through words taken from participants) to understand the context.  | A static process that quantifies variations in a phenomenon, situation, issue (through numbers) to make generalisations.   | To quantify and explore a phenomenon to enhance accuracy and get more depth.   |
| <b>Sample size</b>                   | Few cases.  | Large sample size.   | Different sizes of samples.  |
| <b>Methods</b>                       | Emerging methods (open-ended questions).  | Pre-determined methods (instrument-based and close-ended questions).   | Both pre-determined and emerging methods (open-ended and close-ended questions).   |
| <b>Strategies of inquiry</b>         | Interviews, ethnography, observations, documents, archives, or audio-visual data.   | Numeric data (experiments and performance, attitudes, and observational data).   | Multiple forms of data.  |
| <b>Type of analysis</b>              | Text and image analysis to explore meanings.  | Statistical analysis to explore behaviour.   | Statistical and text analysis.   |
| <b>Type of interpretation</b>        | Interpretation of themes and patterns.  | Statistical interpretation.  | Qualitative and quantitative interpretation.   |
| <b>Practices of research</b>         | <ul style="list-style-type: none"> <li>- Collect participant meanings.</li> <li>- Focus on concepts or phenomena.</li> <li>- Study the context.</li> <li>- Validate the accuracy of findings.</li> <li>- Make interpretations.</li> <li>- Collaborate with participants.</li> </ul> | <ul style="list-style-type: none"> <li>- Test and verify theories and explanations.</li> <li>- Identify variables to study.</li> <li>- Relate variables in questions or hypotheses.</li> <li>- Use standards of validity and reliability.</li> <li>- Observe and measure information numerically.</li> <li>- Use unbiased approaches.</li> <li>- Employ statistical procedures.</li> </ul> | <ul style="list-style-type: none"> <li>- Collect both qualitative and quantitative data.</li> <li>- Develop rationale for mixing data.</li> <li>- Integrate data at different stages of inquiry.</li> <li>- Employ the practices of both qualitative and quantitative research.</li> </ul> |

### 3.3. Research Design

Research design is about “the plan, structure, and strategy of investigation to find answers to research questions as validly, objectively, accurately, and economically as possible” (Kumar 2014, p.122). Based on that definition, this section outlines the framework for implementing the study, and how data will be gathered, coded, and analysed to find solutions for high-rise residential buildings in the hot-arid region of the Middle East and North Africa, using a computational process that concern with enhancing the social life inside buildings, improving the well-being qualities, and reflecting the cultural context of the society.

#### 3.3.1. Research Framework

A research process has different steps that need to be stated at early stages (Kumar 2014). After formulating a research problem, and conceptualising a research design, researchers need to construct instruments for data collection, analysis, interpretation, and evaluation.

##### a. Formulating the Research Problem

As revealed from the literature review about the impact of contemporary high-rise buildings on aspects of social and cultural sustainability (Al-Kodmany 2018; Kennedy *et al.* 2015; Li 2013; Magee *et al.* 2012; Cuthill 2010; Colantonio 2008; Roaf *et al.* 2005; Partridge 2005; Al-Sallal 2004), and the limitations of computational tools for addressing such issues in new developments (Yüksel 2014; Lee *et al.* 2013; Eilouti and Al-Jokhadar 2007; Colakoglu 2000), the study aims to contribute to this growing area of research through finding solutions for these problems.

The study seeks to develop a computational model for the design of high-rise buildings that could enhance the social life between neighbours, improve the well-being qualities, and reflect the specifics of the cultural context. Moreover, it seeks to find a mechanism for the representation of social realities in computational models. The following are the main areas of investigation:

- What are factors that affect social sustainability in residential buildings?
- How to measure and code qualitative aspects of designs, and integrate these qualities with geometrical parameters?
- How could provide an evidence about aspects of social sustainability in current high-rise residential buildings and vernacular houses/neighbourhoods in the study area?

- How to design a flexible computational tool that guides the emergence of socially sustainable high-rise residential buildings?

### **b. Conceptualising the Research Design**

To answer the research questions, and benefit from potentials of computational models, it is essential to put a series of actions and goal-oriented steps, which enable architects to define spatial parameters that reflect specific social qualities in the early stage of the design.

One approach to deal with the problem is to draw inspirations from local traditions and historical cases, without the direct use of traditional forms and materials, through adopting a 'critical regionalism approach' (Al-Kodmany 2015; Pomeroy 2013; Wood 2008; Ragette 2003). Although there are negative impacts for the vernacular model of houses and neighbourhoods in the study area (Al-Thahab *et al.* 2014; Modi 2014; Al-Kodmany 1999), different studies highlighted the social rewards for such previous precedents (Othman *et al.* 2015; Sobh and Belk 2011; Goethert 2010; Mitchel 2010; Sözen and Gedik 2007; Zako 2006; Bahammam 2006; Mortada 2003; Ragette 2003; Bianca 2000; Al-Kodmany 1999; Hakim 1986; Taylor 1985). Such a process seeks to generate a 'contemporary vernacular' building that incorporates the local heritage with future development. This way of thinking is a balance between two views: the 'traditional' perspective, where designers see the loss of traditional ways and values, and the 'modern' perspective, where designers declare the inevitability of change (Ragette 2003).

However, addressing the different preferences of users, assessing the current situation of residential buildings, and exploring potentials of social sustainability in vernacular houses, require multiple sources of evidence. Thus, the study adopted a 'pragmatic philosophical approach' by combining qualitative and quantitative methods for studying the objectivity and subjectivity of the social world. This approach could help the researcher in knowing how residents act and live in the different spaces, and giving more explanations about the social preferences of families. Moreover, a 'typological analysis approach' for analysing spatial and topological qualities of current residential buildings and vernacular houses could be helpful for understanding the space-form language and the different characteristics of the locality.

A 'cross-sectional study' to obtain the overall picture of the residential environment in the different regions within the study area is adopted. Sources of information for establishing a database for the design of high-rise buildings include the following:

- Documents, by examining books, scholarly studies and reports that discuss aspects of social sustainability.
- Multiple case studies, through evaluating spatial and social qualities of contemporary and traditional residential buildings that cover the study area.
- Questionnaires, by distributing questionnaire forms to families within the study area to explore their problems and wants.
- Interviews, through conducting in-depth interviews with architects to understand their philosophies in addressing the different requirements of residents, developers, and the context in the design process.

In terms of the reference period, the study is a 'retrospective-prospective' study, which focuses on understanding past trends of living, and existing situations of residential buildings, to suggest alternatives for future designs. In terms of the nature of investigation, it is a 'partially-experimental' study that has two parts. The first part is non-experimental, as it observes the past living experiences through observations and surveys. The second part is experimental, which focuses on using different computational tools for analysis and design.

Information gained from the analytical process, and responses collected from interviews and questionnaires, will be used to establish a database that identifies design elements (vocabularies), and topological relationships between spaces (rules). Shape grammar, as a rule-based system for analysing and generating layouts, associated with spatial descriptions, is adopted. This system will be used for constructing spatial rules that address potentials of vernacular houses/neighbourhoods, in addition to specifications of high-rise buildings. Finally, the constructed grammar will be translated into a computational tool that is useful for the design of high-rise residential buildings that have potentials of social and cultural sustainability. Table (3.4) summarises the overall phases of the study.

Table 3.4: Main phases of the study

| <b>Phases of the study</b>   | <b>In which chapter the phase is presented</b> |
|--|--|
| Phase (1): Data collection   | Chapter Four (Parts A and B)                   |
| Phase (2): Data analysis   | Chapter Four (Parts A and B)                   |
| Phase (3): Grammar construction  | Chapter Five (Parts A and B)                   |
| Phase (4): The development of a computational design tool  | Chapter Five (Part C)                          |
| Phase (5): The generation of new solutions, validation of results, and usability evaluation for the tool | Chapter Five (Part D)                          |

### 3.3.2. Phases of the Study and Research Methods

There are different issues affecting the choice of one methodological approach over another in the design of any research: reliability, validity, and practicality (Haralambos and Holborn 1995; Kumar 2014).

- *Reliability*: The reliability of a research technique means that “it is consistent and stable, hence predictable and accurate” (Kumar 2014, p.215). A method could be reliable if it is suitable for time, and other researchers use it on the same material and produce the same results (Bryman 2016). In general, quantitative methods provide higher reliability as it produces standardise data in a statistical form (Haralambos and Holborn 1995). In contrast, qualitative methods have a low level of reliability due to several factors, such as interpreting the questions differently by respondents. Moreover, the physical setting, respondent’s and interviewer’s moods, and the nature of the interaction between the interviewer and participants may affect the responses given during the interview (Kumar 2014).
- *Validity*: A valid method or technique means that it gives an accurate reflection and a real picture of what is being studied or measured. Qualitative methods, such as interviews or field observations, could provide a valid picture of the social reality. Quantitative methods, on the other hand, may not give the same picture as it lacks the depth to describe meanings and motives that form the basis of social life (Haralambos and Holborn 1995; Bryman 2016).
- *Practicality*: In general, quantitative methods need less time consuming and less personal commitment (Haralambos and Holborn 1995). Also, it could give an overall picture of the society, as it represents a significant representative sample. In contrast, conducting qualitative studies means that the researcher wants to see more details and go in-depth into a smaller sample. In that case, this needs more time to handle the research.

Based on these criteria, the following illustrates the different methods that are adopted in each phase of the study.

#### a. Phase (1): Data Collection

Data collection phase aims to define the current spatial characteristics of residential buildings in the study area, in addition to social/spatial wants of residents. Moreover, it seeks to know how designers address the different design requirements that consider the context. The best approach for collecting data is a phenomenological approach that

includes a triangulation of both (a) qualitative methods, such as observations, field notes, photographs, in-depth interviews, and case studies; and (b) quantitative methods, such as questionnaires, to compare and correlate social and spatial aspects of the house. (Figure 3.3).

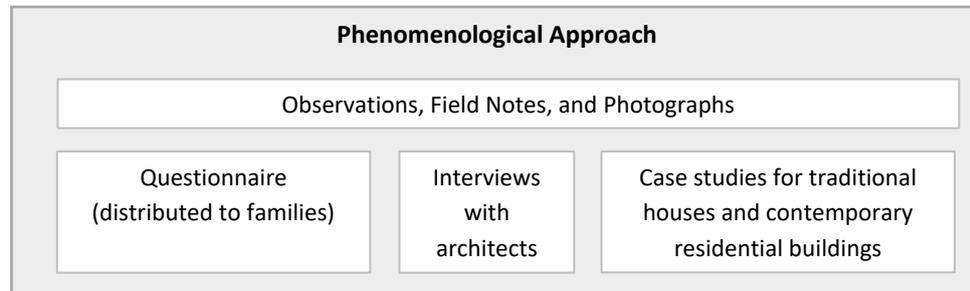


Figure 3.3: Data collection phase

#### *i. Observations*

The social world and the behaviour of people could be objectively observed and recorded, classified and measured (Haralambos and Holborn 1995; Bryman 2016). This type of methods, which represents the positivism, offers for the researcher to focus on the context, relationships, symbolic meanings embedded in cultural life, patterns of interpretations and how people react with their circumstances (Groat and Wang 2013; Kumar 2014). However, coding observations requires from the researcher to be consistent to have more reliability, and the researcher needs to measure what is supposed to be measured to have valid data (Bryman 2016). There are two types of such method: participant and non-participant observations. In the former one, a researcher participates as a member in the activities of the group being observed. In contrast, a researcher in non-participant observation remains a passive observer to capture conclusions and do not get involved in the activities of the sample.

For this study, non-participant observations will be conducted namely in Jordan as a case, as there are some implications in visiting other regions within the study area due to the current political situation. These surveys aim to achieve the following objectives:

- On-site familiarity, which is essential for observing the daily lifestyle and routine activities of the family inside their home (how they are carried out, how they are associated with other activities).

- Observing hierarchy of spaces, patterns of movement inside the house, size of rooms, and availability of outdoor spaces.
- Searching for any specific treatment and its relation to social purposes (such as privacy and social interaction).

All of these issues should be recorded suitably. These include, for instance, field notes, writing a description of interactions between residents, or developing a scale or categories to rate and classify various aspects of living patterns.

However, depending on such a method could have some problems especially when people become aware when they are being observed. Moreover, there is a possibility of observer bias, incomplete recording of observations, or variations in interpretations (Kumar 2014). Therefore, other methods, such as interviews and questionnaires, will be used for completing the picture about social patterns.

#### *ii. Questionnaire*

A questionnaire is a structured set of questions to discover facts about population (age, gender, size..), and to analyse unique aspects to have causal relationships between dependent variables (what we are mearing in research questions) and independent variables (the causes of variations in the dependent variables) (Leddy-Owen 2016).

In this study, and as potential respondents (residents) are scattered over a wide geographic area and different countries within this study, an online self-completion questionnaire is much better to collect data. The questionnaire form will be hosted on computer software packages and distributed by email across the three geographic regions: the Middle East, North Africa, and the Gulf Area. There are many benefits of such a method. It provides more interactive elements to a survey, reduces financial and time costs, covers different geographic locations, and reduces human errors or missing data as the data entry is an automated process (Leddy-Owen 2016; Bryman 2016).

However, this type could have low response rate, multiple replies, and the sample could be biased since respondents tend to be better educated and younger (Bryman 2016). Therefore, considering these issues requires from the researcher to motivate people, and distribute paper questionnaire in addition to the online questionnaire, on a variety of respondents to give more responses.

### - Types of Questions

To avoid any misleading issue, questions should be in a simple and everyday language (in both languages Arabic and English). Moreover, it is essential to ask questions clearly and avoid ambiguous questions that contain more than one meaning or could be interpreted differently. However, questions should follow a logical progression, which starts with simple themes and progress to complex ones.

#### *(a) Open-ended Questions*

Respondents are given the opportunity and freedom to provide answers in their own words, and allow unexpected responses and new ideas to be derived. Coding process for this type is much complicated and requires more considerable efforts from the researcher.

#### *(b) Closed-ended Questions*

Respondents have a set of categories to choose. However, categories should be developed to ensure that they are inclusive. This type of questions is much easier to process answers, to enhance comparability, to reduce the variability in answers, and to conclude statistical results and quantitative analysis (Bryman 2016). Therefore, it could produce more valid and reliable data.

#### *(c) Binary and Categorical Closed Questions*

This type offers for the participant to choose between two response categories (e.g. yes or no).

#### *(d) Interval-level Closed Questions*

In this type, the participant has to rank or to choose from a range of numerical ranking, or measuring attitudes, through five-point scale ranging from strongly agree to strongly disagree.

### - Variables

A variable is an image, perception or concept that is capable of measurement and taking different values (Kumar 2014, p.81), while concept cannot be measured. However, converting concepts into variables that can be measured, requires first to determine different indicators that reflect the concept (Kumar 2014). For example, the concept of rich/poor has two potential indicators: income, and value of all assets. The income could be measured by the total income per year, and the

value could be measured through knowing the total value of home, car, and investments.

There are three types of variables:

- (a) *Independent*: the cause supposed to be responsible for bringing about change in a phenomenon.
- (b) *Dependent*: the outcome or change brought about by the introduction of an independent variable.
- (c) *Intervening or confounding*: which links the independent and dependent variables, and the cause independent will have the assumed effect only in the presence of an intervening variable.

#### - Categories

In questionnaires, categories could be divided into four types:

- (a) *Ordinal*: which can be ranked in order, with unequal distances between categories (e.g. visiting neighbours (every day, 2-3 days, 4-6 days)),
- (b) *Interval (Ratio)*: where distances between categories are identical across the range (e.g. age (16-25, 26-35, 36-45, 46-55, 56-65); No. of residents (2-3, 4-5, 6-7); Income (£500-1000, £1001-1500, £1501-2000)),
- (c) *Nominal (Categorical)*: categories cannot be ranked in order (such as reasons),
- (d) *Dichotomous*: data that have only two categories (e.g. True/False).

#### - Validating the Questionnaire

The questionnaire should be validated and tested before conducting the actual data collection. This pre-tested phase aims to explore if the measures of each question reflect the concept and themes that need to be measured. Also, it is useful to avoid any problem or unclear issue in understanding questions. One method for validating the questionnaire, which is adopted in this study, is to ask other people who have experience if the measure of a question seems to reflect the concept concerned.

#### iii. *Semi-Structured Interviews with Architects*

As this study aims to develop a design tool for high-rise residential buildings, it is useful to engage with architects through face-to-face talks, to collect information about their philosophies for the design of contemporary buildings in the study area.

Interviews could be unstructured with complete flexibility of wording and questions to go deeper into a phenomenon, or structured with a predetermined set of closed and open-ended questions. To have more reliability and consistency in answers, questions will be asked by the researcher in the same words and order. Answers will be recorded by the interviewer (researcher).

To facilitate the process of coding the results from this method, structured interviews with designers and developers are adopted to explore the following aspects:

- What are different architectural treatments in the house for achieving social interaction and privacy for the family?
- How can architects and developers reflect the context and the cultural identity?
- What are different environmental solutions that are adopted in the design of residential buildings in hot-arid regions?

There are different types of questions that could be asked:

- Introductory questions (e.g., Please tell me about...),
- Follow-up questions (e.g., What do you mean by that?),
- Probing questions (e.g., Could you say more about that issue?)
- Specifying questions (e.g., What did you do then?, What effects did this issue have on you?)
- Direct questions (e.g., Are you happy with..?, Do you find it easy to...?)
- Indirect questions (e.g., What do most people think about...?, Is that the way you feel?)
- Structuring questions (e.g., I want now to move to another topic)
- Silence: which gives the opportunity for the participant to reflect and amplify the answer)
- Interpreting questions (e.g., Do you mean that....?)

#### *iv. Case studies*

Studying historical cases for vernacular houses and neighbourhood, in addition to examples of contemporary cases for residential buildings could inform evidence about specific themes. Such a method, which does not entail participants, requires from researchers some interpretations to know where to look and how to look (Groat and Wang 2013; Bryman 2016). Like natural sciences, analysing floors plans,

and thinking casually about the design, represent a positivist approach, which could then produce some general concepts.

Since the study area is large and widely distributed on different regions, a satisfied random sampling is adopted. The sampling frame is divided into groups, which represents countries in the Middle East, North Africa, and the Gulf Area that share the hot-arid climate. After that, different vernacular houses, traditional neighbourhoods, and contemporary apartment buildings, are randomly selected from each group. However, the selection process from each region depends on the following criteria:

- As the study aims to propose solutions for socially sustainable high-rise residential buildings in urban areas, the selection of cases will cover mainly town-houses and buildings in cities rather than village-houses.
- Choosing different sizes of houses, buildings, and clusters of houses (neighbourhoods).
- Availability of drawings and illustrations.

## **b. Phase (2): Data Analysis**

Data analysis phase includes the analysis of responses, cases, documents, and textual information to explore the different spatial and social qualities, and then constructing meanings and interpretations.

### *i. Encoding Interviews and Questionnaires*

To develop a holistic picture about residential buildings in the study area, interpret the different meanings for using specific elements, and understand how residents make sense of their circumstances, information gathered from interviews and surveys, will be encoded into social parameters and spatial constraints. This process is useful for making comparisons, and organising data into categories or instances of occurrence (Bryman 2016). It aims to reduce the massive data into themes and concepts that seem to be of significant potential. Encoding responses includes three steps: (1) identifying central themes and concepts to discrete phenomenon; (2) assigning codes, keywords, and labels to these themes, and then a value to each piece of information using a data matrix; (3) classifying responses that include the different labels and keywords under the central themes (Groat and Wang 2013; Bryman 2016). However, codes should be exclusive, which means that a response

must fit into only one category. Also, codes must be exhaustive, which covers all possible options.

### *ii. Encoding Floor Plans*

To understand relationships between spatial layouts and social aspects, and to explore features that have social or experiential significance, floor plans for traditional houses/neighbourhoods and contemporary residential buildings will be analysed using spatial reasoning approach. A scheme for encoding these layouts will be developed based on two types of analysis:

- (a) Typological analysis, which involves categorising components of designs that have shared characteristics according to predefined criteria, such as location, area, geometric properties, and patterns of arrangement (Eilouti 2009).
- (b) Space syntax analysis, which refers to the study of social patterns, and the spatial configuration of spaces to understand the topological structure, or how spaces are related to each other (Hillier 2014; Sayed 2012; Emo *et al.* 2012). These relationships are represented as measures, such as: control, depth, and integration values, and number of connections.

Three computational tools will be used for carrying out space syntax analysis and arriving at a comprehensive understanding of spatial layouts. Firstly, *AGRAPH*, for drawing and calculating space syntax graphs. Secondly, *Syntax2D*, to execute isovist analysis that addresses the visual fields of a person at one location of the environment (e.g., the main entry point of the neighbourhood, and from the entry point(s) of each house in the cluster). Secondly, *DepthmapX*, which is a 'Visibility Graph Analysis (VGA)' tool to understand the spatial configuration of the environment. VGA includes two types of tests: (i) connectivity analysis that creates visibility connections between all spaces; and (ii) agent analysis, which indicates patterns of movement, and the frequent use of spaces released from the public gathering space.

### *iii. Displaying and Visualising Data*

To reach a deep level of understanding about the collected and coded data, visualising data is a powerful tool to start the process of analysis. This could be implemented for both quantitative and qualitative data through displaying results in the form of tables, charts, visual images, measured drawings and plans.

#### *iv. Data Verifications, Correlations and Analysis*

After the process of coding and visualisation, the researcher needs to clarify patterns and examine correlations between variables to test hypotheses and draw conclusions and interpretations. For quantitative data, this phase starts with knowing relationships between variables, whether they are normally distributed or not. This offers to choose the suitable statistical analysis and test the different relationships between variables, using 'Statistical Package for the Social Sciences (SPSS)' platform. The final outputs will be presented as conditions and parameters that affect the social life.

#### **c. Phase (3): Grammar Construction**

Results of analysis will be used as inputs for implementing the third phase of the study, grammar construction (Figure 3.4). A discursive approach, which depends on combining programming grammar, as a description-based system for specifying social constraints and design briefs; and shape grammar, as a rule-based system for describing geometries, topologies, proportions and formal aspects, is adopted for constructing a tool for the design of high-rise residential building.

This process has a bottom-up approach, which starts with generating an initial shape. The framework for developing this shape to create a functional layout could be outlined in four stages:

- (1) Defining vocabularies as main shapes (which represent spaces with specific properties).
- (2) Determining spatial relationships and descriptions.
- (3) Formulating rules to be applied on forms.
- (4) Combining/articulating shapes through applying rules recursively, to define a language of design.

Spatial elements (vocabularies), and spatial rules, that are important for promoting aspects of social sustainability, will be used for the construction of the grammar. Moreover, specific requirements for high-rise buildings will be associated with rules. However, creativity, flexibility, and adaptability are essential issues that need to be addressed in the design process. Therefore, a parametric design approach, where designers can revise parameters and rules, at any stage, to modify their designs and generate a number of alternatives, will be incorporated in the construction of the grammar.

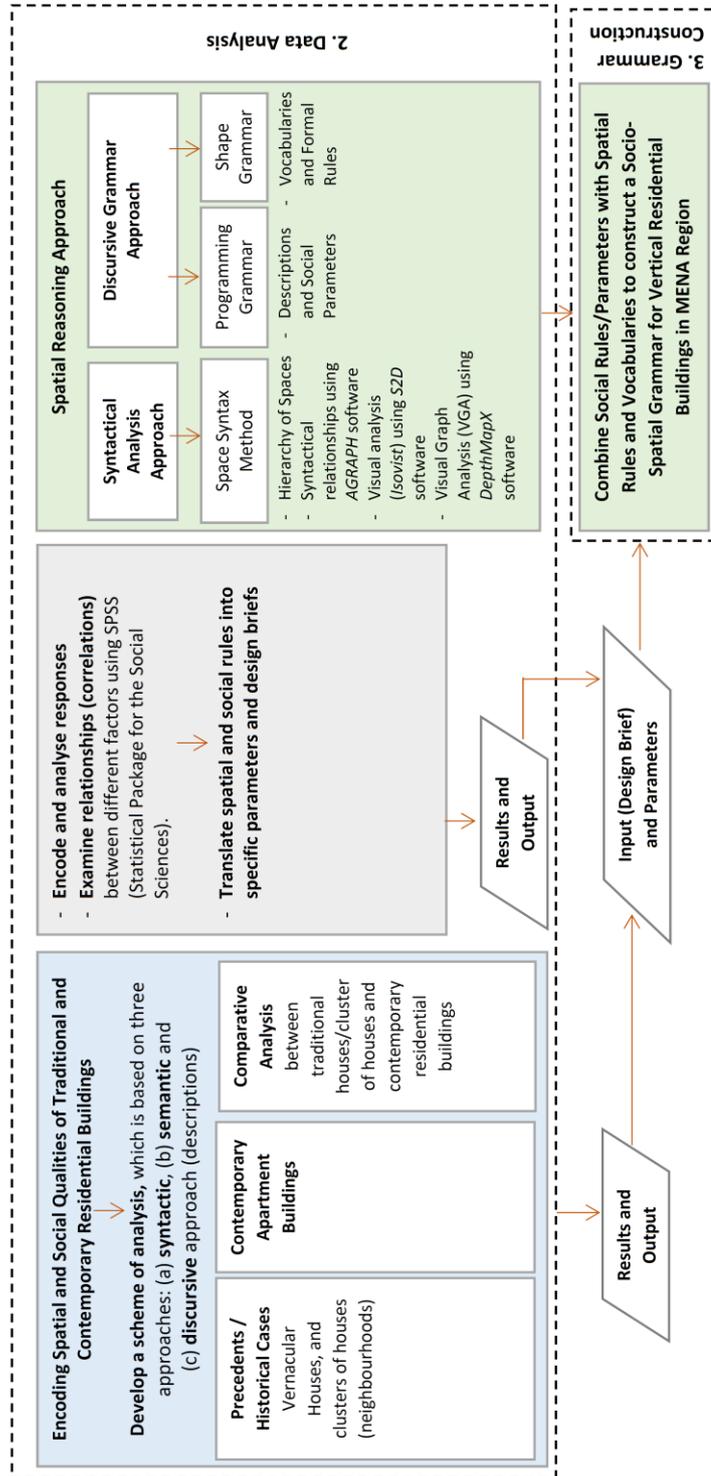


Figure 3.4: A diagram showing relationships between Phase 2: Data analysis, and Phase 3: Grammar construction

#### d. Phase (4): The Development of a Computational Design Tool

The constructed grammar for high-rise residential buildings will be translated into a computational parametric tool, using 2D/3D CAD modelling software ‘Rhinceros 3D’, with its plugin ‘Grasshopper’, to facilitate the generation of new solutions with a high degree of accuracy in a short time of execution.

#### e. Phase (5): The Generation of New Solutions, Validation of Results, and Usability Evaluation for the Tool

The design of a computational tool requires at the final stage a process of testing and evaluation. This process is useful for checking the efficiency and reliability of the model, and its ability for achieving the actual need. Moreover, it concerns with evaluating the clarity, functionality, accessibility, and flexibility of the tool (Easterbrook 2010; Carley 1996; Simon 2013).

The developed computational tool will be tested through generating different solutions for high-rise buildings. Two sets of solutions will be produced. The first set includes alternatives generated by the researcher. The second set includes alternatives produced by professional designers and architecture students, through conducting an experimental study at Cardiff University. These alternatives will be evaluated against spatial and social qualities using space syntax analysis, visibility graph analysis, and spatial assessment. Moreover, an experimental study through asking professionals and architecture students to use the tool for the design of a multi-story residential building. Finally, a usability evaluation, which assesses the efficiency of the tool in the early stage of design, will be conducted through distributing a questionnaire to the same sample of participants (Figure 3.5).

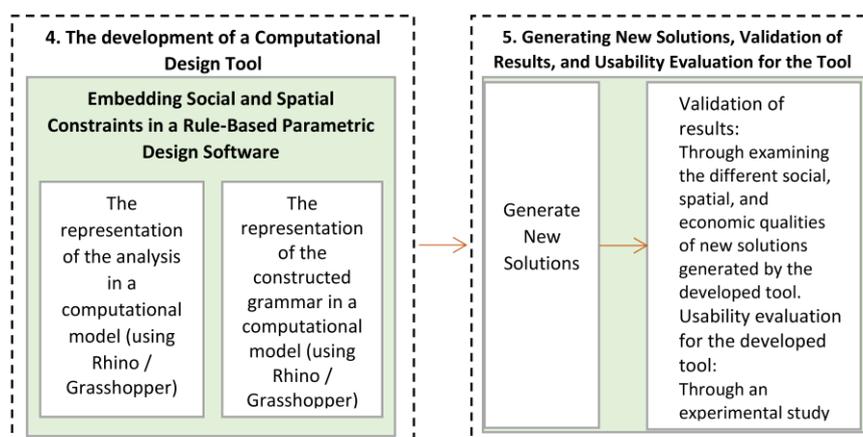


Figure 3.5: A diagram showing (Phase 4: Developing a computational tool), and (Phase 5: Generating new layouts, testing, and evaluation)

## Chapter Four

# **An Investigation of Social and Spatial Qualities of Residential Buildings in MENA Region**

**Part (A): Survey of Social Qualities of Residential Buildings:  
The Perspective of Users**

**Part (B): Spatial Qualities of Residential Buildings in MENA Region**

## Chapter Four:

# **An Investigation of Social and Spatial Qualities of Residential Buildings in MENA Region**

### **4.1. Introduction**

This chapter aims to investigate the current situation of residential buildings in the study area (MENA region) in terms of spatial and social qualities. The chapter starts with identifying criteria for measuring aspects of social sustainability in residential buildings, as illustrated in Section (4.2). Such measurements are useful for the translation of the different social indicators into spatial parameters that could be integrated in the design of buildings.

These aspects, which represent the input data for the design of new developments, are extracted from two approaches: (a) a phenomenological survey, which records the everyday life of residents, in addition to their needs and concerns; and (b) a typological and spatial reasoning analysis, which addresses the social reality of formal and geometric qualities of designs.

In the first part of this chapter (Part A: Survey of Social Qualities of Residential Buildings in MENA Region - the Perspective of Users), data collected from the phenomenological survey, which includes observations, interviews with architects, and questionnaires distributed on families from 17 countries within the study area, are presented in Section (4.3). Based on this survey, all responses have been coded and analysed, as illustrated in Section (4.4), to understand factors that affect the living residential environment, quantify any differences or similarities in data, allow comparisons across the different variables, and construct meanings and interpretations. Finally, results extracted from the analysis have been transformed into social/spatial parameters and design briefs, as presented in Section (4.5), which will be used for the construction of spatial rules for high-rise residential buildings in MENA region.

In the second part of the chapter (Part B: Spatial Qualities of Residential Buildings in MENA Region), a detailed spatial analysis for examining aspects of social sustainability in different vernacular houses/neighbourhoods and contemporary apartment buildings in MENA region,

is presented. These evaluations are useful for exploring topological relationships between spaces and any spatial treatments that could achieve certain social qualities, such as privacy, social interaction, and accessibility. Different tools of analysis are defined, evaluated and discussed in Section (4.6). Based on that assessment, and the different limitations of analytical methods, presented in Chapter 2, a spatial-syntactical model of analysis for encoding floor plans and topological relations is presented in Section (4.7). Results of analysis, and information extracted from the selected cases, are presented in Sections (4.8) and (4.9) as diagrams, descriptions, and spatial parameters, in order to be used for identifying spatial constraints that could achieve the different indicators of social sustainability for future developments.

## 4.2. Spatial Analysis of Social Qualities of Designs

To solve a design problem, architects need to integrate all environmental, economic, social and cultural requirements of designs. Each aspect has different indicators and measurements that could be translated into specifications and guidelines. However, social and cultural dimensions are more difficult to be measured than other aspects.

This research aims to fill such a gap, through defining indicators that reflect the social needs of users, and at the same time, could be quantified and integrated in the spatial design of buildings and houses. Different modes of representations, such as numbers, diagrams, or textual descriptions, could be used as spatial design parameters. Based on the definition of each social indicator, as presented in (Section 2.2.1) in (Chapter 2), the researcher identified the following spatial features that could be analysed at the scale of the house, building, or neighbourhood (Table 4.1). Such a process is useful to facilitate the design process, and to achieve these social qualities.

Table 4.1: Spatial features and modes of representation for defining and measuring aspects of social sustainability

| Social indicators and spatial features   | Modes of representation  |
|--|--------------------------|
| <b>- Social Indicator (1): Population Density and Crowding</b>   |                          |
| - Number of rooms for the apartment based on the size of the household structure (single, couple, couple with children). | Number                   |
| - Area of apartment based on the size of the household structure.  | Number (m <sup>2</sup> ) |
| - Number of apartments/houses in the building/cluster.   | Number                   |
| - Area of common spaces in the building/neighbourhood.   | Number (m <sup>2</sup> ) |
| - Width of alleys and transitional spaces between houses.  | Number (m)               |

|  |                                       |
|--|---------------------------------------|
| <b>- Social Indicator (2): Hierarchy of Spaces</b>   |                                       |
| - Arrangement of spaces from public to private zones, and from formal to less formal spaces (in neighbourhoods/buildings, and inside the house). | Diagrams                              |
| - Relationships between spaces according to connectivity, integration, depth, and control values.  | Diagrams & Numbers (syntactic values) |
| <b>- Social Indicator (3): Social Interaction and Area of Living Spaces</b>  |                                       |
| - Area of common and gathering spaces in buildings and neighbourhoods.   | Number (m <sup>2</sup> )              |
| - Area of living spaces inside the house.  | Number (m <sup>2</sup> )              |
| <b>- Social Indicator (4): Human Comfort</b>   |                                       |
| - Percentages of covered, semi-open (shaded), and open spaces relative to the total area of the house/building/neighbourhood.                    | Number (%)                            |
| - Architectural treatments, such as shading devices, louvers, screens, water features, wind towers, or greenery.                                 | Diagrams                              |
| - Area of glazed facades.  | Number (m <sup>2</sup> )              |
| - Thickness of walls.  | Number (cm)                           |
| - Construction materials.  | Textual descriptions                  |
| - Geometric shapes of spaces.  | Diagrams                              |
| - Proportion of spaces.  | Number (x:y)                          |
| - Orientation of spaces.   | Diagrams                              |
| - Height of spaces (inside the house), and height of adjacent buildings/houses (urban scale).  | Number (m)                            |
| <b>- Social Indicator (5): Accessibility</b>   |                                       |
| - Width of transitional areas and circulation elements.  | Number (m)                            |
| - Area of transitional spaces and circulation elements in comparison to the area of the building/neighbourhood/house.                            | Number (m <sup>2</sup> )              |
| - Spatial arrangement of transitional areas and circulation elements in buildings/neighbourhoods/houses.   | Diagrams                              |
| - Special treatments for alleys and transitional spaces (such as ramps, handrails, differences in levels).                                       | Diagrams                              |
| - Arrangement of functions and facilities in vertical buildings, or multi-floor houses.  | Diagrams                              |
| - Differences in levels should be considered especially for the elderly and children.  | Diagrams                              |
| - Number of entrances for the building, neighbourhood, or large-size residential units.  | Number                                |
| <b>- Social Indicator (6): Visual Privacy</b>  |                                       |
| - Distribution of openings (doors and windows).  | Diagrams                              |
| - Special treatments, such as screens, partitions or greenery in front of private spaces.  | Diagrams                              |
| - Location of spaces that are dominantly used by female.   | Diagrams                              |
| <b>- Social Indicator (7): Acoustical Privacy</b>  |                                       |
| - Spatial arrangement of quiet zones and living activities inside the house.   | Diagrams                              |
| - Treatments for walls, floors, and windows (materials and thicknesses).   | Textual descriptions, Number (cm)     |
| - Height of spaces.  | Number (m)                            |

|  |                      |
|--|----------------------|
| <b>- Social Indicator (8): Olfactory Privacy</b>   |                      |
| - Location and orientation of kitchen and sanitary facilities.   | Diagrams             |
| - Orientation of open spaces.  | Diagrams             |
| - Availability of trees and flowers.   | Diagrams             |
| <b>- Social Indicator (9): Spirituality</b>  |                      |
| - Meanings associated with orientation of spaces.  | Textual descriptions |
| - Special treatments for sleeping areas, dining rooms, or bathrooms.   | Diagrams             |
| - Availability of fountains, trees and green areas.  | Diagrams             |
| <b>- Social Indicator (10): Security and Safety</b>  |                      |
| - Availability of fences on balconies and terraces.  | Diagrams             |
| - Availability of secure gates for houses and buildings.   | Diagrams             |
| - Treatments for open spaces and commons areas that are connected with the outside context.  | Diagrams             |
| <b>- Social Indicator (11): Views to the Exterior</b>  |                      |
| - Area of open spaces, terraces, balconies, and glazed facades that are connected directly with the outside context.                             | Diagrams             |
| <b>- Social Indicator (12): Availability of Services</b>   |                      |
| - Percentages of storage spaces relative to the total area of the house.   | Number (%)           |
| - Availability of entrances that are connected with services (kitchen and storage areas).  | Diagrams             |
| - Availability of commercial activities and services in neighbourhoods or buildings.   | Diagrams             |
| <b>- Social Indicator (13): Hygiene</b>  |                      |
| - Size of windows, which allow the penetration of natural light and air inside houses and common spaces in buildings/neighbourhoods.             | Number (m)           |
| - Special treatments, such as the separation of clean areas from services, entrances, and open spaces, using gates, sunken areas, or thresholds. | Diagrams             |
| - Arrangement of alleys in neighbourhoods, and open spaces in buildings/houses to block excessive air movement that carries sand and dust.       | Diagrams             |

## Part (A): Survey of Social Qualities of Residential Buildings in MENA Region - the Perspective of Users

### **4.3. Data Collection**

This phase of research aims to observe the current situation in residential buildings in the study area, and to identify the social and spatial preferences of residents. A triangulation of two approaches is adopted: (a) a phenomenological approach, using qualitative methods that include: observations, field notes, photographs, and interviews with professionals; and (b) surveys, using quantitative methods that include questionnaires to be distributed to families.

#### **4.1.1. Field Survey and Observations**

The social world and the behaviour of people could be objectively observed, recorded, classified and measured (Haralambos and Holborn 1995; Bryman 2016). This method, which represents the positivism, emphasises on in-depth engagement with people, and face-to-face talks, which focus on the context, symbolic meanings embedded in the cultural life, and how people react with their circumstances (Groat and Wang 2013; Kumar 2014).

In this study, non-participant observations have been conducted by the researcher, namely in Amman, Jordan, as a case, in the summer of 2016 (1/8/2016 – 25/8/2016), through visiting five contemporary apartment buildings. The reason for choosing contemporary samples is to observe problems in current residential buildings, and avoid these issues in the development of the design tool for generating high-rise buildings. The survey includes photographic record and field notes to achieve the following objectives:

- Observing the daily lifestyle and routine activities of families inside their homes (where these activities are carried out, and how they are associated with other activities),
- Documenting spatial arrangement of spaces, and movement patterns for guests and for family members inside the house,
- Documenting spatial arrangement of apartments on each floor, and they are connected with common areas,
- Searching for any specific treatment in the apartment or the building, and its relation to social or environmental purposes,
- Observing any problems that affect the social life of residents inside apartments or buildings.

The following issues summarise the main observations.

- Percentages of living areas, terraces, and balconies are limited in comparison to the area of guest and dining rooms (Figure 4.1).
- Entrances of houses are opened directly on the inside, with a sudden transition from the entrance (a public space) to living room and kitchen (private zone) due to the lack of an entry hall (Figure 4.2).
- The guest room is used as a living space due to the lack of area.
- The main characteristic of modern houses is the open layout, which means that public, semi-public and most of private spaces (e.g. kitchen and living room) are connected with guest/dining rooms with visual separation (such as transitional spaces, partitions or doors).
- Protecting the privacy of living areas in new apartments depends on decorations and furniture items.
- Bedrooms are controlled zones, and they are not easily accessible.
- Semi-public and semi-private spaces in front of apartments in residential buildings are limited to circulation paths. Therefore, social interaction among neighbours decreased accordingly.
- Entrances in most current developments are located opposite to each other with no visual barriers in front of doors.



Figure 4.1: Limited open spaces and areas for children



Figure 4.2: Visual/spatial connections between the main entrance, living spaces and areas for the guests

### **4.1.2. Interviews with Professionals**

Interviews with architects offer an understating of their design philosophies for residential buildings, and how they can reflect the context and the cultural identity. Moreover, it deals with exploring the different strategies for enhancing social interaction and achieving the privacy of the family. Five interviews with professionals have been conducted in Amman, Jordan in the summer of 2016 (1/8/2016 – 25/8/2016).

#### **a. The Interview Guide**

The interview has a structured format, with predetermined sets of closed and open-ended questions. To have more reliability and consistency in answers, questions have been asked in the same words and order.

The interview guide included 12 questions that investigate three categories:

- (1) Traditional houses in the Middle East and North Africa;
- (2) Contemporary houses and vertical residential developments; and
- (3) The design philosophy adopted by the architect.

Each category has specific questions that ask about features and qualities of traditional houses and contemporary buildings in MENA region (Table 4.2)<sup>1</sup>.

#### **b. Ethical Considerations**

As part of the research ethics, the work was carried out by the codes of ethics applied by the researching body. An ethical approval form appended with the research proposal and ethics statement were submitted to the Ethics Committee in the Welsh School of Architecture at Cardiff University, and approval was obtained<sup>2</sup>.

Moreover, all participants were informed about the purpose of the study, how they were expected to take part in it, how much time the participation was expected to take, and the right of any participant not to answer any particular question, or to withdraw from the study at any time. All participants were assured that their responses would only be used for academic research.

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<sup>1</sup> See (Volume 2 - Appendix (4-A-1): The Interview Guide with Architects)

<sup>2</sup> See (Volume 2 - Appendix (4-A-4): Ethical Approval Forms)

Table 4.2: The interview guide with architects

| Categories  | Sets of Questions  |
|---|--|
| 1. Traditional Houses in the Middle East and North Africa   | <p>1.1. How would you describe the traditional house in the Middle East and North Africa region? What are its key features you visualize?</p> <p>1.2. Can you please draw a sketch for a traditional house with all distinctive features?</p>  |
| 2. Contemporary Houses and High-rise Residential Developments in the Middle East and North Africa | <p>2.1. How would you describe the contemporary house and high-rise residential developments in the Middle East and North Africa Region? What are its key features?</p> <p>2.2 What are the key features that developers want in these developments?</p> <p>2.3 What are problems facing the design of a contemporary high-rise building?</p>  |
| 3. Design Philosophy  | <p>3.1. What do you think the most appropriate house type for this region? Why?</p> <p>3.2. In your opinion, is it possible to include a courtyard in each apartment in the design of a high-rise building?</p> <p>3.3. When you design an apartment building, what are the general requirements and design features that the client usually ask for?</p> <p>3.4. Which of the following factors do you aspire to have significant in your design? How?</p> <ul style="list-style-type: none"> <li>- The culture</li> <li>- The context and the identity of the place</li> <li>- Modernity</li> <li>- Environmental requirements</li> <li>- Functional requirements</li> </ul> <p>3.5. What are the different treatments for achieving the following qualities in the design of apartment buildings?</p> <ul style="list-style-type: none"> <li>- Hierarchy of spaces (from public to private zones)</li> <li>- Public spaces inside the building when you have a small footprint</li> <li>- Visual privacy</li> <li>- Controlling sounds</li> <li>- Controlling smells</li> <li>- Playgrounds for children</li> <li>- Accessibility</li> <li>- Social interaction</li> <li>- Separation between male and female zones</li> <li>- Security and safety</li> <li>- Natural lighting</li> <li>- Natural ventilation</li> <li>- Reducing energy consumption for heating and cooling</li> <li>- Landscape and greenery</li> </ul> <p>3.6. Do you think that vernacular elements should be used in contemporary designs? How?</p> <p>3.7. Do you insert vernacular elements in your design? If yes, what are these features?</p> |

### c. Responses from Interviews

The following is a highlight for the main responses to the different questions<sup>3</sup>.

#### i. *Traditional Houses and Neighbourhoods in the Middle East and North Africa*

- In most traditional houses, there are two courtyards: one for residents and the other for animals. This concept is adopted in contemporary houses or apartment buildings using the side area of the house as parking.
- There is a hierarchical movement (from public to semi-public to private), which reflects the local culture. For example, there is a path (called *majaz* or *zuqak*) between the main entrance and the courtyard. This provides privacy for all family members, as well as it offers safety and security, and prevents dust entering the house.
- The guest room (*madafa*) is located near the entrance.
- The outside walls of the house are located on the boundary of the plot, and opened to the inside through using courtyards. Gardens are located inside the house and not surrounding it.
- The use of *mashrabiyyah* in front of the staircase to provide privacy and comfortable conditions.
- Roofs are used as terraces especially in the Gulf area and KSA.
- The main bedroom in traditional houses is located on upper floors, to preserve the privacy of the family, and allow the wind to enter the space.
- In Lebanon and Syria (such as Aleppo), there are summer and winter zones.
- The proportion of each space is the most important feature that gives the residents the feel of comfort inside the house.
- In the current time, old houses are not suitable to live in it. Architects need to understand the meaning of each element (such as *mashrabiyyah*), and then reuse it in a new and contemporary way and material.
- From an economic point of view, old houses require more plot areas, and they are not suitable for the current building regulations, especially the courtyard model, as it needs to be built on the edges of the plot with not setbacks.
- The high ceilings in traditional house require more energy for heating in winter.
- The power of traditional houses is in the geometry of each space.
- Main features are centrality, axis, hierarchy, and orientation (toward the *qibla*).

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<sup>3</sup> See (Volume 2 - Appendix (4-A-5): Responses from the Interviews with Architects)

- Orientation of houses is from inside to the outside, which offers for the sun and wind to enter the house naturally without depending on any mechanical equipment.
- The courtyard is surrounded by walls that offer shade.
- Most traditional houses have a fountain that is located in the middle of the courtyard.
- Two significant elements offer sustainability: (a) materials; and (b) construction methods. The use of local and natural materials such as stone, clay, and brick with 80-100 cm thicknesses instead of insulation. The humidity in the clay, and the small size of windows offer comfortable conditions inside rooms, as the climate is hot and dry.
- The use of wind towers provides the house with low temperatures in the daytime. There is an opening at the end of the tower in the direction of the air (e.g. the west direction in Amman), which allows the cold air to enter the courtyard instead of hot air. Sometimes, cubes of straw, with water basins or jars, are used at the top of the wind tower for cooling.
- Each area in the neighbourhood benefits from what is available in the context, taking into consideration the local climate.
- People depended on the concept of 'trial and error' when they designed their buildings.
- Planning of cities is based on the needs of people more than specific rules. For instance, the width of alleys is equal to 7 arms ( $= 0.75 \text{ m} \times 7 = 5.25 \text{ m}$ ), which is suitable for two animals to walk in both directions.
- The height of any building should be the same of the opposite one to offer shade between them for pedestrians.
- The orientation of alleys is East-West.
- Markets are planned in a linear pattern, and not around a plaza or square.
- In each city, people respect the rights of pedestrians and the privacy of residents.
- There is modesty in the design of residential buildings, as all houses are same from the outside regardless of the poor or rich status of the family.
- Each neighbourhood has a gate, which offers comfort and safety for children to play in public areas.
- Regarding privacy, windows are located in a way that prevents direct access to the neighbours. Moreover, the height of houses is approximately the same, which provides privacy for each family.

- Connections between houses and nearby windows provide social interaction between neighbours.
- The expansion of houses has a vertical scheme, where each family builds a room on the roof as needed.

**ii. Contemporary Houses and High-rise Residential Developments in the Middle East and North Africa**

- Balconies and terraces in apartment buildings do not offer the privacy for the family as the courtyard. These elements are oriented to the outside and connected only with one space, while the courtyard can connect more than one space.
- Developers need each meter square in the apartment, so they do not prefer to insert open spaces, such as terraces. In contrast, people prefer to have balconies, terraces, and gardens in their apartments.
- The problem of setbacks between buildings limits the opportunity for inserting a courtyard inside the apartment or the house, as the users want to benefit from the area that is allowed.
- Many people, especially the young generation, in the Gulf area, preferred duplex apartments.
- The most suitable area of the apartment is 150 m<sup>2</sup>.
- The current building regulations are not flexible, especially regarding heights, setbacks, and areas. This affected the design of apartment buildings, such as inserting public spaces, or designing a two-floor apartment.
- To have a successful apartment building, developers should think about the issue of facility management, as many problems between residents are due to responsibilities of cleaning common spaces.
- The current problem in contemporary developments is that it depends on the concept of setbacks, so most of the plot area is a wasteland.
- The current problem in the Gulf area (especially in KSA) is the high outside walls, which prevent the wind and sun entering the house. Moreover, there is no connection between the street, the house, and the garden within setbacks.
- Terraces surrounding the apartment are considered as a good solution for viewing the outside. These terraces are preferred to be directed to the wind (e.g. the west direction in Amman).
- A central problem in apartment buildings is that the residents do not care about public spaces and plazas inside the building. Therefore, developers do not prefer

to include common spaces inside buildings, as these areas need regular maintenance.

**iii. Design Philosophy**

- As architects do not know the end-users of apartment buildings, they need to be neutral in the design of facades. This means that they need to use contemporary materials (such as glass and louvres) and understand the meaning of each element instead of inserting traditional elements (such as arches, *mashrabiyyah*, and small windows).
- One of the best layouts for the house is to locate the terrace, and the courtyard at the corner of the apartment, with the use of glazed facades.
- Shared spaces between buildings and inside buildings (especially in lower floors), encourage social interaction between neighbours.
- Instead of using shutters, architects can use louvres, which provide privacy, natural lighting, and natural ventilation.
- Appropriate numbers and areas for apartments are:
  - a. 180 – 240 m<sup>2</sup> (three bedrooms): two apartments on each floor.
  - b. 60 – 80 m<sup>2</sup>: four apartments on each floor.
- Current regulations in Jordan specify the maximum number of apartments on each floor to five. As a result, developers solve the small area of each apartment by converting it to duplex (two floors).
- The separation between male and female guests is still a priority in the spatial layout of the apartment, as it is part of the local culture.
- Old typologies of houses should be developed to achieve the modern and recent needs of users. Therefore, it is recommended in contemporary designs to change the location of the courtyard from the middle to the corner of the house, or as a U-shape layout to fit the standards of living.
- People prefer the open plan for their apartments with some partitions to have privacy for the family members.
- One solution for a residential building that has a courtyard inside the house is to divide the spatial layout into two zones, public and private, through inserting an outdoor covered path (opened from the two ends) that is connected from one end with a courtyard. The design of this path depends on connecting the inside with the outside, inserting vegetation, and distinguishing the tiles of the inside from the outside.

- Apartments that have more than one entrance, and separated from other apartments in the building, are more desired for the residents.
- The power of any design is to allow children to feel free when they play, and at the same time provide security and safety.
- It is not recommended to increase the height of the ceiling as it increases the cost of the house.
- It is sufficient to allow residents to adapt their houses according to their 'wants', as they are the end-users, and know how to solve their problems with 'trial and error' method.
- The open plan is not suitable for our culture, especially the open kitchen, as each space has its privacy and use.
- It is not recommended to include a courtyard for the whole building. Each three to four floors could have a common space (courtyard).
- The problem of terraces in residential buildings is that there is no connection between the inside and the outside. They are only connected to the outside environment, and there is no interaction between the users of other spaces. In contrast, U-shape layouts facilitate the interaction between the users of these spaces (Figure 4.3).

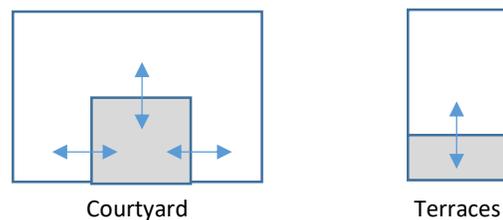


Figure 4.3: Visual connections between the different spaces of the house, and (a) courtyards, (b) terraces

- Courtyards should be used as living areas and not as transitional spaces.
- As designers depend on the use of air-conditioning, there is no need to divide the house into summer and winter zones.
- The best location of terraces is to be oriented to the wind and the view. For instance, the north is the best location in Kuwait. In Jordan, it is not recommended to be oriented toward the north as residents cannot use it in summer.
- In the Gulf area, it is not recommended to include open courtyards, as the climate is very harsh. These spaces could be covered with skylights and louvers.

### 4.1.3. The Questionnaire

A questionnaire is a structured set of questions to discover facts about population (age, gender, size..), and to analyse particular aspects to have causal relationships between dependent and independent variables (the causes of variations in the dependent variables) (Leddy-Owen 2016). For this study, potential respondents (residents) are scattered over a wide geographic area and different countries within this study. Therefore, a questionnaire is much better to collect data.

The study adopts the distribution of an online self-completion questionnaire as a method to collect data from the study area. Two versions of the questionnaire (one in English, and the other in Arabic) have been hosted on a computer software package ([www.esurv.org](http://www.esurv.org)), and distributed to families from 17 countries within the study area, randomly. The process started on 15/7/2016 and lasted for 60 days (15/9/2016). This method for collecting responses prevents multiple replies, reduces financial and time costs, covers different geographic locations, and reduces human errors or missing data as the data entry is an automated process (Leddy-Owen 2016; Bryman 2016).

#### a. The Design of the Questionnaire

The questionnaire included different types of questions:

- i. Binary and categorical closed questions: which offer for the participant to choose between two response categories (e.g. yes or no).
- ii. Interval-level closed questions: participant has to rank, or to choose from a range of numerical ranking or measuring attitudes through five-point scale ranging from strongly agree to strongly disagree.
- iii. Close-ended questions: respondents have sets of response categories to choose. These categories have been developed to ensure that they are inclusive. Using this type of questions, it is much easier to process answers, to enhance comparability, to reduce the variability in answers, and to conclude statistical results and quantitative analysis. Therefore, answers could produce more valid and reliable data (Bryman 2016).
- iv. Open-ended questions: this type gives the opportunity and the freedom for participants to provide answers in their own words, and allows for unexpected responses and new ideas to be derived. However, coding process for this type is much complicated. Therefore, those questions are minimal.

A total number of 51 questions were categorised into five main aspects. Each category included several questions that describe or measure the social, spatial, contextual, and environmental qualities of the house<sup>4</sup>. These aspects are:

- Part (1): Information about the house and the household structure (8 questions).
- Part (2): Spatial descriptions (9 questions).
- Part (3): Social merits (11 questions).
- Part (4): Environmental qualities (10 questions).
- Part (5): Information about neighbours and the housing context (13 questions).

#### **b. Ethical Considerations**

As part of the research ethics, the work was carried out by the codes of ethics applied by the researching body. An ethical approval form appended with the research proposal and ethics statement was submitted to the Ethics Committee in the Welsh School of Architecture at Cardiff University, and approval was obtained<sup>5</sup>.

Moreover, all participants were informed about the purpose of the study, how they were expected to take part in it, how much time the participation was expected to take, and the right of any participant not to answer any particular question, or to withdraw from the study at any time.

#### **c. Validating the Questionnaire**

The questionnaire should be validated and tested before carrying out the actual data collection. This pre-tested phase has been conducted by asking colleagues and professional, and by distributing the draft questionnaire to a random sample. The aim is to explore if the measures of each question reflect the themes that need to be measured. Also, it is useful to avoid any problem or unclear issue in understanding questions.

#### **d. The Sample**

The study population is “the universe of units from which the sample is to be selected” (Bryman 2016). For this research, the study population comprised the community living in urban areas within the hot-arid region of the Middle East and North Africa. According to recent statistics published by the World Bank in 2017<sup>6</sup>, more than 42 million families live in urban areas within the study area. To capture the overall picture of residential

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<sup>4</sup> See (Volume 2 - Appendix (4-A-2): The Questionnaire (in both languages: Arabic and English))

<sup>5</sup> See (Volume 2 - Appendix (4-A-4): Ethical Approval Forms)

<sup>6</sup> [www.worldbank.org/en/region/mena](http://www.worldbank.org/en/region/mena) (accessed on 2/5/2018)

developments in such a large setting, and to explore the social/cultural wants of users, the researcher sent an online questionnaire to families from 17 countries within the study area. A total number of 212 responses from 12 countries were returned. After sorting and revising the returned questionnaires, a final overall sample size of 173 households was achieved - a reasonable response rate of 81.6%. Reasons for the disqualification of 39 responses include some contradictions in the answers, and incomplete responses. Although the final sample size is small, it is reasonable to the limited timeframe and financial resources, and representative as the sample covers the three regions of the study area (Table 4.3, and Figure 4.4).

Table 4.3: Number of returned questionnaires per region

| Region              | Countries                  | No. of Returned Questionnaires | No. of Questionnaires that are completely and properly filled |                 |        |
|---------------------|----------------------------|--------------------------------|---|-----------------|--------|
| Gulf Area and Yemen | Saudi Arabia (KSA)         | 19                             | 16  | 9.2 %           | 28.3 % |
|                     | Kuwait                     | 11                             | 11  | 6.4 %           |        |
|                     | United Arab Emirates (UAE) | 16                             | 13  | 7.5 %           |        |
|                     | Qatar                      | 8                              | 7   | 4.0 %           |        |
|                     | Yemen                      | 2                              | 2   | 1.2 %           |        |
| The Middle East     | Jordan                     | 65                             | 56  | 32.4 %          | 46.2 % |
|                     | Syria                      | 5                              | 5   | 2.9 %           |        |
|                     | Lebanon                    | 1                              | 0   | 0.0 %           |        |
|                     | Palestine                  | 15                             | 13  | 7.5 %           |        |
|                     | Iraq                       | 3                              | 3   | 1.7 %           |        |
|                     | Turkey                     | 3                              | 3   | 1.7 %           |        |
| North Africa        | Egypt                      | 62                             | 42  | 24.3 %          | 25.5 % |
|                     | Algeria                    | 2                              | 2   | 1.2 %           |        |
| <b>TOTAL</b>        |                            | <b>212</b>                     | <b>173</b>  | <b>100.00 %</b> |        |

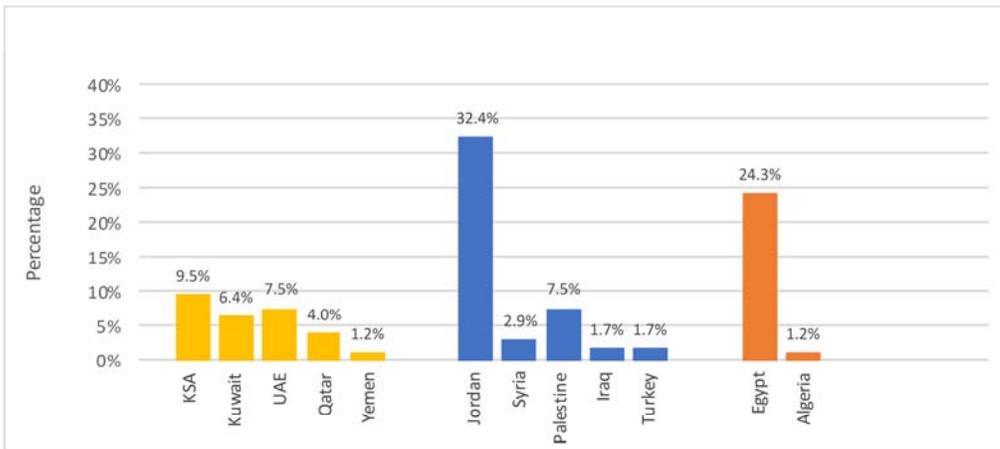


Figure 4.4: Percentages of returned questionnaires that are thoroughly and adequately filled

### e. Results from the Survey

The following tables and charts show responses to each question. However, correlations between data and interpretation of results are illustrated in the next section (Data Analysis).

#### - **Part 1: Information about the House and the Household Structure**

Results showed that most respondents live in apartments that were built within the last ten years. More than 40% of those families have 2-3 children (Figures 4.5 to 4.11).

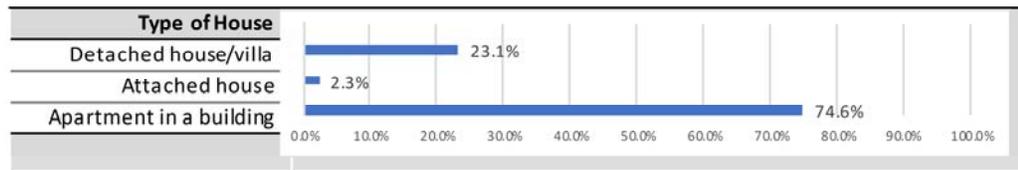


Figure 4.5: Frequencies showing types of houses

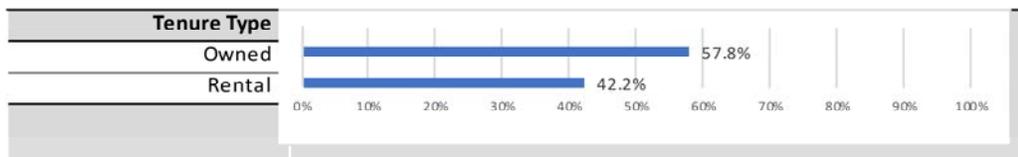


Figure 4.6: Frequencies showing tenure type

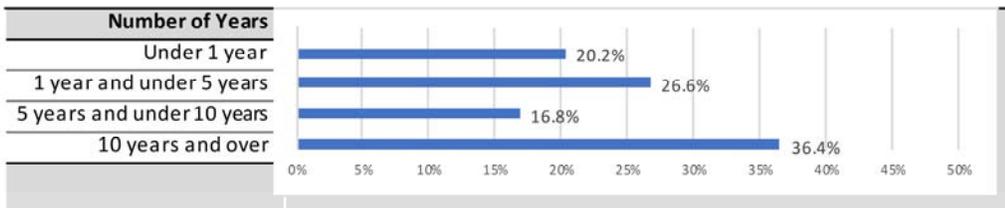


Figure 4.7: Frequencies showing number of years living in the current house

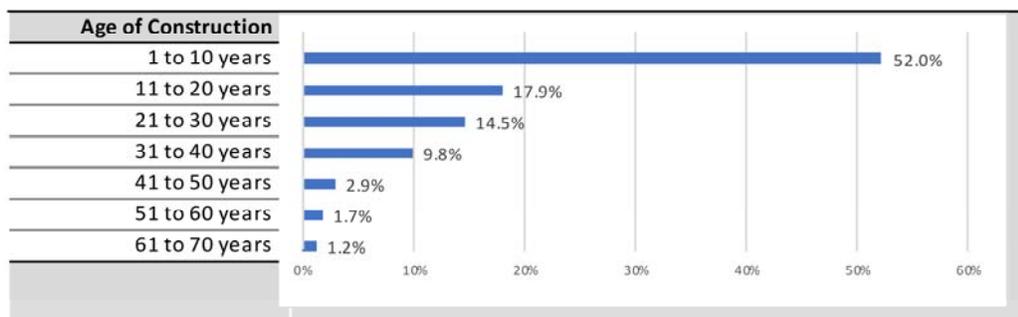


Figure 4.8: Frequencies showing age of construction

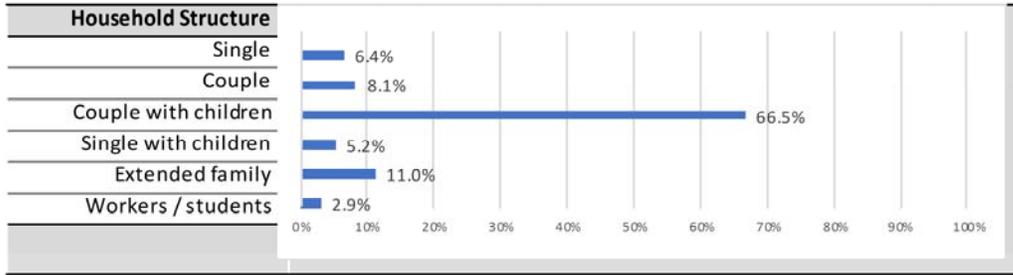


Figure 4.9: Frequencies showing household structure

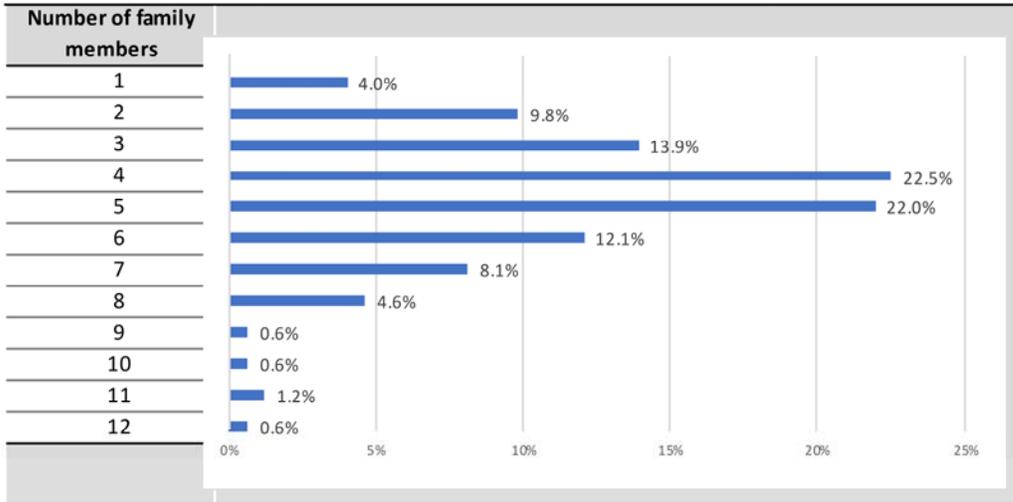


Figure 4.10: Frequencies showing number of family members living in the house

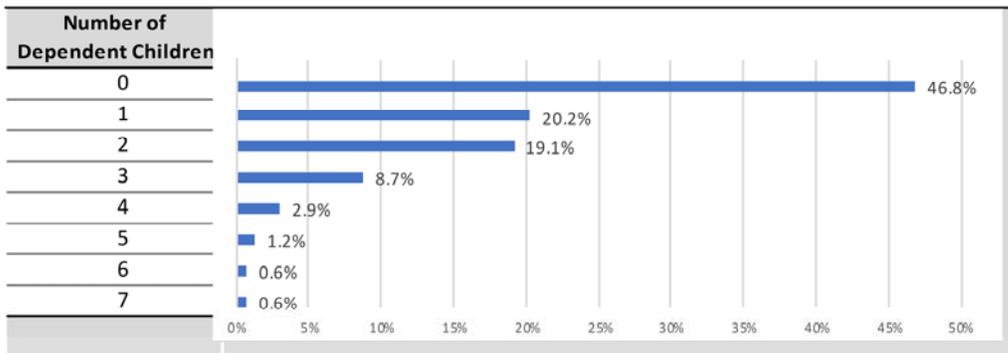


Figure 4.11: Frequencies showing number of dependent children (under 18 years) living in the house

- **Part 2: Spatial Description**

Results showed that areas of houses are ranged between 100 and 250 m<sup>2</sup>. However, most contemporary apartments are crowded due to the small area of family zones, multi-purpose halls, and outdoor spaces, such as terraces and balconies. Although old houses include outdoor spaces, the same problem of small size of rooms was observed. Moreover, 85% of the sample needs more storage areas and breakfast zones. To deal with

these issues, 25% of families changed the original layouts of their houses to accommodate their needs. For instance, they converted the outdoor balconies and terraces into closed spaces to increase the area of living rooms or to add an extra bedroom. Also, they feel that there is no privacy between living spaces and guest rooms. Therefore, they added partitions in front of private/intimate spaces, or changed the location of living rooms and entrances to solve this problem. Other modifications include increasing width of windows, especially in old houses, to benefit from the natural lighting and ventilation (Figures 4.12 to 4.20, and Tables 4.4 to 4.6).

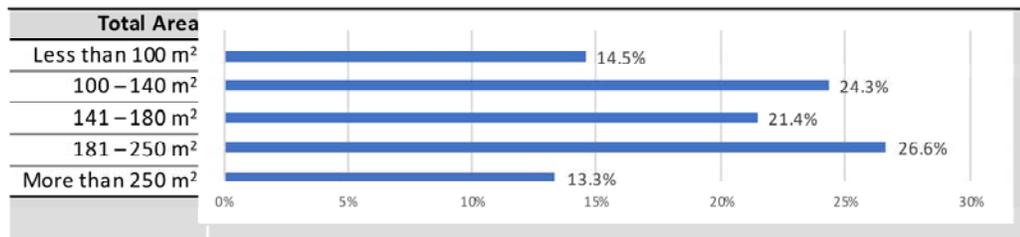


Figure 4.12: Frequencies showing total area of the house

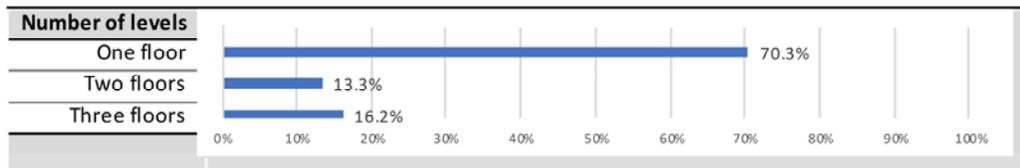


Figure 4.13: Frequencies showing number of levels/floors in the house

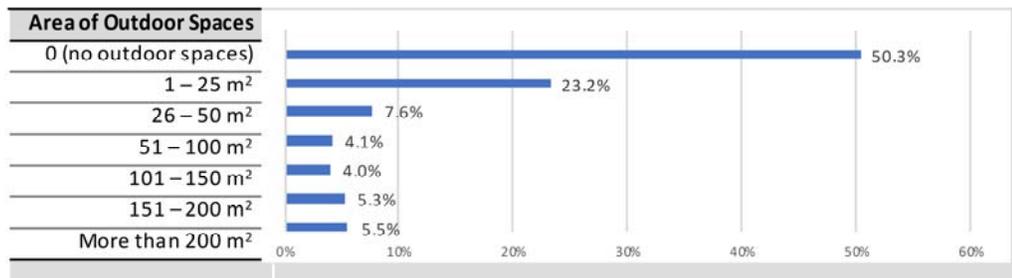


Figure 4.14: Frequencies showing approximate area of outdoor spaces in the house

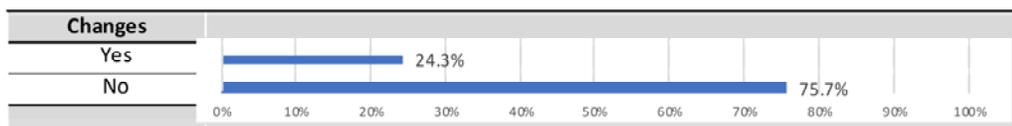


Figure 4.15: Percentages of families who changed the original interior layout of the house

Table 4.4: Types and reasons for changes to the original interior layout

| Reasons for Changes   | Types of Changes  |
|---|---|
| <b>To increase the privacy of livings spaces</b>                            | <ul style="list-style-type: none"> <li>- Add a screen wall to increase the privacy of the living space.</li> <li>- Change the location of the entrance to provide privacy for the kitchen.</li> <li>- Change the location of the living space when it is located near bedrooms.</li> <li>- Change the location of the secondary entrance, which is used by the family members, to increase the privacy.</li> <li>- Add a partition between the kitchen and the living space.</li> <li>- Add a secondary entrance for female guests.</li> <li>- Add a partition between the living space and the dining room.</li> </ul>   |
| <b>To increase the area of the house</b>                                    | <ul style="list-style-type: none"> <li>- Close the double volume between the ground floor and the first floor, and use it as a living space.</li> <li>- Demolish the guest toilet and add it to the kitchen.</li> <li>- Demolish the wall between the living room and the kitchen.</li> <li>- Increase the area of the living space.</li> <li>- Increase the area of balconies.</li> <li>- Changes that were mainly implemented in old houses that are aged more than 20 years:               <ul style="list-style-type: none"> <li>o Demolish walls between the guest room and the dining room.</li> <li>o Close the balcony space and add it to a bedroom (as a space for activities).</li> <li>o Close the balcony space (as it needs continuous cleaning due to the dust) and use it as a living space.</li> <li>o Close the terrace near kitchen and use it as a breakfast area.</li> </ul> </li> </ul> |
| <b>Change the orientation of some spaces for environmental requirements</b> | <ul style="list-style-type: none"> <li>- Change the location of the living space, toward the west direction, to benefit from the wind and the natural ventilation, and change the location of the kitchen toward the east direction.</li> <li>- Increase the area of some windows to benefit from the natural lighting and natural ventilation, especially in old houses.</li> </ul>  |

Table 4.5: Frequencies showing types of rooms and indoor spaces in houses

| Indoor Rooms and Spaces               | Applicable | Not Applicable | Percentage |
|---------------------------------------|------------|----------------|------------|
| Entry hall                            | 68.8 %     | 31.2 %         |            |
| Guest room (for both male and female) | 67.6 %     | 32.4 %         |            |
| Guest room (only for male)            | 14.5 %     | 85.5 %         |            |
| Guest room (only for female)          | 10.4 %     | 89.6 %         |            |
| Dining room                           | 65.9 %     | 34.1 %         |            |
| Guest toilet                          | 67.6 %     | 32.4 %         |            |
| Family living room                    | 80.3 %     | 19.7 %         |            |
| Multi-purpose hall                    | 30.1 %     | 69.9 %         |            |
| Office/Study area                     | 24.9 %     | 75.1 %         |            |
| Master bedroom (1)                    | 83.3 %     | 16.2 %         |            |
| Master bedroom (2)                    | 23.7 %     | 76.3 %         |            |
| Master bedroom (3)                    | 15.0 %     | 85.0 %         |            |
| Master bedroom (4)                    | 5.2 %      | 94.8 %         |            |
| Bedroom (1) for kids                  | 60.1 %     | 39.9 %         |            |
| Bedroom (2) for kids                  | 42.8 %     | 57.2 %         |            |
| Bedroom (3) for kids                  | 13.9 %     | 86.1 %         |            |
| Bedroom (4) for kids                  | 4.6 %      | 95.4 %         |            |
| Guest bedroom                         | 12.1 %     | 87.9 %         |            |
| Bathroom (1)                          | 100.0 %    | 0.0 %          |            |
| Bathroom (2)                          | 53.2 %     | 46.8 %         |            |
| Bathroom (3)                          | 25.4 %     | 74.6 %         |            |
| Kitchen                               | 80.3 %     | 19.7 %         |            |
| Breakfast area                        | 26.0 %     | 74.0 %         |            |
| Storage                               | 35.3 %     | 64.7 %         |            |

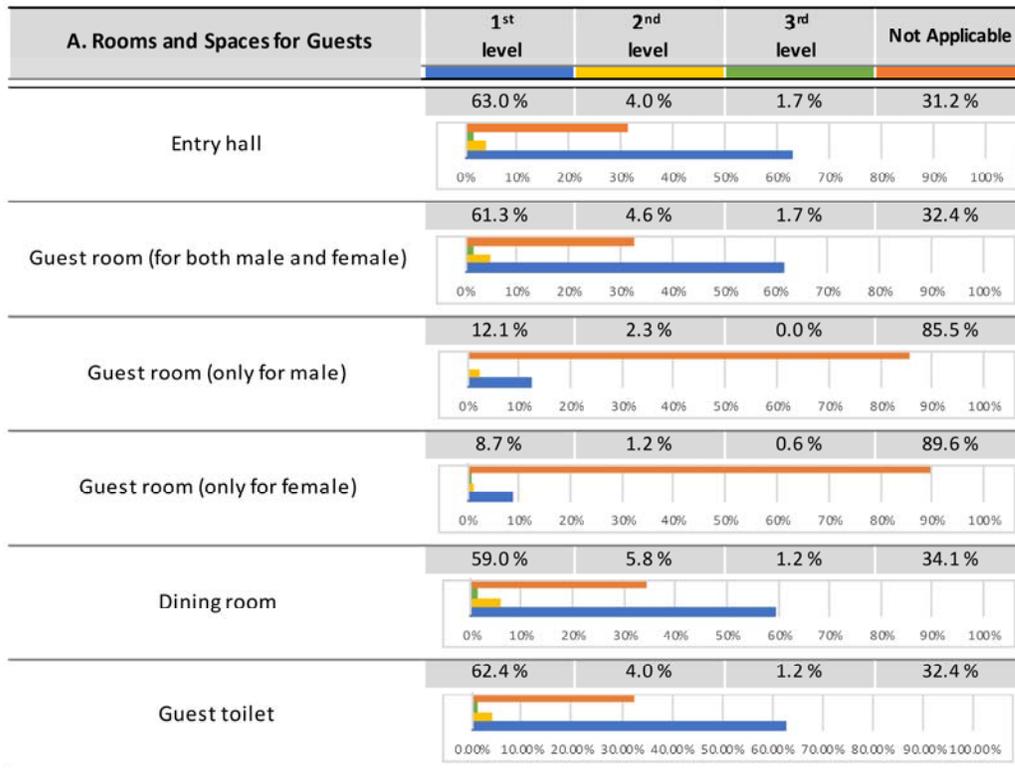


Figure 4.16: Frequencies showing location of rooms for guests

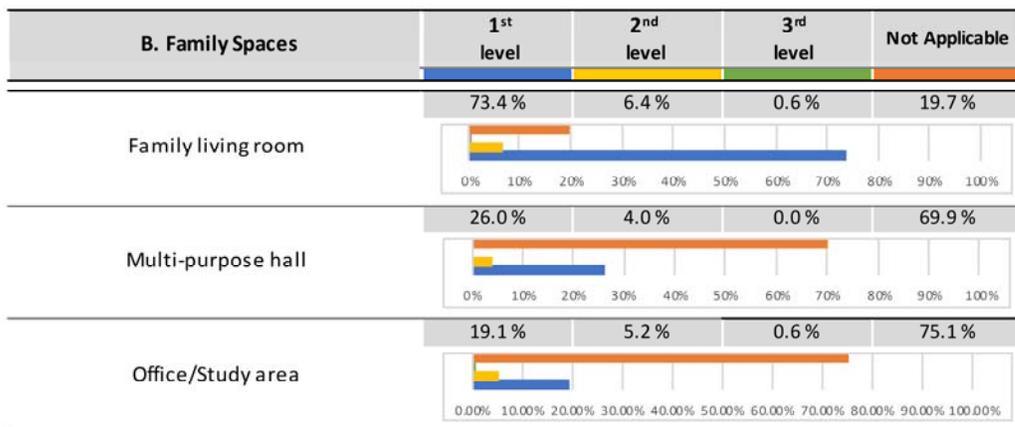


Figure 4.17: Frequencies showing location of family rooms

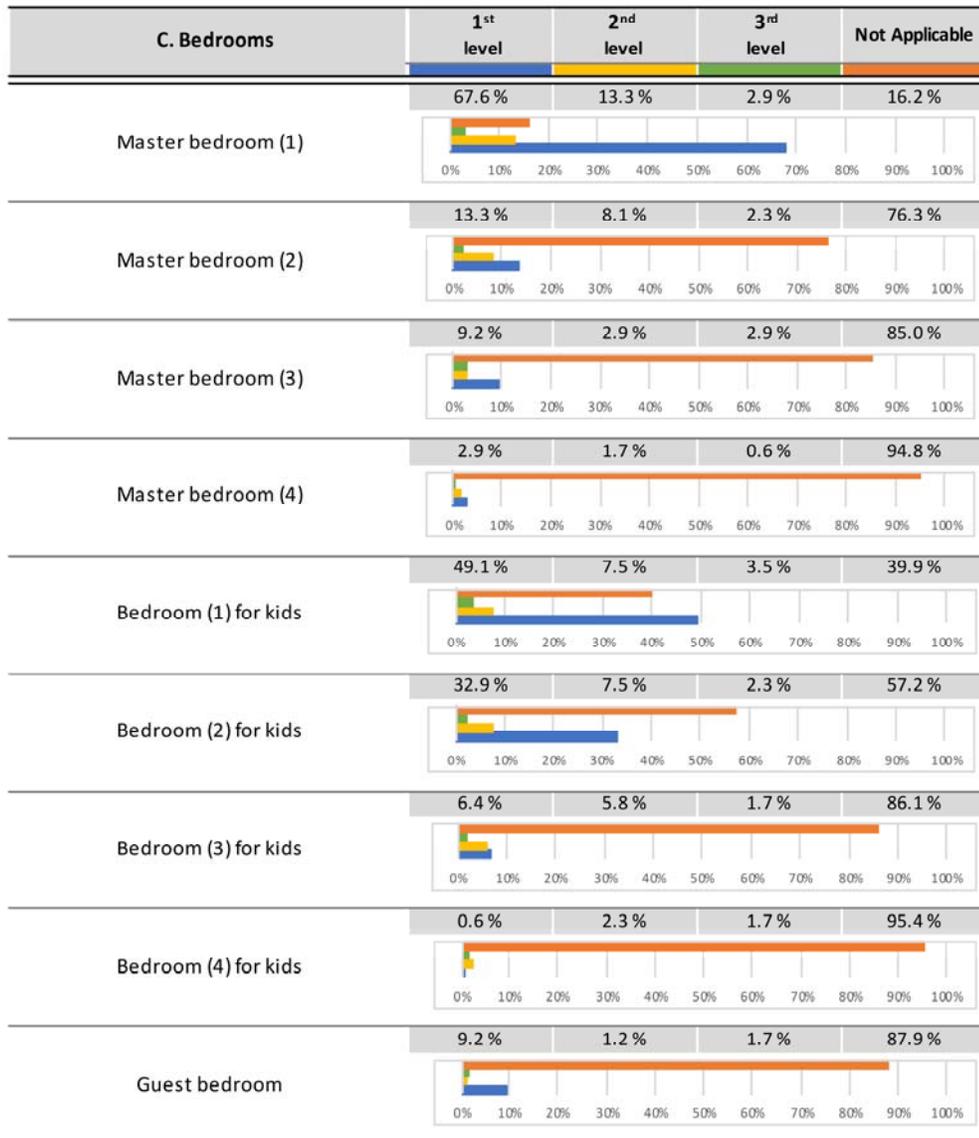


Figure 4.18: Frequencies showing location of bedrooms

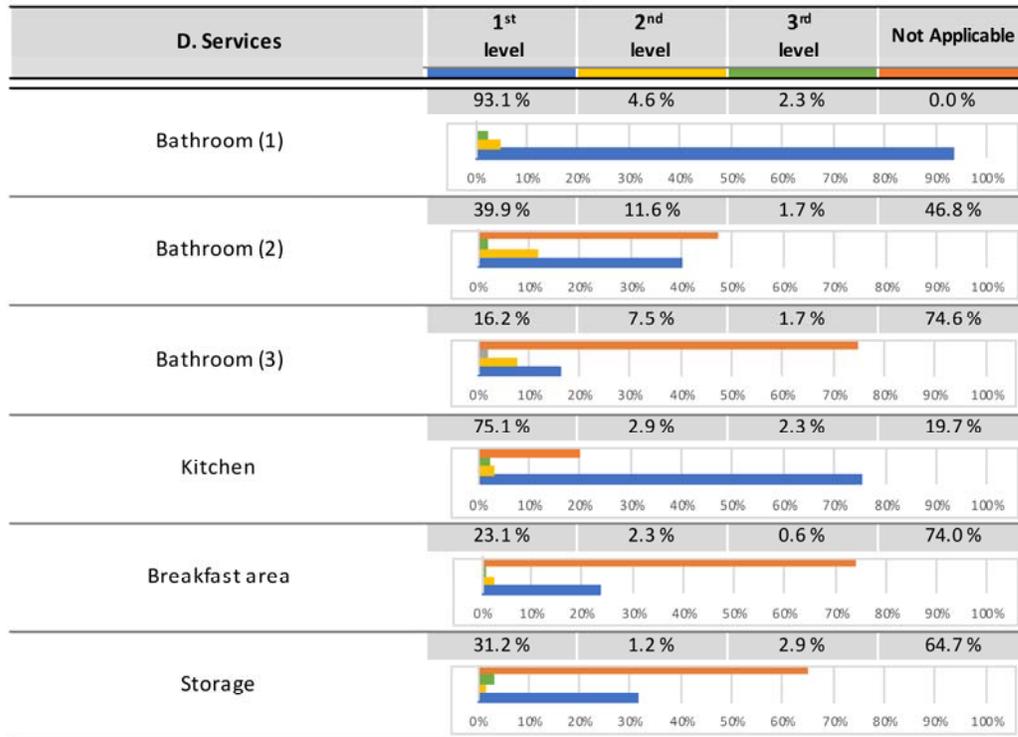


Figure 4.19: Frequencies showing location of services

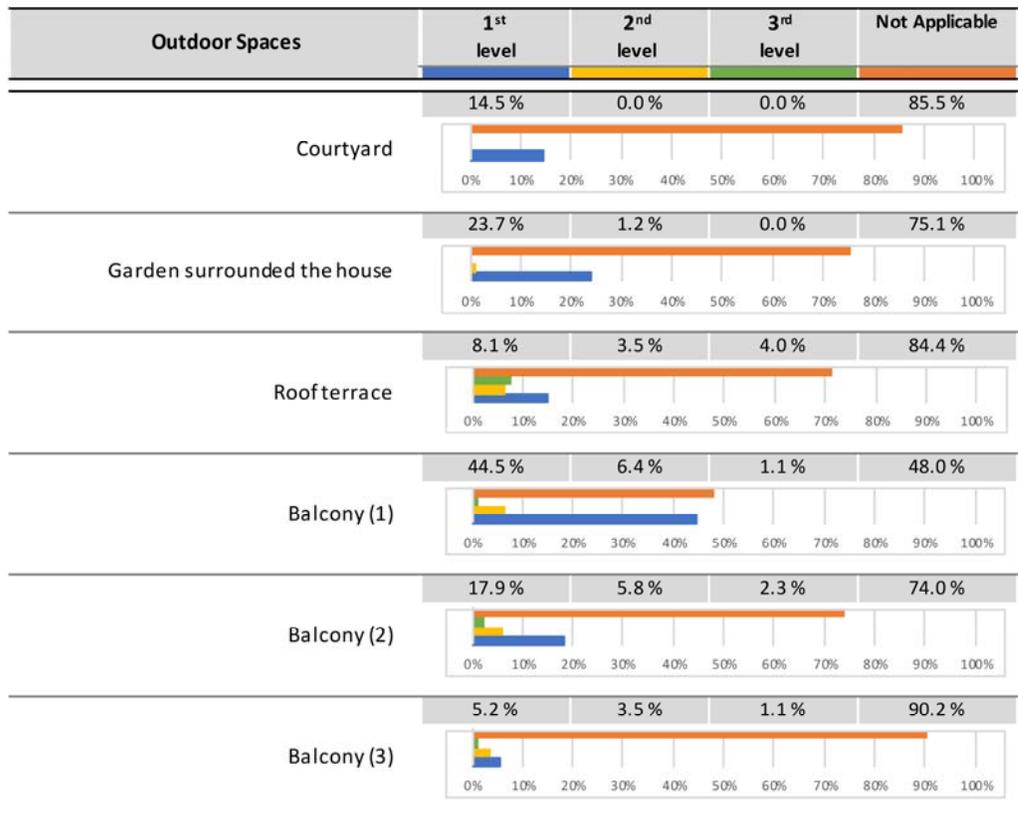
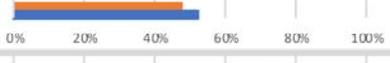


Figure 4.20: Frequencies showing location of outdoor spaces

Table 4.6: Frequencies showing outdoor spaces in houses

| Outdoor Spaces              | Applicable | Not Applicable | Percentage   |
|-----------------------------|------------|----------------|--|
| Courtyard                   | 14.5 %     | 85.5 %         |  |
| Garden surrounded the house | 24.9 %     | 75.1 %         |  |
| Roof terrace                | 15.6 %     | 84.4 %         |  |
| Balcony (1)                 | 52.0 %     | 48.0 %         |  |
| Balcony (2)                 | 26.0 %     | 74.0 %         |  |
| Balcony (3)                 | 9.8 %      | 90.2 %         |  |

### - Part 3: Social Merits

Residents highlighted the different spaces that are needed in their houses. Responses indicated that outdoor spaces (such as terraces, balconies and courtyards) are the most important features as 26.7% of residents missed it. Moreover, 15.8% of respondents need more storage rooms inside their houses. Regarding family rooms, 10.2% of residents need additional living areas and spaces for studying, while 8.7% prefer to have a multi-purpose hall for activities.

Results from the survey showed that 71% of the sample considered that their houses do not afford privacy for the family members, or private outdoor spaces for their children. Moreover, 62% of the sample respondents reported that they live in houses that have crowded living areas in comparison to the size of guest rooms. This problem is mainly in old and contemporary houses as residents feel that large size guest rooms is a social requirement in their culture. However, 87% of residents would prefer to have outdoor areas inside their houses (Figures 4.21 to 4.26, and Tables 4.7 to 4.9).

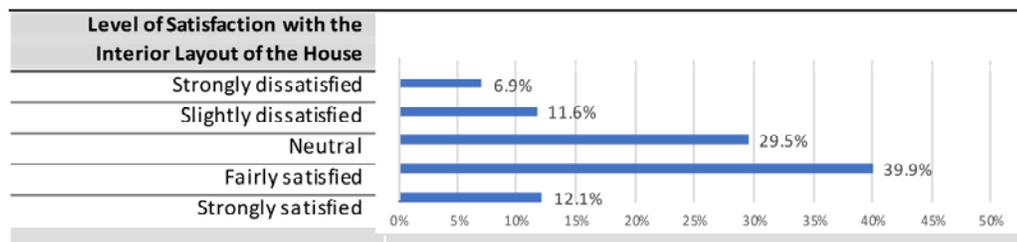


Figure 4.21: Frequencies showing level of satisfaction with the interior layout of the house

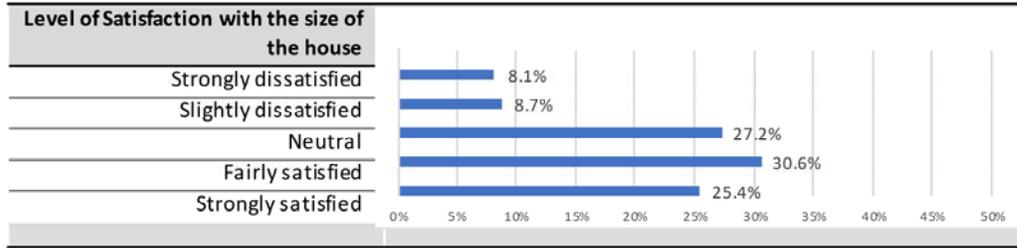


Figure 4.22: Frequencies showing level of satisfaction with the size of the house in comparison to the size of the family

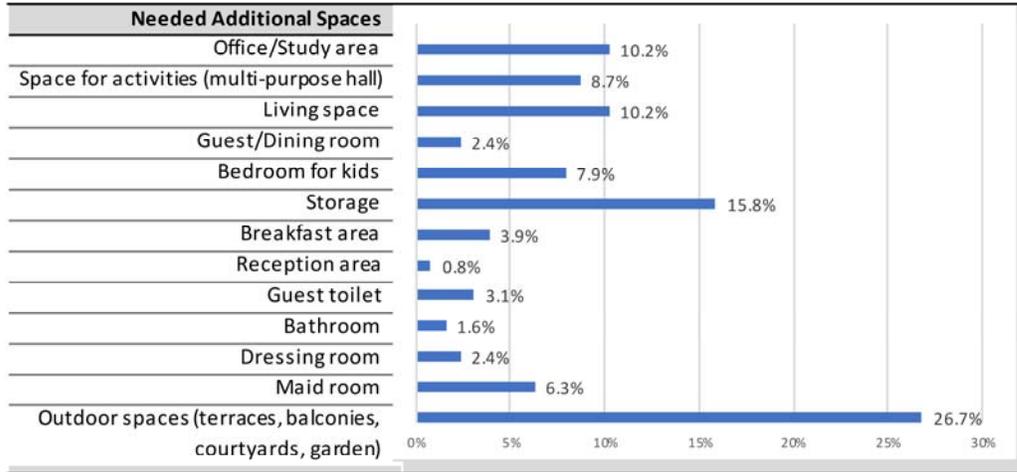


Figure 4.23: Frequencies showing needed additional spaces in current houses

Table 4.7: Aspects that people like the most in the spatial design of their house

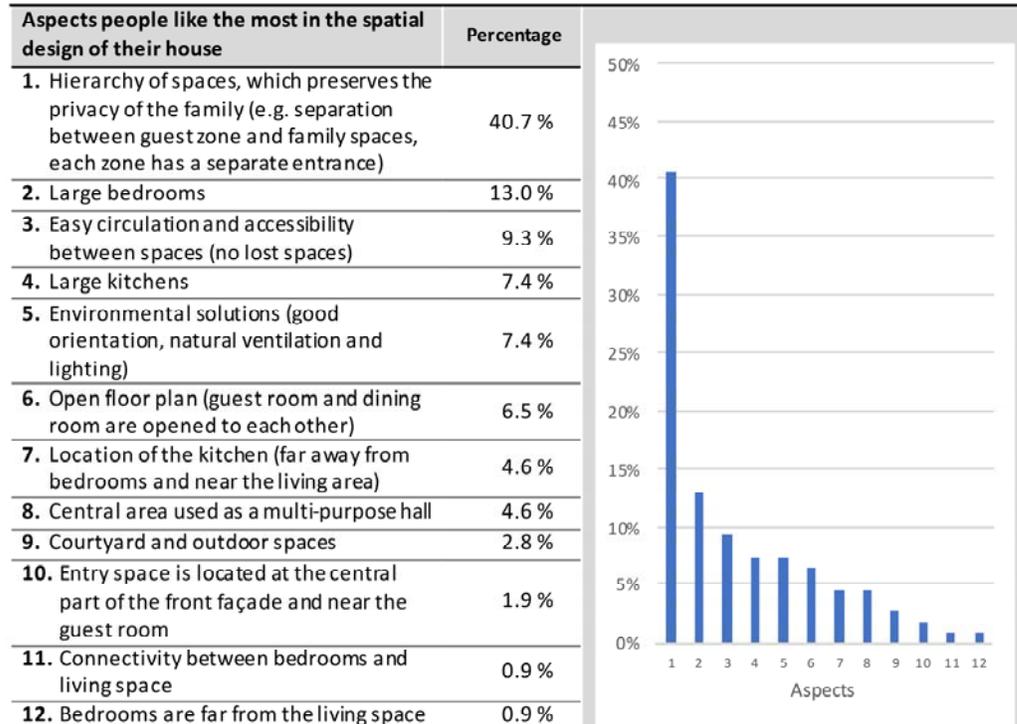
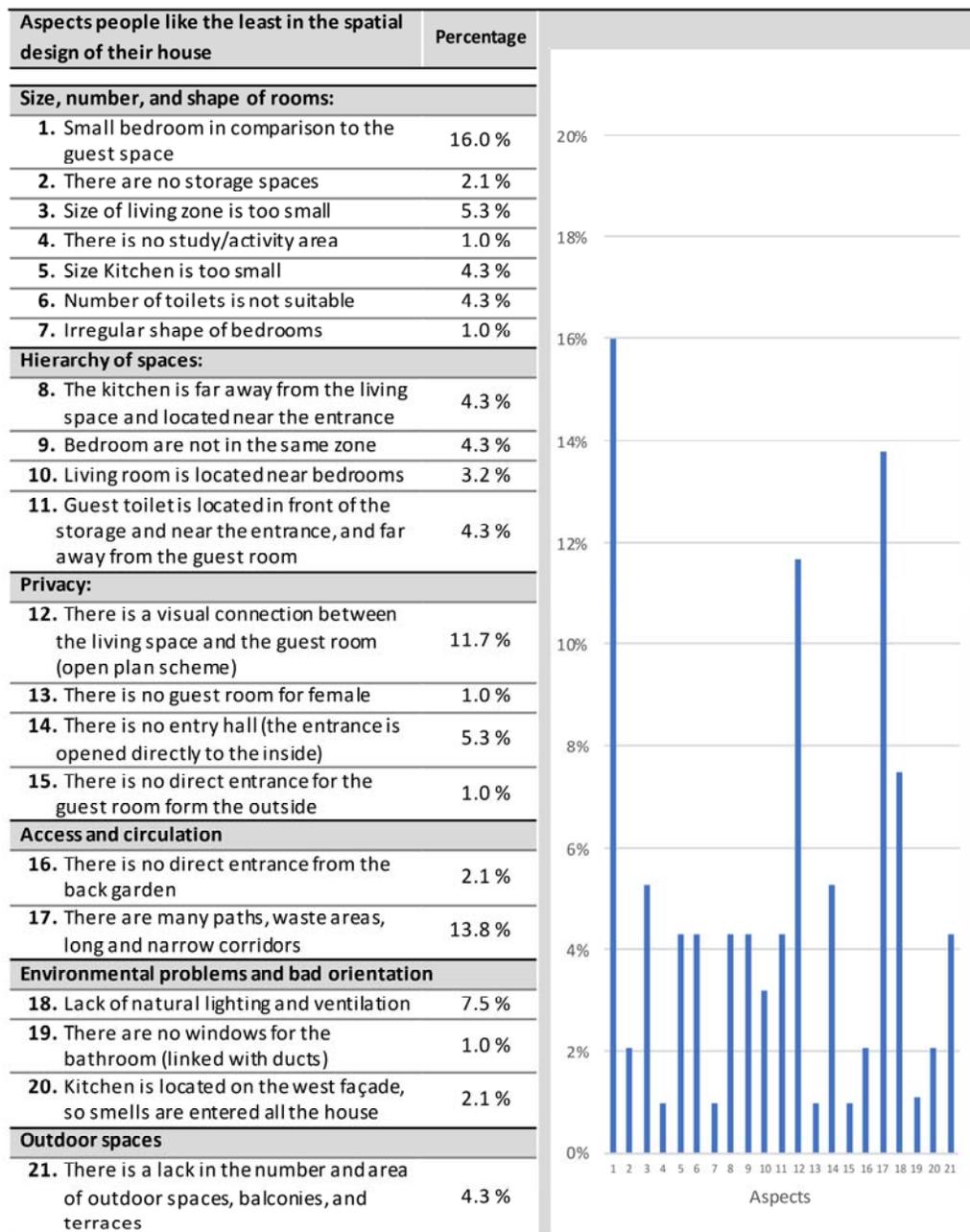


Table 4.8: Aspects that people like the least in the spatial design of their house



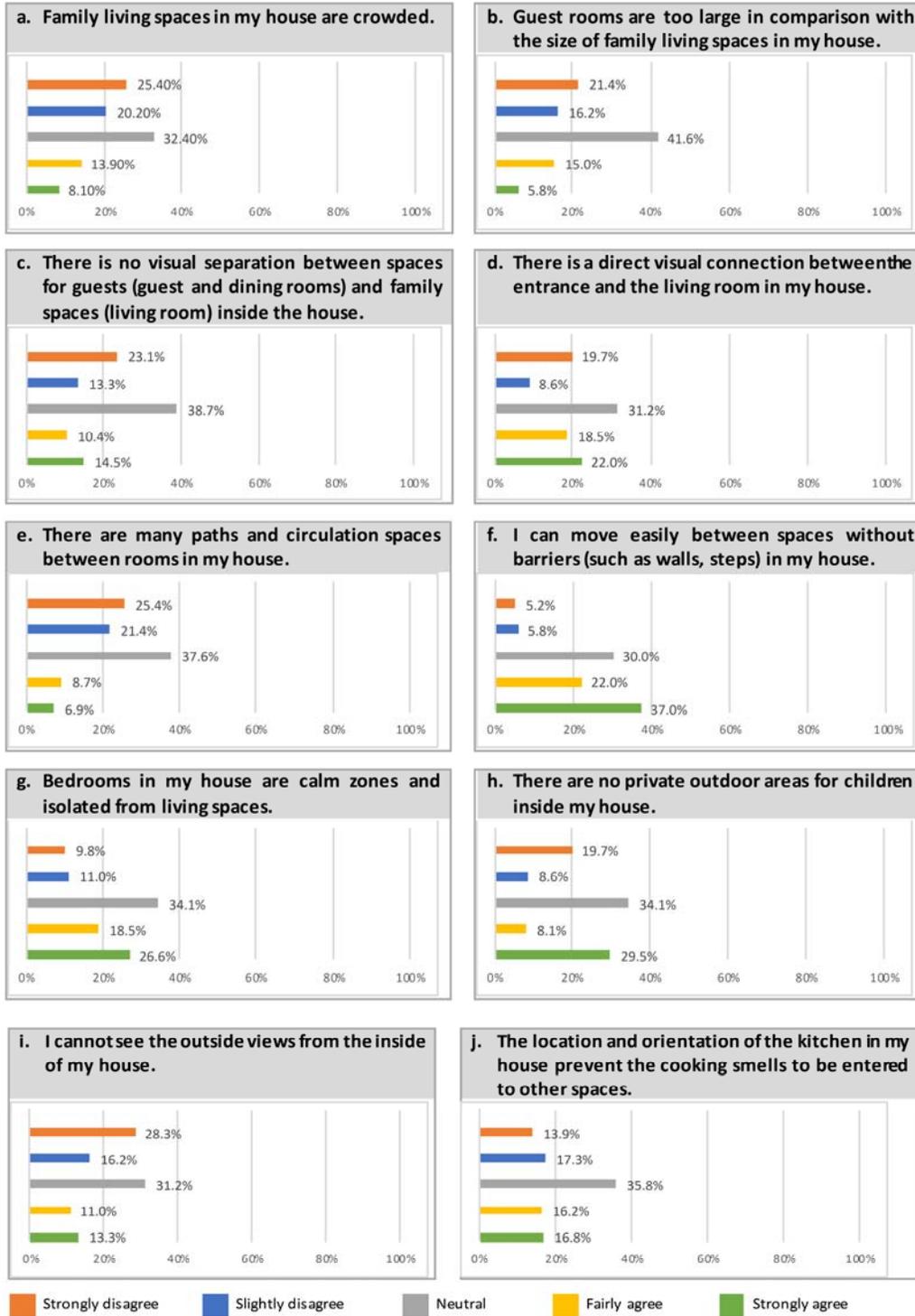


Figure 4.24: Frequencies showing opinion of residents with the different social qualities in their houses

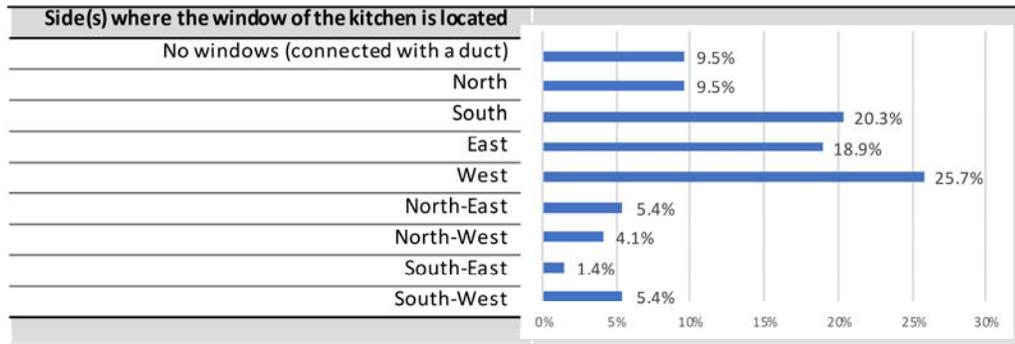


Figure 4.25: Frequencies showing side(s) where the window of the kitchen is located

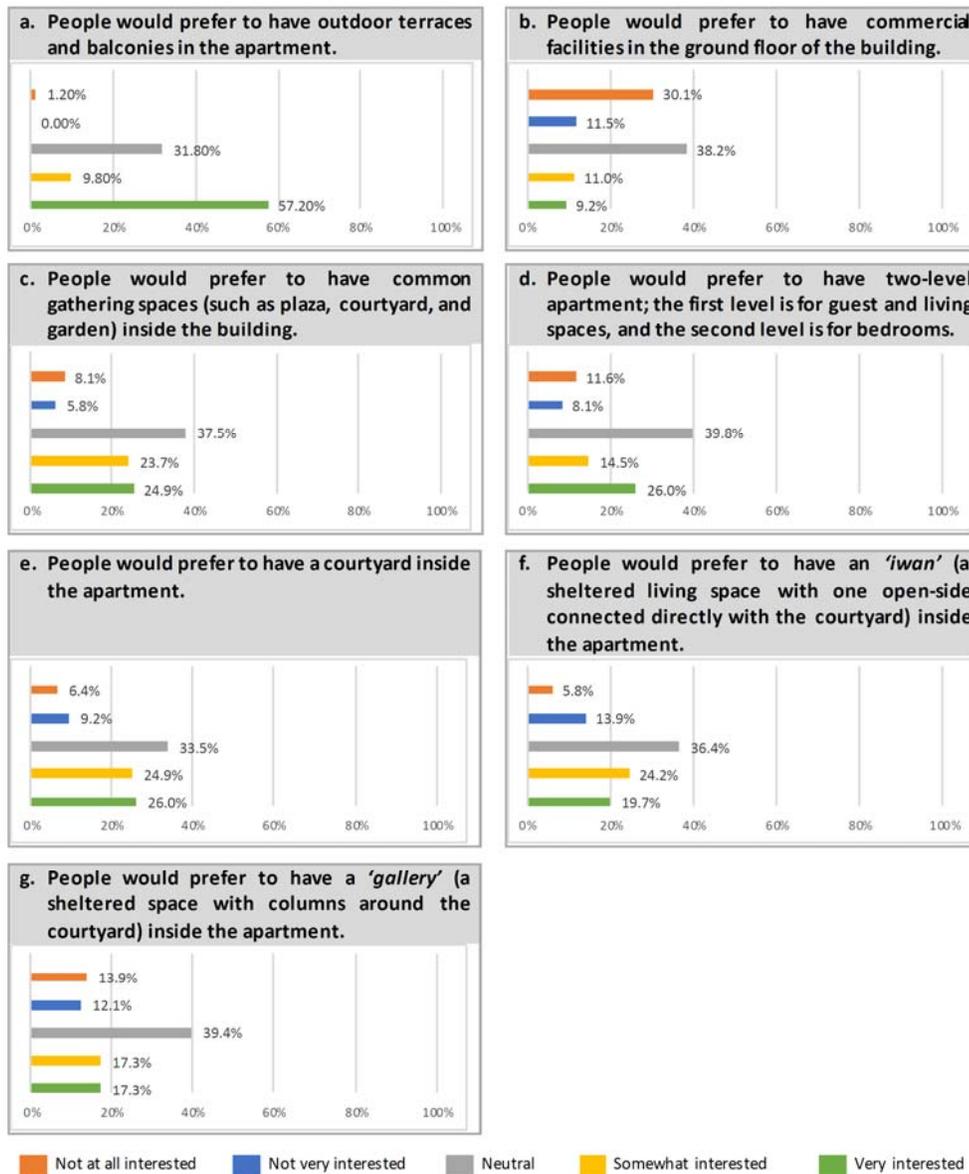
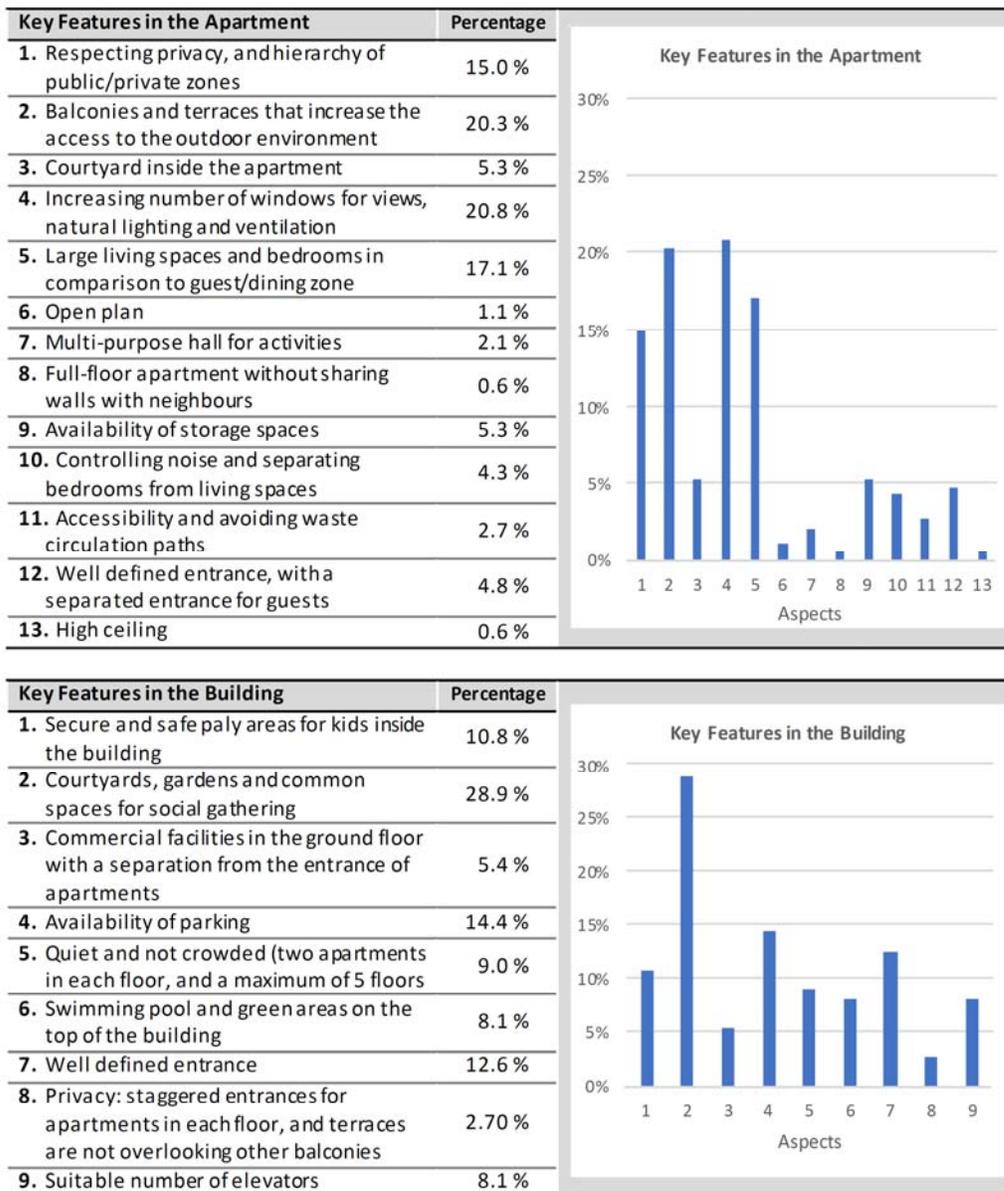


Figure 4.26: Frequencies showing opinions to include certain spaces if people have the chance to buy an apartment in a multi-story (or high-rise) residential building

Table 4.9: Key features in the apartment and the building if people have the chance to buy an apartment in a multi-story (or high-rise) residential building



Another problem that affects circulation and accessibility inside houses, especially in old buildings that are aged more than 20 years, is the different levels between spaces through using 1 to 3 steps in most cases, and sometimes 5 and 7 steps between living areas and kitchen or bedrooms. More than 33% of respondents stated that these steps are not practical inside the house (Figure 4.27). Such a problem is limited in contemporary apartments due to the limited height of the ceiling. On the other hand, most residents (95%) would prefer the use of steps in front of main doors, as a separation between the outdoor and the indoor, to keep the house clean from dust (Figure 4.28).



Figure 4.27: Frequencies showing changes in levels between spaces inside the house

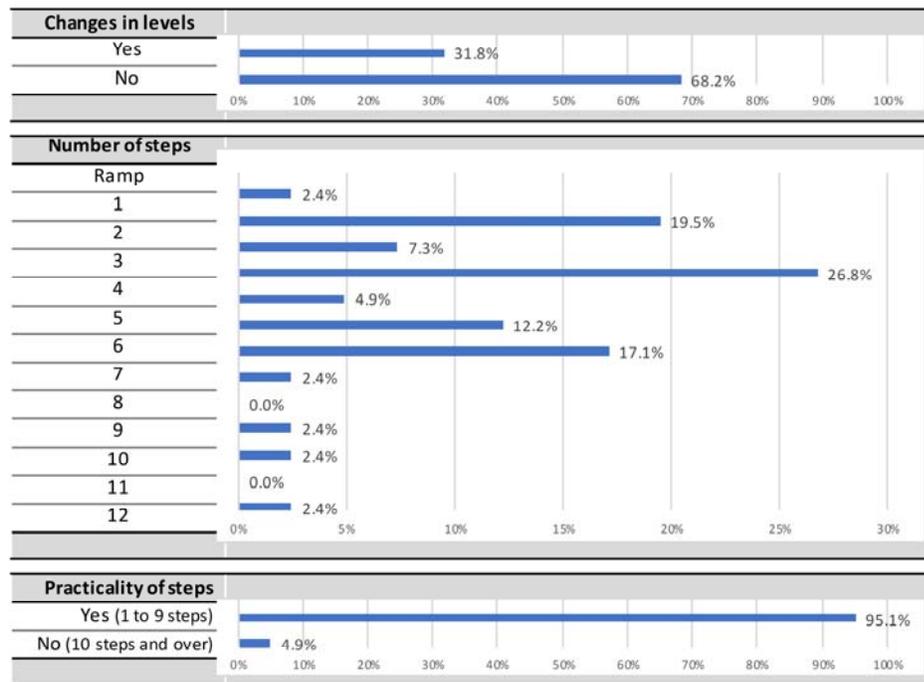


Figure 4.28: Frequencies showing changes in levels between the outside and the entrance of the house

**- Part 4: Environmental Qualities**

Results from the survey showed that there is no specific space used in summer nor winter. However, 50% of the sample needs more green areas and outdoor spaces in their houses. Despite these needs, residents feel that the temperature and the ventilation inside their buildings are acceptable (Figures 4.29 to 4.37, and Table 4.10).

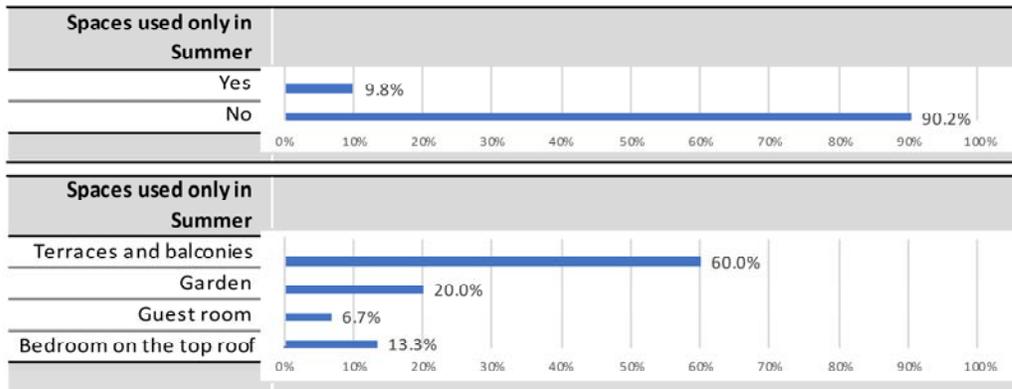


Figure 4.29: Frequencies showing any specific space used only in summer

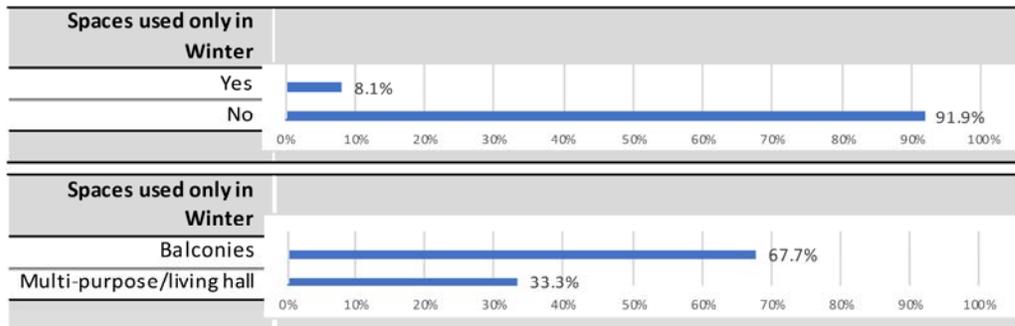


Figure 4.30: Frequencies showing any specific space used only in winter

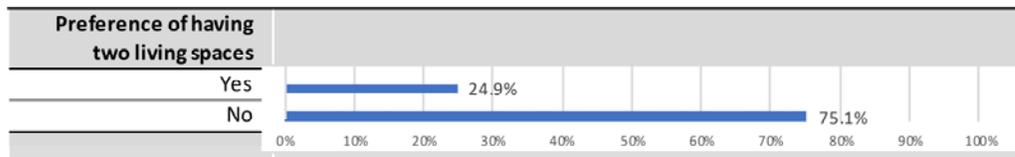


Figure 4.31: Frequencies showing preferences to have two living spaces; one used in winter, and the other in summer, if people move to another house

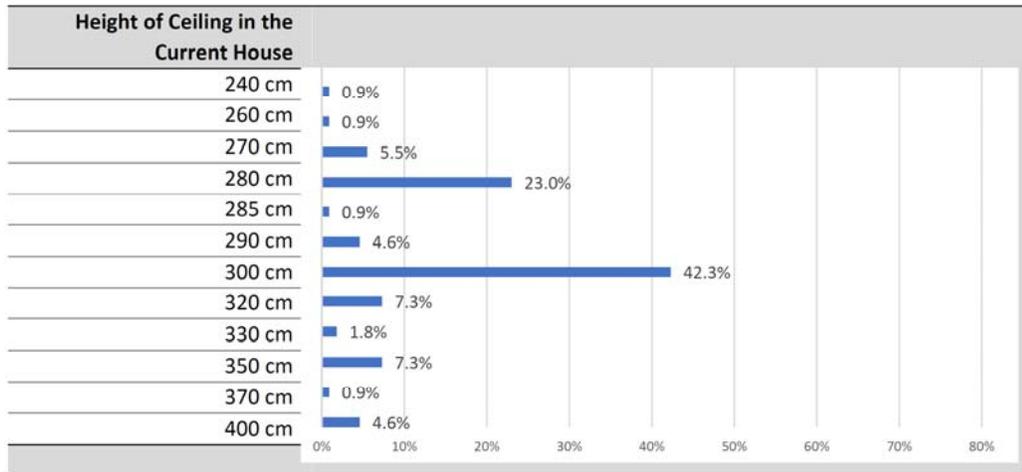


Figure 4.32: Frequencies showing height of ceiling in the house

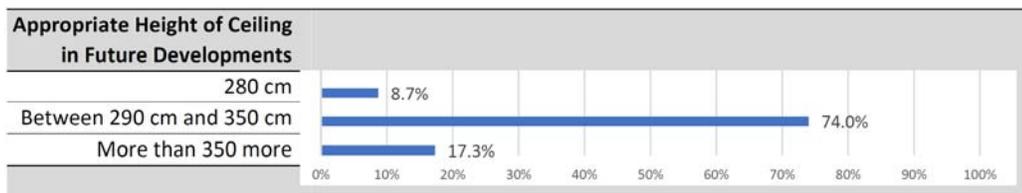


Figure 4.33: Frequencies showing the most appropriate height of ceiling if people move to another house

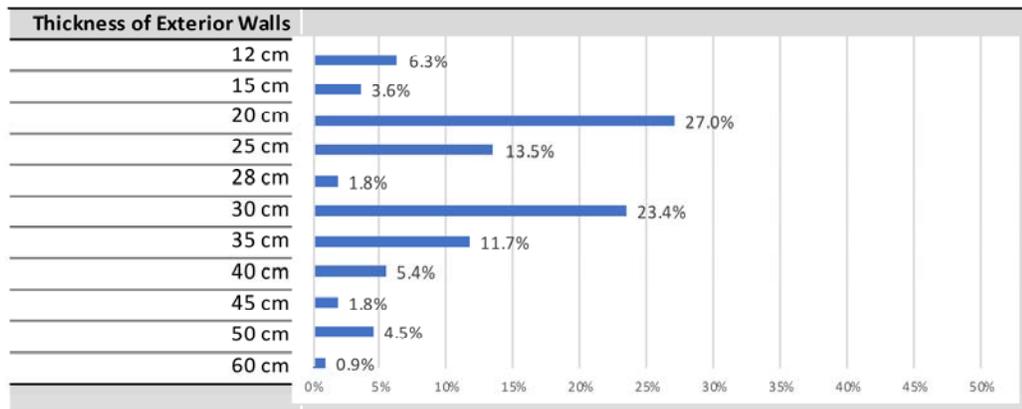


Figure 4.34: Frequencies showing the overall thickness of exterior walls

Table 4.10: Percentages showing if people have any environmental problem in their houses

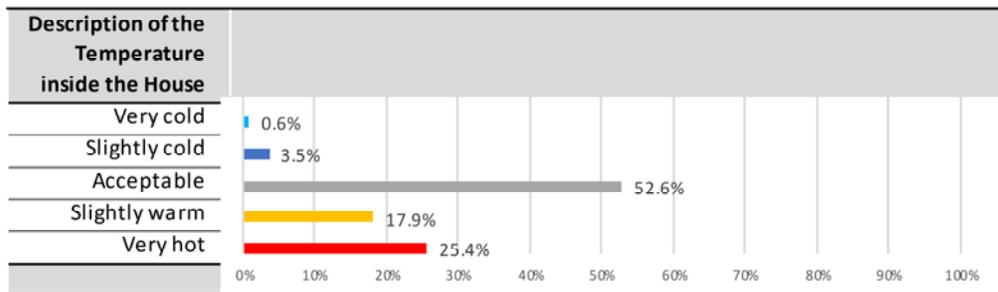
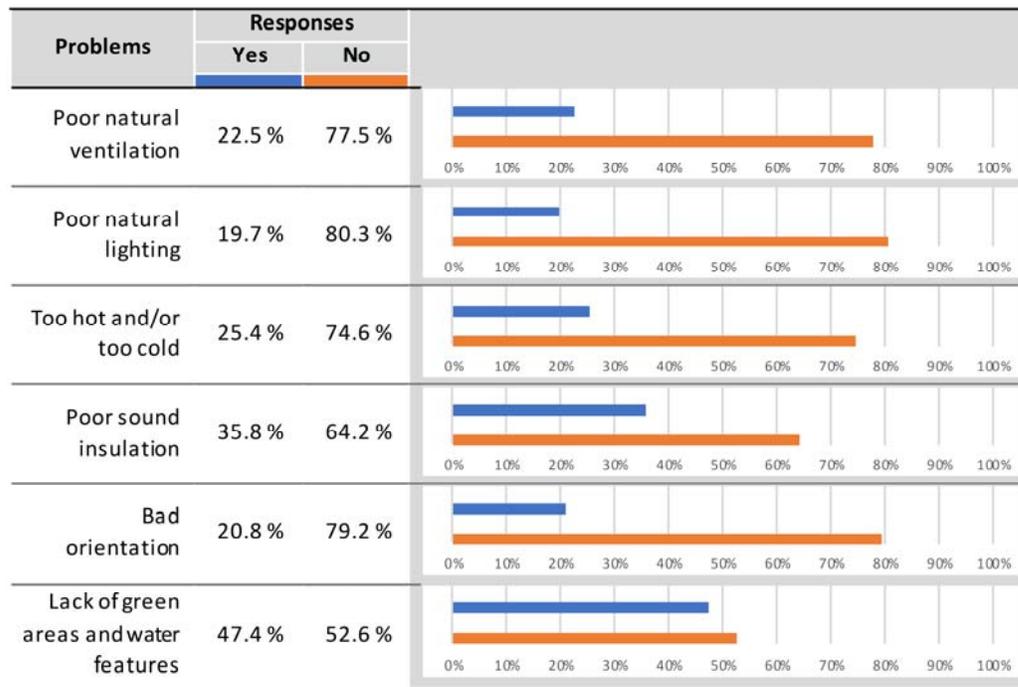


Figure 4.35: Frequencies showing description of the ‘temperature’ inside the house during summer (without any use of mechanical equipment)

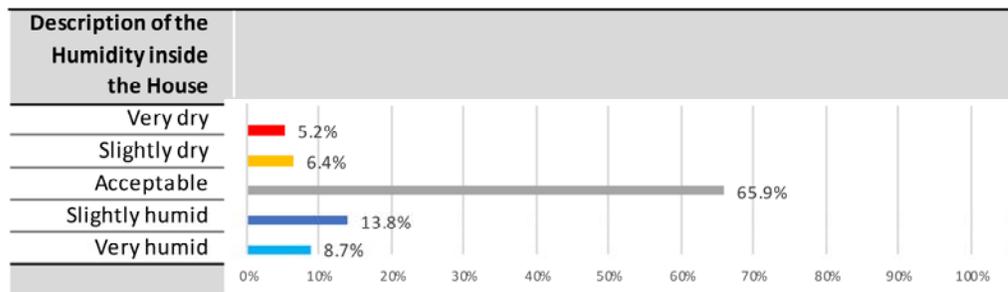


Figure 4.36: Frequencies showing description of the ‘humidity’ inside the house during summer (without any use of mechanical equipment)

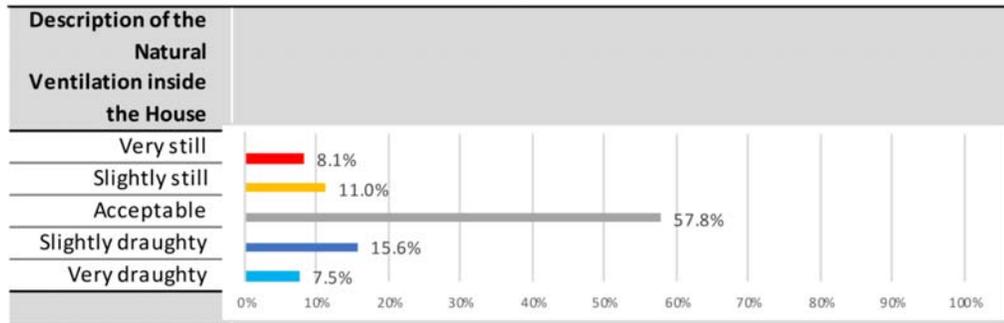


Figure 4.37: Frequencies showing description of the 'air movement and natural ventilation' inside the house during summer (without any use of mechanical equipment)

- **Part 5: Information about neighbours and the housing context**

The survey showed that 69% of residents chat between 3 and 7 times weekly with their neighbours in common gathering spaces. In contrast, only 31% of residents chat between 3 and 7 times with their neighbours, as they do not have any space for talking.

Furthermore, the results indicated that 67% of residents have the problem of social interaction with neighbours. To adapt with this social problem, 86% of residents chat with other neighbours at the entrance of the building, and approximately 45% of residents meet and talk with their neighbours at the entrance of their apartment. On the other hand, only 12% and 13% of residents chat with others at the outside garden and the courtyard inside their building, respectively (Figure 4.38 to 4.45, and Tables 4.11 to 4.14).

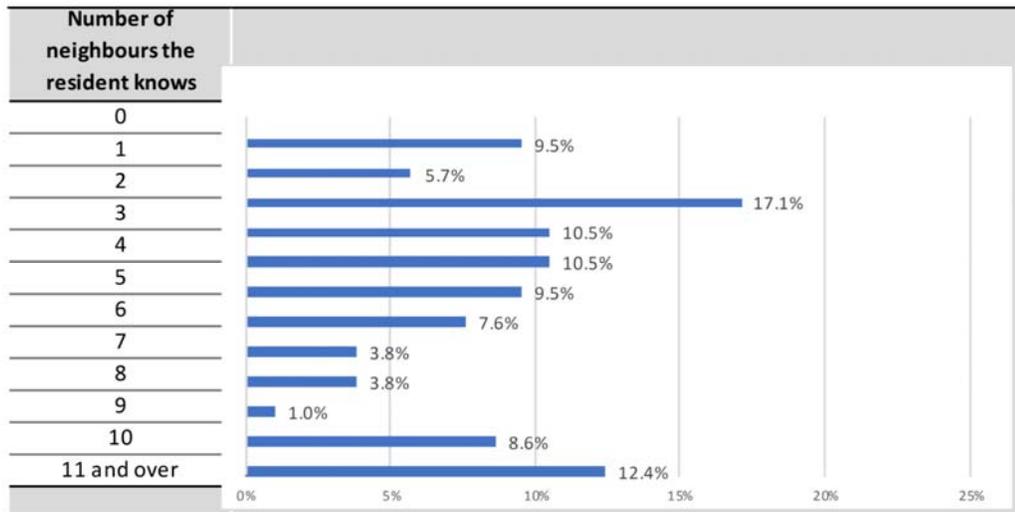


Figure 4.38: Frequencies showing number of neighbours the resident knows

Table 4.11: Percentages showing problems facing the resident

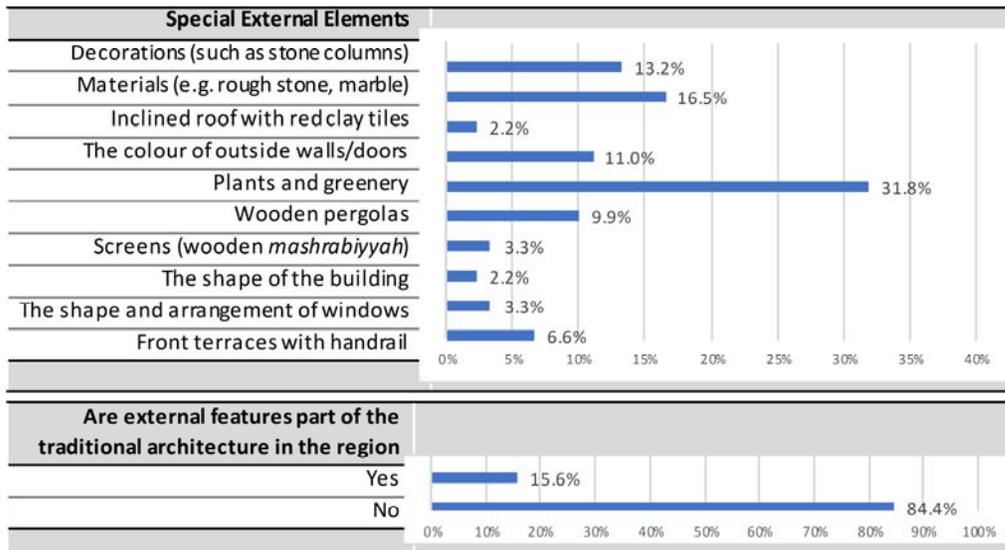
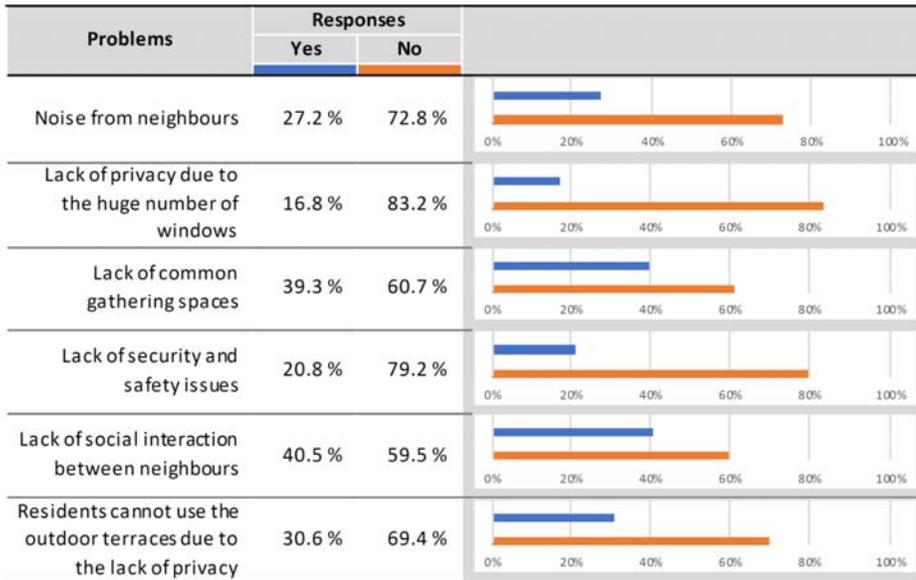


Figure 4.39: Frequencies showing types of external elements that give the house a special character

Table 4.12: Percentages showing treatments that protect the privacy of the family from neighbours

| Treatments  | Applicable | Not Applicable |  |
|---|------------|----------------|--|
| Curtains  | 63.0 %     | 37.0 %         |  |
| No opening overlooking neighbours                       | 24.3 %     | 75.7 %         |  |
| The use of screens (mashrabiyyah), shutters and louvers | 19.7 %     | 80.3 %         |  |
| High walls between neighbours                           | 12.1 %     | 87.9 %         |  |
| High roof parapet                                       | 11.0 %     | 89.0 %         |  |
| Greenery and Trees                                      | 3.6 %      | 96.4 %         |  |
| Setbacks between buildings                              | 0.9 %      | 99.1 %         |  |
| Specialised type of glass                               | 0.9 %      | 99.1 %         |  |
| Shelters and cantilevers                                | 0.9 %      | 99.1 %         |  |

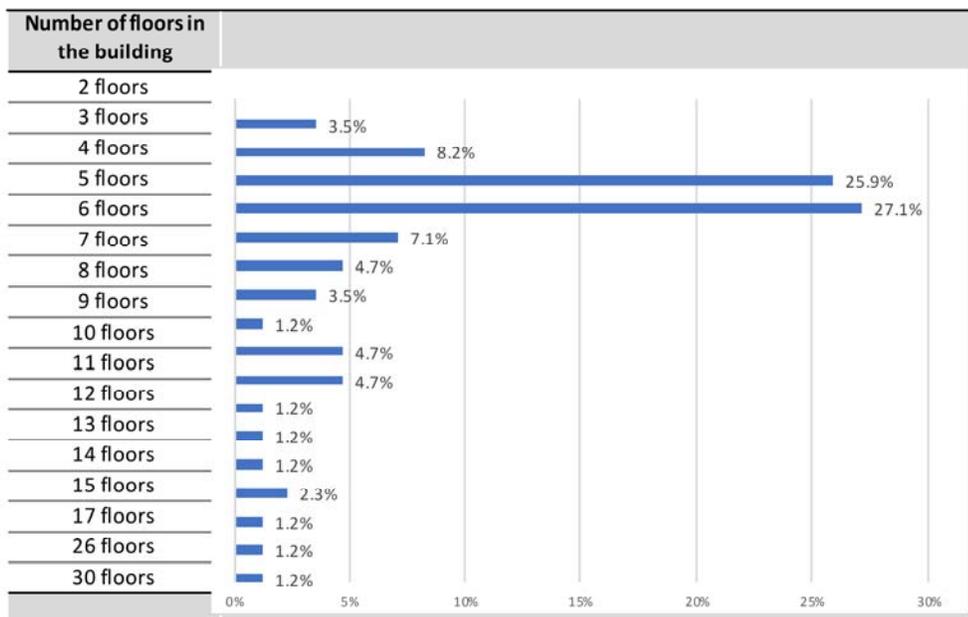


Figure 4.40: Frequencies showing the total number of floors in the apartment building

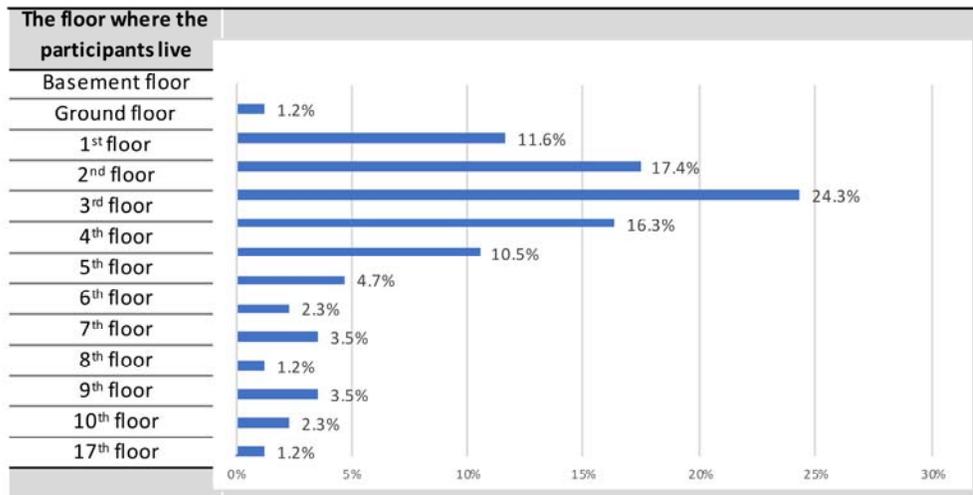


Figure 4.41: Frequencies showing the floor where the participants live

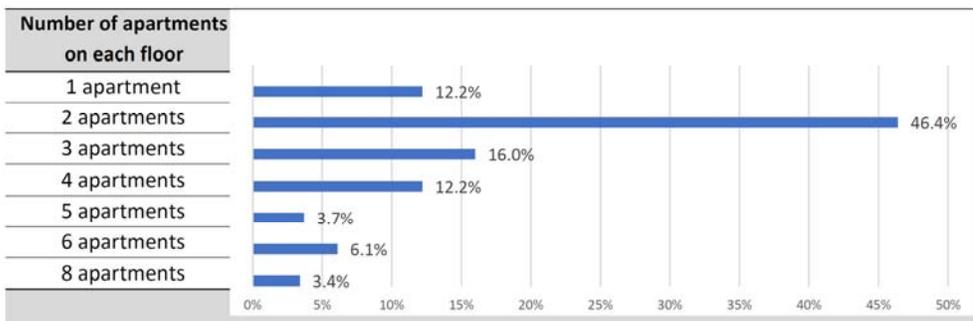


Figure 4.42: Frequencies showing number of apartments on the floor where the participants live

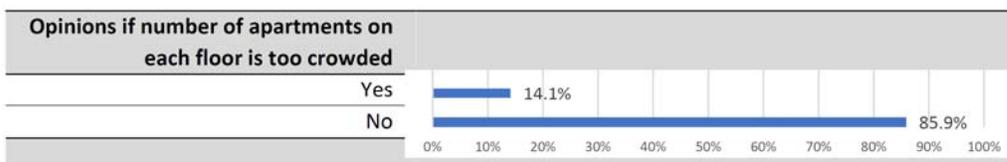


Figure 4.43: Frequencies showing opinions if number of apartments on each floor is too crowded

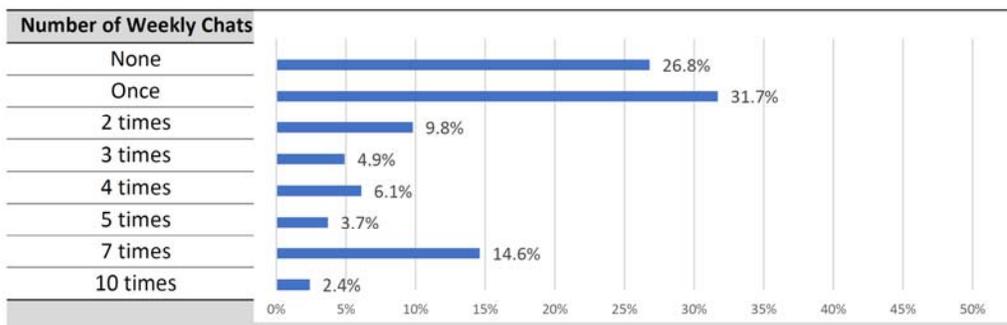


Figure 4.44: Frequencies showing number of weekly chats with neighbours in the building

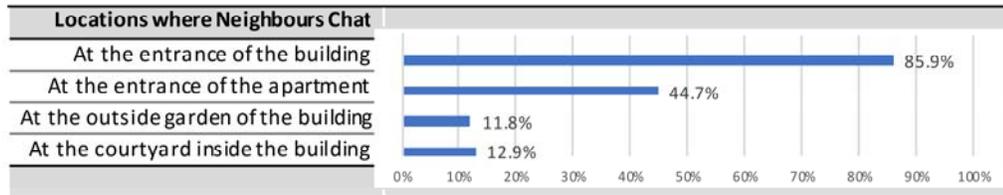


Figure 4.45: Frequencies showing locations where neighbours chat with each other

Table 4.13: Aspects people like the most in their building

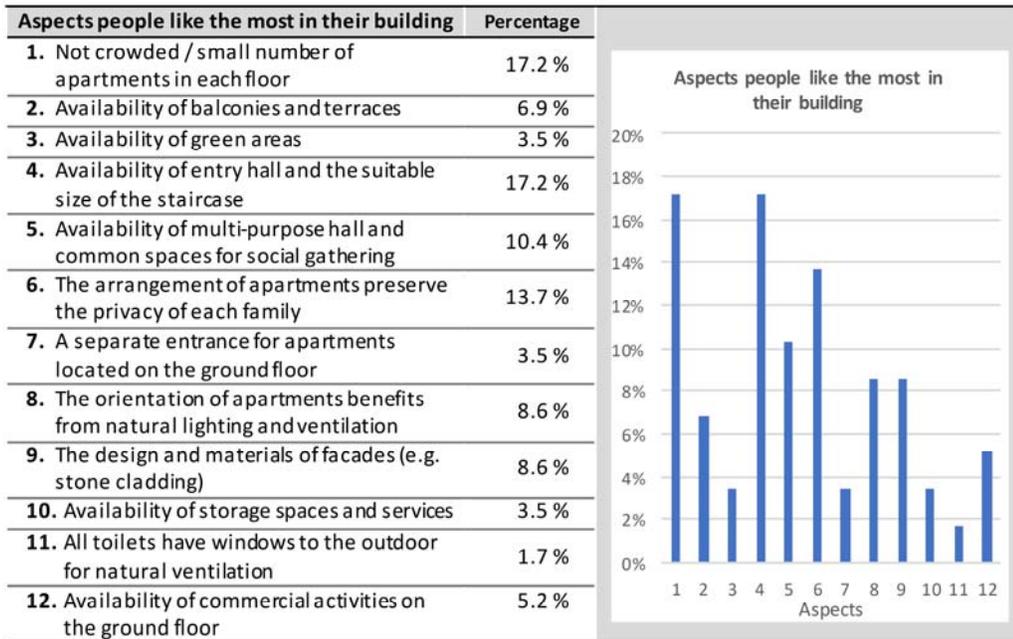
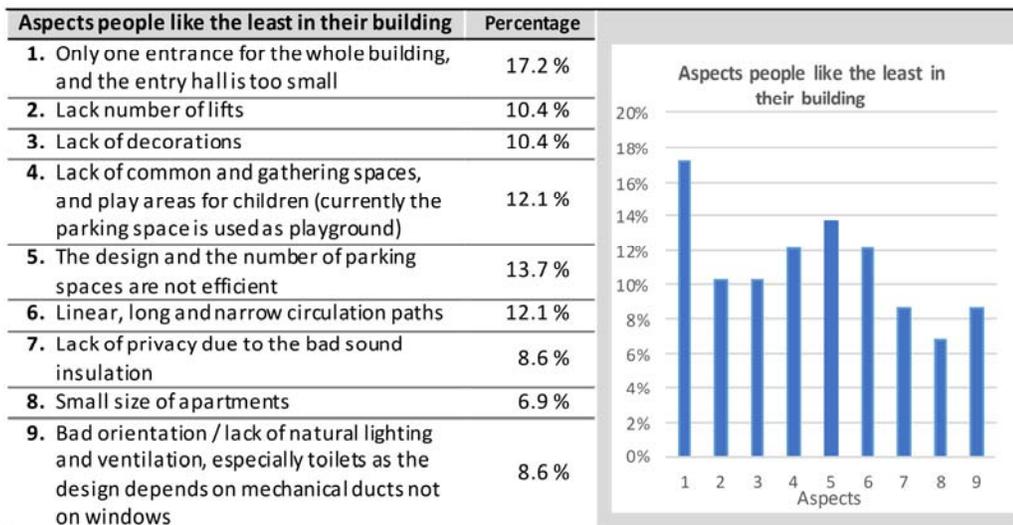


Table 4.14: Aspects people like the least in their building



#### 4.4. Data Analysis

The analysis of data, collected from the questionnaire, offers the researcher an understanding for the different factors that affect the living residential environment. Statistical analysis helps in quantifying any differences or similarities in data, and allows comparisons across variables. Different computer software make this process much more manageable. 'Statistical Package for the Social Sciences (SPSS)' is a robust worldwide computer package that helps the researcher to interpret what the data means.

Responses from the questionnaire are considered as variables that could be measured and manipulated. Using SPSS, two types of variables need to be defined. The first set is independent variables, which are manipulated; and the second set is dependent variables that are measured. Variables have different forms and scales of measurement: nominal, ordinal, or scale data. Nominal data are values that represent names of things or categories, such as gender, or country. There is no order to the categories, and each one is as equally important as the next, and cannot be divided into another. Ordinal data are values that have a natural order to the categories, such as attitudinal/Likert type questions, or the level of satisfaction of residents. In ordinal data, one category is greater or lesser than another. The third type of variables is scale. The scale could be classified into two types: (a) numerical interval, which is a scale without a fixed zero point (such as Fahrenheit); and (b) ratio, which is a scale that has a fixed zero point, and could be classified into: continuous, and discrete. A continuous ratio can take any value within a defined range, such as height, age, or cost. Discrete values represent a whole number, such as number of children, or number of rooms.

Different statistical tests and procedures were applied concerning the type of analysed data. These include (a) descriptive univariate analysis, and (b) descriptive bivariate analysis including. In the first type, values of each variable could be summarised using frequency tables, which include responses on each category, mean, median, and mode. In the second set, cross-tabulations, correlations, and relationships between different variables could be examined. This process is called 'hypothesis testing', which is started by writing a question or hypothesis that needs to be answered. For instance, if we want to study the relationship between times of chatting with neighbours, and years of living at the house, then the null hypothesis is that there is a relationship between these two issues, while the alternative hypothesis is that there is no relationship between them. These relationships called correlations, which represent a statistical technique that is used to determine the strength and direction of a relationship between two variables. In SPSS, these correlations are

represented through cross-tabulation tables, which are a combination of two (or more) frequency tables, to examine frequencies of observations that belong to specific categories on more than one variable, and to identify relations between cross-tabulated variables.

However, the most important value that can be extracted from cross-tabulation tables is the 'significant value'. The lower significant value (less than 0.05) means that a result is unlikely to have occurred by chance, and therefore, there is a relationship between the two variables. In contrast, high values (0.05 and more) mean that the null hypothesis is rejected, and the alternative is accepted, as there is no relationship between the two variables.

#### **4.4.1. Social/Spatial Qualities**

##### **a. Correlations related to the Context (Region)**

Type of a house - whether it is detached house/villa, attached house, or an apartment in a building - is associated with the location within the study area. Most apartment buildings are located in the Gulf Area (24.8%), Egypt (29.5%) and Jordan (29.5%), due to the increasing number of urban areas. However, the area of the house is not associated with its location. Different sizes of houses, ranged between 100 and 250 m<sup>2</sup>, are distributed randomly in the study area according to the needs of each family.

The context and building regulations are significant factors for determining the height of the building. However, the survey did not ask about building regulations in each country, or heights of the surrounding buildings. Therefore, results extracted from the questionnaire did not give the researcher a clear image about the relationship between number of floors, and the allowable height of the building. Observations indicated that the average height of a building, located in the Middle East (Jordan, Palestine and Syria), is 4-6 floors. In North Africa (e.g. Egypt), and Turkey, where the population increases accordingly, the average height of buildings is ranged between 5 and 17 floors. The same issue exists in the Gulf Area (e.g. KSA, UAE, Qatar, and Kuwait), where the height is ranged between 7 and 30 floors.

Regarding outdoor spaces, there is a healthy relationship between the availability of a garden surrounding the house and the region where the house is located. For instance, setbacks from all sides of a building are required in detached houses in Jordan. Moreover, roof terraces are used dominantly in the Gulf area, Jordan and Egypt, especially for social events. Another type of outdoor spaces that are used extensively in Jordan and Egypt is

the balcony. However, the significant value of this relationship, based on Chi-Square statistical test, indicates that there is no association between the availability of a courtyard and the region (Figure 4.46, and Table 4.15).

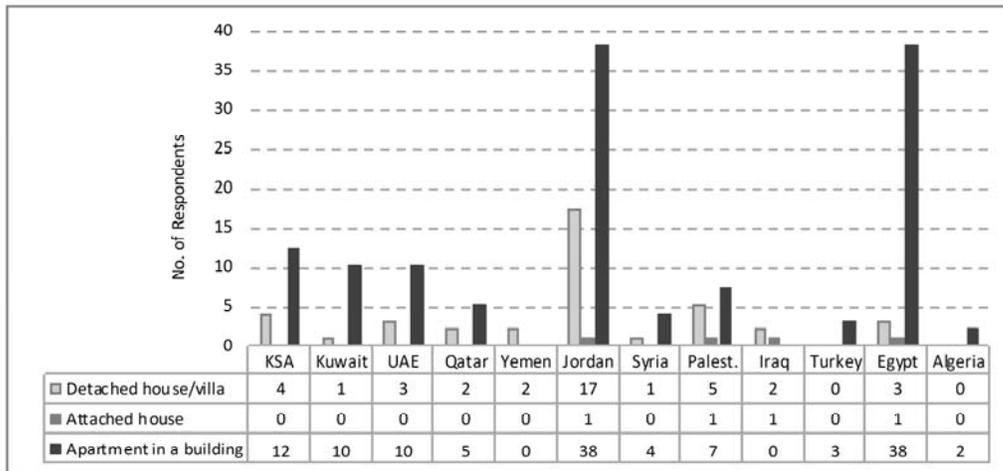


Figure 4.46: Frequencies showing types of houses according to the region

Table 4.15: Factors related to the context (region)

| Variables |                               | Significant Value<br>(according to<br>SPSS Chi-Square<br>Tests) | Association<br>between the<br>Two Variables |    |
|-----------|-------------------------------|---|---|----|
|           |                               |   | Yes   | No |
| Region    | Type of house                 | 0.012 (< 0.05)  | X   |    |
|           | Total Area of the house       | 0.125 ( $\geq$ 0.05)  |   | X  |
|           | Availability of a courtyard   | 0.351 ( $\geq$ 0.05)  |   | X  |
|           | Availability of a garden      | 0.000 (< 0.05)  | X   |    |
|           | Availability of roof terraces | 0.000 (< 0.05)  | X   |    |
|           | Availability of balconies     | 0.003 (< 0.05)  | X   |    |

#### b. Factors related to the Availability of a Courtyard

The significant value (based on Chi-Square statistical test) indicated that there is no association between the availability of a courtyard, the region, and the area of the house. The survey showed that houses with a courtyard were distributed all over the study area (one case in each country), except Jordan, as there are 11 cases from a total of 25 courtyard houses. This limited number of such cases is due to the harsh environment in the Gulf area and North Africa.

On the other hand, the availability of a courtyard depends on the type of the house. The survey showed that 68% of residential buildings that have a courtyard are detached houses (villas). This is due to an economic reason, as developers are not interested in providing common gathering spaces that facilitate social relations between residents, or inserting it as an environmental modifier. In contrast, they depend on using mechanical equipment for cooling, and want to save every square meter of the building.

However, 51% of residents were interested to have a courtyard inside their apartments in the future. The results also showed that 60% of residents who are currently live in a courtyard house want to keep this feature if they move to another house in the future (Table 4.16).

Table 4.16: Factors related to the availability of a courtyard

| Variables                      |  | Significant Value<br>(according to<br>SPSS Chi-Square<br>Tests) | Association<br>between the<br>Two Variables |    |
|--------------------------------|--|---|---|----|
|                                |  |   | Yes   | No |
| Availability of<br>a courtyard | Region   | 0.351 ( $\geq 0.05$ )   |   | X  |
|                                | Type of house  | 0.000 ( $< 0.05$ )  | X   |    |
|                                | Area of the house  | 0.117 ( $\geq 0.05$ )   |   | X  |
|                                | People prefer to have a courtyard<br>inside their future apartment/house | 0.004 ( $< 0.05$ )  | X   |    |

### c. Factors related to the Area of the House

There is a strong relationship between the area of the house, and both number of people living in that house or the household structure. This reflects the actual need of spaces that should serve the number of users live in that house. For instance, couple that have children occupy 70% of houses with an area ranged between 181 m<sup>2</sup> and 250 m<sup>2</sup>. Moreover, the survey concluded that there is a need to offer three different types of areas (100-140 m<sup>2</sup>, 141-181 m<sup>2</sup>, and 181-250 m<sup>2</sup>), as 24%, 21%, and 26% of residents, respectively, live in houses that have such areas, and 56% of total responses were satisfied with the size of their house.

However, the area of the house does not express the number of children live in the house. Families in different countries, especially in the Gulf area, want to show their prestigious status in front of others, through building large houses, regardless if they have children or not.

The area of the house is associated with the availability of an entry hall, a multi-purpose hall, a storage space, a guest room for male visitors only, and a guest room for female visitors only. As the area of houses is small, people desire to have more rooms for essential purposes (such as TV/living room and bedrooms) instead of allocating spaces for storage, or particular areas for activities. Moreover, the separation between male and female guests is associated with the area of the house, although it is an essential issue for preserving privacy. Therefore, people prefer to have one guest room, as the area of the house is relatively small, and cannot accommodate more than one guest room. To deal with this issue, they use the living room for female guests and the reception room for male visitors.

Another observation is that the area of the house is associated with the availability of a separated dining room. If it does not exist, due to the small area of the house, the eating activity usually happens in the kitchen, the living room, the balcony or the terrace. In contrast, there is no association between the area of the house and the availability of a breakfast zone inside the house. Moreover, there is no relationship between the area of outdoor spaces and the area of the house (Table 4.17).

Table 4.17: Factors related to the area of the house

| Variables                | Significant Value<br>(according to<br>SPSS Chi-Square<br>Tests)      | Association<br>between the<br>Two Variables |    |
|--------------------------|--|---|----|
|                          |  | Yes   | No |
| The area of<br>the house | Number of people living in the house                                 | 0.000 (< 0.05 )                             | X  |
|                          | Number of dependent children (under<br>18 years) living in the house | 0.110 (≥ 0.05 )                             | X  |
|                          | Household structure  | 0.001 (< 0.05 )                             | X  |
|                          | Availability of an entry hall  | 0.007 (< 0.05 )                             | X  |
|                          | Availability of a multi-purpose hall                                 | 0.000 (< 0.05 )                             | X  |
|                          | Availability of storage spaces                                       | 0.033 (< 0.05 )                             | X  |
|                          | Availability of a guest room (only for<br>male visitors)             | 0.008 (< 0.05 )                             | X  |
|                          | Availability of a guest room (only for<br>female visitors)           | 0.018 (< 0.05 )                             | X  |
|                          | Availability of a guest room (for both<br>male and females visitors) | 0.059 (≥ 0.05 )                             | X  |
|                          | Availability of a dining room  | 0.000 (< 0.05 )                             | X  |
|                          | Availability of a breakfast area                                     | 0.305 (≥ 0.05 )                             | X  |
|                          | Area of outdoor spaces   | 0.133 (≥ 0.05 )                             | X  |

#### d. Factors related to Level of Satisfaction with the Area of the House

People live in small or large houses according to their needs. The survey showed that more than 56% of residents were satisfied with the area of the house. However, there is no association between level of satisfaction with the area of the house, and the household structure. Statistics indicated that there are variations between the household structure and opinions regarding the size of the house. For instance, 77% of couple who have children, 69% of extended families, and 93% of singles and workers were satisfied with the area of their residential units.

The area of outdoor spaces is not associated with the area of the house. The survey showed that 23% of houses, which include balconies, terraces and courtyards, have only less than 25 m<sup>2</sup> of outdoor areas. The total area of those houses ranged between 100 m<sup>2</sup> and 250 m<sup>2</sup>. However, the area of such recreational areas represents 10-20% of the total area of the house (Table 4.18).

Table 4.18: Factors related to level of satisfaction with the area of the house

| Variables   |                         | Significant Value<br>(according to<br>SPSS Chi-Square<br>Tests) | Association<br>between the<br>Two Variables |    |
|---|-------------------------|---|---|----|
|   |                         |   | Yes   | No |
| Level of satisfaction with<br>the area of the house | Area of the house       | 0.009 ( < 0.05 )  | X   |    |
|   | The household structure | 0.056 ( ≥ 0.05 )  |   | X  |
| Area of the house                                   | Area of outdoor spaces  | 0.133 ( ≥ 0.05 )  |   | X  |

#### e. Population Density inside the House

Population density depends on two factors: number of rooms per apartment, and the area of the house (Table 4.19). Results of the survey showed that houses are crowded in comparison to international standards, as the average population density equals 4.65 persons per house (Table 4.20). Old houses have the highest population density as they accommodate extended families.

Table 4.19: Population density inside the house based on the area of the apartment

| Area of the apartment        | Population density (persons per house) in the Study Area |
|------------------------------|--|
| Less than 100 m <sup>2</sup> | 2.96   |
| 101 – 140 m <sup>2</sup>     | 3.74   |
| 141 – 180 m <sup>2</sup>     | 4.65   |
| 181 – 250 m <sup>2</sup>     | 4.91   |
| 250 m <sup>2</sup> and more  | 6.57   |

Table 4.20: A comparison between the population density in the study area, and in Europe

| Number of rooms per apartment in the study area (*) | Population density (persons per house) in the Study Area | Standard population density (persons per house) in Europe <sup>7</sup> | Percentages represent if the density in the study area is above (or below) the international standards |
|---|--|--|--|
| 1-room apartment                                    | 3.93   |  | +314 %   |
| 2-rooms apartment                                   | 5.00   | 1.25   | +400 %   |
| 3-rooms apartment                                   | 2.50   | 2.00   | +125 %   |
| 4-rooms apartment                                   | 3.09   | 2.75   | +112 %   |
| 5-rooms apartment                                   | 3.90   | 3.50   | +111 %   |
| 6-rooms apartment                                   | 4.17   |  |  |
| 7-rooms apartment                                   | 4.81   |  |  |
| 8-rooms apartment                                   | 5.29   |  |  |
| 9-rooms apartment                                   | 5.10   |  |  |
| 10-rooms apartment                                  | 5.17   |  |  |
| 11-rooms apartment                                  | 5.33   |  |  |
| 12-rooms apartment                                  | 7.75   |  |  |

(\*) This number excludes the following spaces: toilets, bathrooms, storage areas and outdoor spaces.

#### f. Factors related to Level of Satisfaction with the Spatial Design of the House

Any changes implemented on the layout of the house affected level of satisfaction with the spatial layout directly. After these changes have been executed, level of satisfaction increased accordingly. On the other hand, people who did not change the interior layout were satisfied with their houses. Therefore, both issues are associated.

The survey showed that 36% of changes on interior layouts had been implemented dominantly on contemporary apartments that have been constructed in the last ten years. In contrast, only 11% of changes have been implemented on old buildings aged to 40 years and more. These percentages indicate that people were more satisfied with old buildings than the contemporary one. Residents highlighted three main types of those changes:

- To increase the privacy of livings spaces.
- To increase the area of the house.
- To change the orientation of some spaces for environmental requirements.

However, results indicated that the tenure type of the house, whether houses were owned or rented, affects flexibility of changes on the interior layout of the house. The survey showed that 70% of people who changed their interiors were the owner of these houses, so it was much easier for them to adapt spaces with their needs, and therefore, increased their association with the place. Furthermore, crowded living spaces influence

<sup>7</sup> [www.deerns.co.uk/ElevatorPlanning](http://www.deerns.co.uk/ElevatorPlanning) (accessed on 29/9/2016)

level of satisfaction with the spatial layout of the house. Results showed that 42% of respondents have this problem in their houses, and they were not satisfied.

Moreover, 59% of residents have no physical barriers (such as walls and partitions) that affect the movement inside their houses. However, these features play a significant factor on level of satisfaction with the spatial design of the house. For instance, 70% of respondents who have no spatial obstacles between the different rooms were satisfied with the arrangement of spaces. In contrast, any changes in levels inside the house have no significant effect on the satisfaction of residents with their interior layouts. More than 67% of residents who have split levels between spaces were satisfied with their houses, while only 8% were not satisfied, and 25% were neutral in their opinions.

Another observation from the survey is that there is no association between level of satisfaction with the spatial design of the house, and area of guest/living zones. Results indicated that there is a balance between opinions of residents regarding area of guest rooms in comparison to the living zone. The main reason behind this issue is that residents in the study area prefer to have large reception halls that reflect a prestigious image about their social/economic status in front of their guests, despite their needs to have a big size living zone for the family.

A significant feature that affected the satisfaction of residents with the spatial design of their houses, is the hierarchal arrangement of spaces (from public, to semi-public/private, to private (such as living zones), to intimate spaces (such as bedrooms)). The survey showed that 45% of respondents have this hierarchy between intimate zones (bedrooms), and living spaces, and accordingly, most of them were satisfied (73%).

Results of the survey indicated that availability of private outdoor spaces (such as terraces, and gardens) was an important reason for the satisfaction of families with their houses. Statistics showed that 70% of residents, who have these spaces, were satisfied, as they feel more secure and safe when they see their children play inside the house. In contrast, only 53% of people who do not have such spaces were satisfied with the layout (Table 4.21).

Table 4.21: Factors related to level of satisfaction with the spatial design of the house

| Variables   |   | Significant Value<br>(according to<br>SPSS Chi-Square<br>Tests) | Association<br>between the<br>Two Variables |    |
|---|---|---|---|----|
|   |   |   | Yes   | No |
| Level of<br>satisfaction<br>with the<br>spatial<br>design of the<br>house | Changes on the interior layout  | 0.021 ( < 0.05 )  | X   |    |
|   | Family living spaces are crowded  | 0.000 ( < 0.05 )  | X   |    |
|   | Changes in levels inside the house  | 0.800 ( ≥ 0.05 )  |   | X  |
|   | Spatial barriers (such as walls and partitions) that affect the movement inside the house | 0.000 ( < 0.05 )  | X   |    |
|   | The area of guest rooms in comparison to the area of living zone                          | 0.085 ( ≥ 0.05 )  |   | X  |
|   | Bedrooms are isolated from living room  | 0.000 ( < 0.05 )  | X   |    |
|   | Availability of private outdoor spaces for children inside the house                      | 0.000 ( < 0.05 )  | X   |    |
| Changes on the interior layout  | Age of construction   | 0.028 ( < 0.05 )  | X   |    |

#### g. Factors related to Number of Dependent Children live in the House

There is a strong relationship between number of children live in the house and number of bedrooms for kids, as this expresses the spatial needs of each family (Table 4.22).

Table 4.22: Factors related to number of dependent children (under 18 years) live in the house

| Variables   |                             | Significant Value<br>(according to<br>SPSS Chi-Square<br>Tests) | Association<br>between the<br>Two Variables |    |
|---|-----------------------------|---|---|----|
|   |                             |   | Yes   | No |
| Number of dependent children (under 18 years) live in the house | Number of bedrooms for kids | 0.031 ( < 0.05 )  | X   |    |

#### h. Factors related to Number of Floors/Levels in the House

Two-third of houses consist of one floor. Statistics showed that couple with children were mainly occupied 50% of two-floor and three-floor houses. Other types of household structures (single, single with children, couple, and workers) live randomly in houses that consist of two to three floors. Therefore, there is no association between the household structure and number of floors (Table 4.23).

Moreover, there is no relationship between number of dependent children live in the house and number of floors. Sometimes, this issue is related to a cultural value, such as expressing the prestigious status in front of others, through living in a two-floor house. In contrast, number of floors depends on the area of the house, as most plots are small, and therefore, people extended their houses vertically.

Table 4.23: Factors related to number of floors/levels in the house

| Variables                                  |   | Significant Value<br>(according to<br>SPSS Chi-Square<br>Tests) | Association<br>between the<br>Two Variables |    |
|--|---|---|---|----|
|  |   |   | Yes   | No |
| Number of<br>floors/levels of<br>the house | The household structure   | 0.782 ( $\geq 0.05$ )   |   | X  |
|  | Number of dependent children<br>(under 18 years) living in the<br>house | 0.761 ( $\geq 0.05$ )   |   | X  |
|  | Area of the house   | 0.000 ( $< 0.05$ )  | X   |    |

#### i. Factors related to Number of Apartments on Each Floor

More than 90% of residents preferred that the maximum number of apartments on each floor is one to four residential units. When this number exceeds four apartments, residents feel uncomfortable due to the noise and crowding. Moreover, the small size of plot areas compels designers to divide each floor into two to three apartments based on the preferred areas for each unit (Table 4.24).

Table 4.24: Factors related to number of apartments on each floor

| Variables                                |   | Significant Value<br>(according to SPSS<br>Chi-Square Tests) | Association<br>between the<br>Two Variables |    |
|--|---|--|---|----|
|  |   |  | Yes   | No |
| Number of<br>apartments on<br>each floor | Opinion of residents if there are<br>too many apartments on each<br>floor | 0.000 ( $< 0.05$ )   | X   |    |

#### j. Factors related to Safety and Security in Outdoor Spaces

There is a strong association between lack of security in the house, and the quality of outdoor spaces, either for children or families. More than 30% of the sample, who have private outdoor spaces for children, suffer from lack of security. Moreover, the survey showed that more than 67% and 88.9% of the sample need secure outdoor terraces in their houses, and secure common gathering spaces with greenery in their buildings, respectively. These areas include courtyards inside the houses (51% of the sample desired

to have this element inside their apartments), and common spaces inside buildings to be shared with all residents (48.6% preferred to live in a building that has this feature) (Table 4.25).

Table 4.25: Factors related to issues of safety and security in outdoor spaces

| Variables                                |  | Significant Value<br>(according to<br>SPSS Chi-Square<br>Tests) | Association<br>between the<br>Two Variables |    |
|--|--|---|---|----|
|  |  |   | Yes   | No |
| Lack of security and<br>safety           | Lack of private outdoor spaces<br>for children   | 0.018 ( < 0.05 )  | X   |    |
|  | People prefer to have a secure<br>outdoor gathering spaces in<br>their houses and the building | 0.011 ( < 0.05 )  | X   |    |
| Lack of common<br>spaces in the building | People prefer to have a<br>courtyard in their buildings  | 0.000 ( < 0.05 )  | X   |    |
|  | People prefer to have common<br>spaces in their buildings                                      | 0.000 ( < 0.05 )  | X   |    |
| Lack of green areas in<br>the building   | People prefer to have common<br>spaces in their buildings                                      | 0.000 ( < 0.05 )  | X   |    |

#### k. Factors related to Social Interaction between Neighbours in Apartment Buildings

The survey showed that there is no relationship between number of years living in the apartment, and number of times chatting with others, or number of neighbours they know. The results indicated that 67% of residents have the problem of social interaction with neighbours, even though they live more than ten years in their houses. This issue is due to the lack of common spaces inside and outside the building. To adapt with this social problem, 86% of residents chat with other neighbours at the entrance of the building, and approximately 45% of residents meet and talk with their neighbours at the entrance of their apartment. On the other hand, only 12% and 13% of residents chat with others at the outside garden, and at the courtyard inside their building, respectively.

One of the main observations from the survey is that number of residents who chat at the entrance of the apartment decreases when number of apartments increases on each floor. This could be due to the narrow paths and the limited number of waiting areas, as developers want to increase number of apartments on each floor. However, results of the survey showed that half of the respondents, who live in apartment buildings, chat only once or twice weekly with their neighbours. Furthermore, number of times they chat with others decreases on upper floors (Table 4.26).

Table 4.26: Factors related to social interaction between neighbours in apartment buildings

| Variables   |   | Significant Value<br>(according to SPSS<br>Chi-Square Tests) | Association<br>between the Two<br>Variables |    |
|---|---|--|---|----|
|   |   |  | Yes   | No |
| Number of weekly times chatting with neighbours           | Lack of common spaces in the building           | 0.000 ( < 0.05 )   | X   |    |
|   | Number of years living in the house             | 0.389 ( ≥ 0.05 )   |   | X  |
| Number of neighbours the residents know                   | Number of years living in the house             | 0.707 ( ≥ 0.05 )   |   | X  |
| Chatting with neighbours at the entrance of the building  | Number of apartments on each floor              | 0.000 ( < 0.05 )   | X   |    |
|   | Number of weekly times chatting with neighbours | 0.000 ( < 0.05 )   | X   |    |
|   | On which floor are residents live               | 0.000 ( < 0.05 )   | X   |    |
| Chatting with neighbours at the entrance of the apartment | Number of apartments on each floor              | 0.000 ( < 0.05 )   | X   |    |
|   | Number of weekly times chatting with neighbours | 0.000 ( < 0.05 )   | X   |    |
|   | On which floor are residents live               | 0.000 ( < 0.05 )   | X   |    |

### I. Factors related to the seeing of outside Views from the House

There is a relationship between the problem of seeing the outside views from inside of the house and the privacy of the family, which affects level of satisfaction of residents with the spatial arrangement of rooms (56% of residents were satisfied). Results showed that 59% of residents, who could see the outside easily, have the problem of lacking privacy. This issue is due to the large glazed facades, which offer people enjoying the outside. However, such features force the residents to use different elements such as curtains in front of glazed windows (63% of responses), or screens, louvres and shutters (20%). In contrast, 76% of people, who suffer from seeing the outside context, especially in old houses, have no problems with the privacy of their family members. This could be related to the small size of windows, which affect adversely the amount of natural light entering the house. Results showed that 56% of residents have poor natural lighting and cannot see the outside context from their houses (Table 4.27).

Another issue, which is related to the lack of seeing the outside, is the small number of balconies, terraces and gardens in buildings. The survey indicated that only 45% of residents have balconies, 24% have gardens, 15% have courtyards inside their houses, and 8% have roof terraces. Therefore, and to generate a balance between seeing the outside,

benefit from the natural light, and preserve the privacy, designers need to think with features that achieve this balance, such as screens, louvres, *mashrabiyyahs*, greenery, private gardens, balconies, and roof terraces. For instance, 51% of respondents desire to have access to the outside environment in their future apartments by inserting courtyards. Moreover, 67% of them prefer to have balconies and terraces, and 44% wish to have a sheltered living room (*iwan*) inside their houses.

Table 4.27: Factors related to the seeing of outside views from the house

| Variables                                     | Significant Value<br>(according to SPSS<br>Chi-Square Tests)   | Association<br>between the Two<br>Variables |    |
|---|--|---|----|
|   |  | Yes   | No |
| Privacy                                       | 0.014 ( < 0.05 )   | X   |    |
| Seeing the<br>outside views<br>from the house | Poor lighting (due to the small<br>size of windows)            | 0.000 ( < 0.05 )                            | X  |
|   | Level of satisfaction with the<br>interior layout of the house | 0.000 ( < 0.05 )                            | X  |

#### m. Factors related to the Privacy of the Family

Living spaces, master bedrooms, and bedrooms for kids are located in most houses on the ground floor with no vertical separation between spaces. On the other hand, only 6.4% of houses have a living room located on the first floor, 13.3% have a master bedroom on the first floor, and 7.5% have bedrooms for kids located on the first floor.

However, 40.5% of the sample were interested in separating the family living area away from bedrooms vertically, for achieving more visual and acoustical privacy. Moreover, results showed that half of the sample, who live currently in a single-floor house, prefer to separate the house into two levels. This means that designers need to offer two types of apartments: part of them are single-floor apartments, and the other is two-floor apartments.

Even though the roof terrace is not a typical feature in the study area (84% of residents do not have this feature in their buildings), it could offer families enjoying the outside environment, especially at night, with a high degree of privacy. This feature allows architects to preserve the privacy of the family members, through using high parapets. Results of the survey showed that 82% of houses that have a roof terrace, do not use it due to the lack of safety and privacy. Furthermore, the survey showed that 25% of residents have the problem of visual continuity between the living area and the guest

room. Therefore, the visual privacy of the family, and level of satisfaction with the spatial design of the house have been affected (significant value = 0.007, based on Chi-Square statistical test). For instance, 21% of respondents that have no visual separation between these two zones were not satisfied with their layouts. In contrast, 65% of residents that have visual barriers are strongly satisfied with their interior environment.

Moreover, 41% of the residents suffer from the lack of visual privacy between the entrance of the house and the living zone, which caused a negative impact on level of satisfaction with the spatial design of the house (Figure 4.28).

Table 4.28: Factors related to the privacy of the family

| Variables                                 |  |
|---|--|
| Issues affected the privacy of the family | Separate family living space, master bedrooms and bedrooms for kids on upper floors (2 <sup>nd</sup> and 3 <sup>rd</sup> floors) |
|   | The use of high parapet in roof terraces   |
|   | Visual separation between guest rooms and living zones   |
|   | Visual separation between the entrance hall and the living zone  |

#### 4.4.2. Environmental Qualities

##### a. Environmental Issues related to the Availability of a Courtyard

Number of houses that have a courtyard is small (only 25 house from the total number of the sample (= 14.4%)). The analysis showed that there is no association between this feature and the quality of the environment inside the house (too hot and/or too cold, natural ventilation, natural lighting, and the sound insulation). More than 43% of the sample have bad atmosphere inside their houses, due to the small thickness of walls, bad orientation, or on which floor is the apartment located. Furthermore, 22.5% of the sample, especially in old houses, have the problem of humidity inside their houses due to the small number/size of windows.

Despite this result, the survey showed that 76% of houses that have a courtyard have no problems with the temperature inside the house, or a problem in sound insulation. This is due to the fact that the soft landscape and the water feature in the courtyard reduce the heat gain and the noise from the surrounding environment. Moreover, 64% of these houses have no problems in the natural ventilation, or natural lighting inside their houses.

Table 4.29: Environmental issues related to the availability of a courtyard

| Variables                         | Significant Value<br>(according to SPSS<br>Chi-Square Tests)               | Association<br>between the<br>Two<br>Variables |    |
|-----------------------------------|--|--|----|
|                                   |  | Yes  | No |
| Availability<br>of a<br>courtyard | The house is too hot and/or too cold<br>(the temperature inside the house) | 1.000 ( $\geq 0.05$ )                          | X  |
|                                   | The problem of humidity inside the<br>house                                | 0.133 ( $\geq 0.05$ )                          | X  |
|                                   | Bad ventilation inside the house   | 0.117 ( $\geq 0.05$ )                          | X  |
|                                   | Poor natural lighting inside the house                                     | 0.052 ( $\geq 0.05$ )                          | X  |
|                                   | Poor sound insulation  | 0.259 ( $\geq 0.05$ )                          | X  |

### b. Environmental Issues related to the Age of Construction

The survey showed that 44% of houses that have a hot atmosphere inside the house had been constructed recently during the last ten years. This percentage decreased to the half (21%) for buildings that were aged 21-40 years ago, and reached only 2.3% for buildings that had been constructed before 41-50 years ago. The same phenomenon is with humidity inside the house. Results showed that 44% of houses that have a very humid atmosphere had been constructed during the last decade, while 28% were aged to four decades and more (Table 4.30).

Table 4.30: Environmental issues related to the age of construction

| Variables              | Significant Value<br>(according to SPSS<br>Chi-Square Tests) | Association<br>between the<br>Two Variables |    |
|------------------------|--|---|----|
|                        |  | Yes   | No |
| Age of<br>construction | Very hot/cold atmosphere<br>inside the house                 | 0.995 ( $\geq 0.05$ )                       | X  |
|                        | Humidity inside the house                                    | 0.216 ( $\geq 0.05$ )                       | X  |

### c. Environmental Issues related to Number of Floor where Respondents Live

There is a strong relationship between the vertical location of the apartment, and the atmosphere inside it. Results showed that people who live in apartments on upper floors, have bad environmental qualities (100% of the sample have very hot atmosphere, 70% have a very humid environment, while 55% enjoyed the natural fresh air and a very draughty wind movement). In contrast, people who live on lower floors (ground floor to the 4<sup>th</sup> floor) have more comfortable environment inside their houses. However, the

analysis indicated that 35% of residents have the problem of still air movement, 65% have a warm environment, 25% and 30% respectively, have very dry air, and very humid atmosphere (Figure 4.47, and Table 4.31).

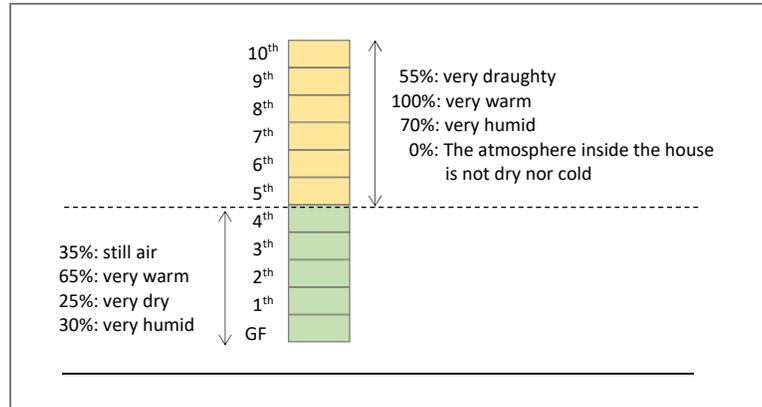


Figure 4.47: A diagram showing qualities of the indoor environment based on the floor where participants live

Table 4.31: Environmental issues related to the floor where respondents live

| Variables                              |  | Significant Value (according to SPSS Chi-Square Tests) | Association between the Two Variables |    |
|--|--|--|---------------------------------------|----|
|  |  |  | Yes                                   | No |
| Number of floor where respondents live | Temperature inside the house             | 0.000 (< 0.05)   | X                                     |    |
|  | Humidity inside the house                | 0.003 (< 0.05)   | X                                     |    |
|  | Bad natural ventilation inside the house | 0.000 (< 0.05)   | X                                     |    |

**d. Environmental Issues related to Level of Satisfaction with the Spatial Layout of the House**

An excellent location and an appropriate orientation for kitchen and other sanitary facilities could prevent smells entering other spaces in the house. These issues have direct impacts on level of satisfaction with the spatial layout of the house. For instance, 72% of residents were satisfied as they have those qualities in the design of service zone. More than 23% of that percentage have East-side windows for their kitchens. Moreover, 15% of respondents who have a South-side window were also strongly satisfied, and the same percentage is for those who have a West-side window. On the other hand, this level of

satisfaction decreased to 59% when residents have both a bad location and inappropriate orientation of windows (Figure 4.48, and Table 4.32).

Table 4.32: Environmental issues related to level of satisfaction with the spatial layout of the house

| Variables  |                            | Significant Value (according to SPSS Chi-Square Tests) | Association between the Two Variables |    |
|--|----------------------------|--|---------------------------------------|----|
|  |                            |  | Yes                                   | No |
| Level of satisfaction with the spatial layout of the house | Orientation of the kitchen | 0.000 ( < 0.05 )                                       | X                                     |    |

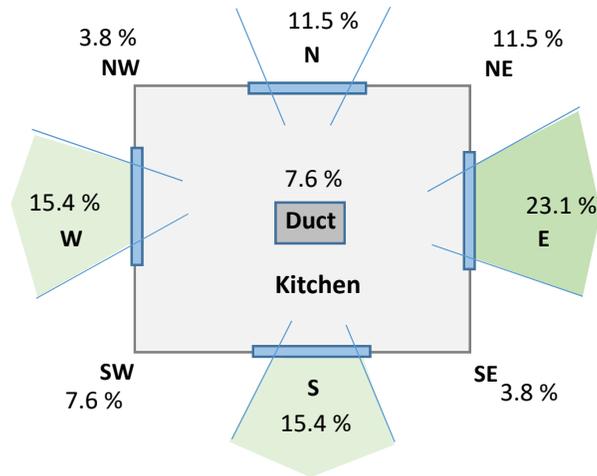


Figure 4.48: Percentages of residents who are satisfied with the location of windows in their kitchens

**e. Environmental Issues related to the Height of Ceiling, and Thickness of outside Walls**

Height of ceilings is a significant factor that affects the natural ventilation, and the temperature inside the house. Results of the analysis showed that more than 36% of the sample have two critical problems inside their houses due the low height of the ceiling (between 240 cm and 290 cm): firstly, the house was too hot/cold; and secondly, lack of natural ventilation in the different spaces of the house. In contrast, more than 65% of houses have no problems with these issues, due to the high ceilings (between 300 cm and 400 cm).

Results showed that houses that have lower ceilings, ranged between 240 cm and 285 cm, had been constructed in the last ten years, while half of that number (= 23.5%) had been constructed four decades ago. However, there is no association between age of construction and height of ceiling, as number of houses that have high ceilings (between 320 cm and 400 cm) increased recently (Table 4.33).

Table 4.33: Environmental issues related to the height of ceilings and thickness of outside walls

| Variables                     |   | Significant Value<br>(according to<br>SPSS Chi-Square<br>Tests) | Association<br>between the Two<br>Variables |    |
|-------------------------------|---|---|---|----|
|                               |   |   | Yes   | No |
| The height<br>of the ceiling  | Age of construction   | 0.573 ( $\geq 0.05$ )   |   | X  |
|                               | Bad ventilation inside the house  | 0.001 ( $< 0.05$ )  | X   |    |
|                               | The house is too hot and/or too cold (the temperature inside the house) | 0.009 ( $< 0.05$ )  | X   |    |
|                               | Bad sound insulation  | 0.000 ( $< 0.05$ )  | X   |    |
| Thickness of<br>outside walls | Age of construction   | 0.000 ( $< 0.05$ )  | X   |    |
|                               | Bad sound insulation  | 0.000 ( $< 0.05$ )  | X   |    |
|                               | Noise from neighbours   | 0.000 ( $< 0.05$ )  | X   |    |
|                               | Very hot/cold atmosphere inside the house                               | 0.000 ( $< 0.05$ )  | X   |    |
|                               | Humidity inside the house   | 0.0 ( $< 0.05$ )  | X   |    |

Two main issues related to the quality of sound insulation inside the house: height of ceiling, and thickness of exterior walls. The results indicated that only one-third of houses with a height of ceiling less than 290 cm (between 240 cm and 285 cm) have a problem with the sound insulation. This issue refers to the small size of wall thickness (between 10 cm and 30 cm), where 85% of houses have a thickness of outside walls less than the standards. Moreover, 76.7% of residents have a problem with hearing noise from their neighbours.

Regarding the age of the building, observations and results of the survey showed that more than 76% of contemporary houses have thin exterior walls (between 10 cm and 30 cm). In contrast, most of old buildings that had been constructed more than 25 years ago have 35 – 60 cm outside walls. On the other hand, 68% of houses, with a 300 cm and more (reach to 400 cm) in their height, have no problems in the quality of sounds. Therefore, when the survey asked people about the preferred height of ceiling in their future houses, 74% of the sample responded that they prefer it to be ranged between 290 cm and 350

cm. Furthermore, when thicknesses of outside walls increase, houses are more isolated, as 37.5% of the sample have no sound problems.

Other environmental issues, such as the temperature and the humidity inside the house, are associated with the thickness of walls. More than 88% of houses have a very humid and warm atmosphere inside the house, as thickness of outside walls is only 10-30 cm.

#### f. Environmental Issues related to the Use of Specific Seasonal Zones

The survey showed that most residents (91%) have no seasonal spaces that are used only during summer or winter. The rest of the sample (= 9%) have some spaces, such as guest rooms, bedrooms on the top floor, living spaces, terraces, and balconies, that are used in a specific season. However, 75% of the sample were not interested in separating spaces according to the time of use during the year, as they prefer to benefit from all spaces for their daily needs (Table 4.34).

Table 4.34: Issues related to the use of specific seasonal spaces

| Variables   |  | Significant Value<br>(according to SPSS<br>Chi-Square Tests) | Association<br>between the Two<br>Variables |    |
|---|--|--|---|----|
|   |  |  | Yes   | No |
| People prefer to have two living zones in their houses: one for summer and the other for winter | People currently have spaces used only in summer | 0.894 ( $\geq 0.05$ )  |   | X  |
|   | People currently have spaces used only in winter | 0.104 ( $\geq 0.05$ )  |   | X  |

### 4.5. Extracting Spatial and Social Preferences from the Survey

Information gained from a phenomenological study for contemporary apartment buildings in MENA region showed that most of the current houses do not afford privacy for the family members, or private outdoor spaces for their children. Moreover, residents reported that they live in houses that have crowded living areas in comparison to the size of guest rooms. However, more than 85% of residents would prefer to have common areas and playgrounds inside their buildings. Also, they prefer to include outdoor terraces and open areas inside their houses.

At the scale of the building, the survey showed that there are several problems affecting the social life of residents. These include lower levels of social support, lower sense of community and familiarity with neighbours, and impacts on children as parents keep them inside

apartments due to safety concerns and difficulties of supervision at a distance. Moreover, the excessive use of glazed facades destruct the privacy of the family.

Based on these results, and correlations between different variables, the following illustrates influences of spatial, social, and environmental preferences of residents on the design of high-rise residential buildings in MENA region, at the scale of the building, and at the scale of the apartment (Table 4.35).

Table 4.35: Influences of spatial, social, and environmental preferences of residents on the parametric design of high-rise residential buildings in MENA region

| Aspects of Design                            |  | Strategies and Parameters for Designers  |   |   |
|--|--|--|---|---|
| <b>1. Spatial Qualities of the Apartment</b> |  |  |   |   |
| 1.1.   | Area of the house in relation to the household structure | Different sizes of apartments ranged from 100 m <sup>2</sup> to 250 m <sup>2</sup> are needed. Residents prefer the following areas based on the household structure:  |   |   |
|  |  | <u>Single-users and workers:</u><br>100-140 m <sup>2</sup> (10% of total number of apartments)   | <u>Couple, and couple with children:</u><br>141-180 m <sup>2</sup> (25% of the total number of apartments)  | <u>Couple with children:</u><br>181-250 m <sup>2</sup> (65% of the total number of apartments)  |
| 1.2.   | Areas of spaces (the principle of modest spaces)         | <ul style="list-style-type: none"> <li>- Area of guest spaces should not be exaggerated in comparison to the area of living zones and bedrooms</li> <li>- The area of living space should be reasonable with the number of people living in the house</li> </ul> |   |   |
| 1.3.   | Number of family members                                 | <u>For areas range between 100 and 140 m<sup>2</sup>:</u><br>1 - 4 members   | <u>For areas range between 141 and 180 m<sup>2</sup>:</u><br>3 - 6 members  | <u>For areas range between 181 to 250 m<sup>2</sup>:</u><br>4 - 8 members   |
| 1.4.   | Number of floors for the apartment                       | <u>For areas range between 100 and 140 m<sup>2</sup>:</u><br>One floor   | <u>For areas range between 141 and 180 m<sup>2</sup>:</u><br>One floor (70%), and Two floors (30%)  | <u>For areas range between 181 to 250 m<sup>2</sup>:</u><br>One floor (40%), and Two floors (60%)   |
| 1.5.   | Spaces for guests  | <u>Houses for single-users and workers:</u><br>- Entry hall  | <u>Houses for a couple, and a couple with children:</u><br><ul style="list-style-type: none"> <li>- Entry hall,</li> <li>- Guest room for both male and female,</li> <li>- Dining room,</li> <li>- Toilet for guests</li> </ul> |   |
| 1.6.   | Family Spaces  | <u>Houses for single-users and workers (100-140 m<sup>2</sup>):</u><br>- Living room with a breakfast corner   | <u>Houses for a couple, and couple with children: (141-180 m<sup>2</sup>):</u><br><ul style="list-style-type: none"> <li>- Family living room,</li> <li>- Office/Study area (optional)</li> </ul>                               | <u>Houses for a couple with children (181-250 m<sup>2</sup>):</u><br><ul style="list-style-type: none"> <li>- Family living room,</li> <li>- Office/Study area</li> <li>- Multi-purpose hall</li> </ul> |

|                                      |  |  |  |
|--------------------------------------|--|--|--|
| 1.7. Bedrooms                        | <u>Houses for single-users and workers (100-140 m<sup>2</sup>):</u><br>- 1 to 2 Master bedrooms  | <u>Houses for a couple, and couple with children: (141-180 m<sup>2</sup>):</u><br>- 1 Master bedrooms<br>- 1 to 2 Bedrooms for kids  | <u>Houses for a couple with children (181-250 m<sup>2</sup>):</u><br>- 1 to 2 Master bedrooms<br>- 2 to 3 Bedrooms for kids<br>- 1 Guest bedroom (optional)  |
| 1.8. Services                        | <u>Houses for single-users and workers (100-140 m<sup>2</sup>):</u><br>- 1 Bathroom<br>- Kitchen<br>- Storage area   | <u>Houses for a couple, and couple with children: (141-180 m<sup>2</sup>):</u><br>- 2 Bathrooms<br>- Kitchen<br>- Breakfast area<br>- Storage area   | <u>Houses for a couple with children (181-250 m<sup>2</sup>):</u><br>- 3 Bathrooms<br>- Kitchen<br>- Breakfast area<br>- Storage area  |
| 1.9. Type and area of outdoor spaces | <u>For areas range between 100 and 140 m<sup>2</sup>:</u><br>- Terrace/Balcony<br><br>Area of outdoor spaces = 10-15% of the total area of the house.  | <u>For areas range between 141 and 180 m<sup>2</sup>:</u><br>- Terrace/Balcony (one for the living space, and one for the kitchen)<br>- Courtyard (for 30% of apartments (two-floors)<br><br>Area of outdoor spaces = 10-18% of the total area of the house. | <u>For areas range between 181 to 250 m<sup>2</sup>:</u><br>- Terrace/Balcony (one for the living space, and one for the kitchen)<br>- Courtyard (for 60% of apartments (two-floors)<br>- <i>Iwan</i> and covered paths/gallery (optional) for the two-floors apartment<br>Area of outdoor spaces = 12-20% of the total area of the house. |
| 1.10. Accessibility and Circulation  | <ul style="list-style-type: none"> <li>- No lost spaces and long corridors between rooms</li> <li>- Steps inside the house (1 to 5 steps) between different zones (e.g. living space and guest room, living space and bedrooms)</li> <li>- In the two-floors apartment, people prefer to have a guest bedroom, or the master bedroom, to be located on the ground floor, as parents and elderly could not have the ability to use the upper floor</li> </ul> |  |  |
| 1.11. Height of ceiling              | - It is recommended to have a high ceiling (between 300 and 350 cm).   |  |  |
| 1.12. Thickness of outside walls     | - It is recommended to be designed not less than 35 cm.  |  |  |

## 2. Spatial Qualities of the Building

|   |   |  |   |
|---|---|--|---|
| 2.1. Number of floors for the building  | <u>Gulf Area:</u><br>Ranged between 7 and 30 floors   | <u>Middle East:</u><br>Ranged between 4 and 6 floors | <u>North Africa and Turkey:</u><br>Ranged between 5 and 17 floors |
| 2.2. Number of apartments on each floor | People prefer to have 1 to 4 apartments on each floor to have a quiet and not crowded environment inside the building |  |   |

|   |   |
|---|---|
| 2.3. Commercial shops on the ground floor | Commercial facilities (1 to 2 shops only) on the ground floor. These shops should have access from the street, and not from inside the building   |
| 2.4. Accessibility                        | <ul style="list-style-type: none"> <li>- No lost spaces and long corridors</li> <li>- Suitable number of elevators based on the number of residents</li> <li>- In buildings that have more than 8 floors, two elevators should be designed: <ul style="list-style-type: none"> <li>o Low-rise elevator shaft ends at 8<sup>th</sup> floor (serves from the ground floor to the 7<sup>th</sup> floor)</li> <li>o High-rise elevator serves the ground floor and from the 8<sup>th</sup> floor to the 14<sup>th</sup> floor</li> </ul> </li> <li>- In the two-floor apartment, people prefer to have a guest bedroom, or the master bedroom, to be located on the ground floor, as parents and elderly could not have the ability to use the upper floor.</li> <li>- The width of circulation paths between apartments needs to serve the number of people living on that floor.</li> <li>- The entrance and the entry hall for the building should be identified.</li> </ul> |

### 3. Social-Cultural Qualities

|  |   |   |
|--|---|---|
| 3.1. Privacy   | Olfactory privacy   | <ul style="list-style-type: none"> <li>- Closed kitchen (not to be opened on the living zone), and separate it from the living space and bedrooms</li> <li>- Window(s) for the kitchen to be located on the east and/or south direction (not on the west) to prevent smells entering the house</li> </ul>   |
|  | Acoustical privacy  | <ul style="list-style-type: none"> <li>- Separate bedrooms from living area to control the noise between private and intimate zones</li> </ul>  |
|  | Visual privacy and spatial hierarchy  | <ul style="list-style-type: none"> <li>- Add a visual separation between the entrance and the family living zone (bent entrance)</li> <li>- Add a visual barrier between the guest zone (guest and dining rooms) and the living family room</li> <li>- Separate the entrance from the kitchen or storage area</li> <li>- Bedrooms should be located in the same zone</li> <li>- Two entrances: one for guests (bent entrance), and the other for the family (which could also be used for female guests)</li> <li>- Hierarchy of spaces (from public zones to private and intimate zones)</li> <li>- Guest toilet should be located near the guest room</li> <li>- Use screens (such as louvres and <i>mashrabiyya</i>) in front of large windows to increase the privacy for the family</li> <li>- In the two-floors apartment with a courtyard inside the house, guest and living zones to be located on the first level, and bedrooms on the second level</li> <li>- Staggered entrance for apartments on each floor, to preserve the privacy of each family.</li> <li>- Terraces should not overlook other balconies</li> <li>- The use of greenery, instead of high walls, on terraces and balconies, to preserve the privacy of the family The use of high parapets on roof terraces to preserve the privacy of the family</li> </ul> |
| 3.2. Social interaction between family members, and between residents and neighbours | <ul style="list-style-type: none"> <li>- Common spaces on the ground floor and between floors (split the building into segments). Each zone could have different gathering spaces, such as courtyards, green areas, entry hall, and large corridors) inside the building, to increase the social interaction between neighbours.</li> </ul> |   |

|                                |   |
|--------------------------------|---|
|                                | <ul style="list-style-type: none"> <li>- It is recommended to have a multi-purpose hall for the building on the ground floor. This space encourages the social interaction and the number of meetings with neighbours.</li> <li>- Outside playgrounds, plazas, and gardens are useful features for encouraging the social interaction between neighbours.</li> </ul>  |
| 3.3. Hygiene                   | <ul style="list-style-type: none"> <li>- 1 to 3 steps between the entry hall and other zones to increase the hygiene inside the house</li> <li>- 1 to 3 steps between the kitchen and the living space to increase the hygiene</li> </ul>   |
| 3.4. Security and safety       | <ul style="list-style-type: none"> <li>- Outdoor spaces for children (such as courtyards, balconies with handrail) near the living zone, to increase the security and safety</li> </ul>   |
| 3.5. Views to the outside      | <ul style="list-style-type: none"> <li>- Terraces and large windows (with screens, such as louvres and <i>mashrabiyyah</i>) to increase the connection with the outside context, through offering the resident to see the outside views from the inside.</li> </ul>   |
| 3.6. The identity of the place | <ul style="list-style-type: none"> <li>- The use of local materials (such as stone)</li> <li>- It is recommended to understand the meaning and purpose of traditional elements, and use contemporary materials. For instance, <i>mashrabiyyah</i> could be replaced with steel louvres or patterned glass, as a method for preserving privacy without copying the past as it.</li> <li>- Different natural colours could be used to identify apartments from each other, and a method to have variations with a unity.</li> </ul> |

#### 4. Environmental Qualities

|                                  |   |
|----------------------------------|---|
| 4.1. Orientation                 | <ul style="list-style-type: none"> <li>- Window(s) for the kitchen to be located on the east and/or south direction (not on the west) to prevent smells entering the house</li> <li>- Living rooms to be oriented to the views, and at the same time to the south, to benefit from natural lighting all day. However, facades need to be protected from the direct sun, such as using screens and louvres.</li> <li>- The orientation of the courtyard: <ul style="list-style-type: none"> <li>o When the courtyard has a rectangular shape, and elongated in the <u>east-west</u> direction, the direct solar radiation in summer can be prevented from entering the longer sides of the house through using slight overhangs, and leaving windows available for the wind to be entered. However, the shorter sides get strong direct sun in the morning or evening of summer, while in winter, these walls are fully shaded.</li> <li>o When the courtyard elongated in the <u>north-south</u> direction, and the longer walls face east-west, there are difficulties with summer sun to be entered in morning or afternoon. The shorter sides get direct sun around noon in summer, and the winter sun is welcome near noon, so walls receive its warmth.</li> </ul> </li> </ul> |
| 4.2. Natural ventilation         | <ul style="list-style-type: none"> <li>- All toilets need to have a window (not on a duct)</li> </ul>   |
| 4.3. Greenery                    | <ul style="list-style-type: none"> <li>- Green areas to be designed in the apartment and the building (e.g. in courtyards, on roof terraces, on balconies, in common gathering spaces in the building, and gardens surrounding the building)</li> </ul>   |
| 4.4. Seasonal zones              | <ul style="list-style-type: none"> <li>- The area of the apartment is limited. Therefore, there is no need to have two living area; one for the summer, and the other for winter.</li> <li>- Particular areas, such as roof terraces, and balconies, could be used only during summer season.</li> </ul>  |
| 4.5. Treatments for upper floors | <ul style="list-style-type: none"> <li>- The study shows that apartments upper than the fourth floor need special treatments (such as louvres, screens, pergolas, or specialised glass) to ensure that inner spaces have a comfortable atmosphere.</li> </ul>   |

## Part (B): Spatial Analysis for Exploring Residential Buildings in MENA Region

Social and cultural qualities of residential buildings could be explained through spatial configurations. In this part, a detailed spatial analysis for traditional houses/neighbourhoods and contemporary residential buildings from the study area, is presented to understand the different factors that affect aspects of social and cultural sustainability.

### **4.6. Methods of Spatial Analysis**

'Spatial reasoning' and 'space syntax analysis' were adopted as rigorous methods for addressing the social reality about formal and spatial qualities. For instance, exploring topological relationships between spaces offers a clear understanding of qualitative properties, such as privacy, social interaction, and accessibility.

#### **4.6.1. Spatial Reasoning**

Spatial reasoning is a logical process of analysis that enables designers' understanding of the layout complexity, and the exploration of features that have social or experiential significance (Abshirini and Koch 2013). For instance, tracing the visual fields from a particular location in a building allows a precise evaluation of spatial elements that affect the privacy of its occupants. To understand this complexity, typological and formal-geometric analyses were used.

A typological analysis study could be divided into four stages (Eilouti 2009):

- Data collection: it includes the selection of relevant cases that have similar formal/functional qualities.
- Interpretation and analysis: it includes defining layers of analysis based on the objectives of the study.
- Classification: data extracted from cases are classified.
- Abstraction and Prototyping: information is represented in more abstracted diagrams, and then labelled and organised in an accessible format.

Using this type of investigation, main elements of houses and clusters of houses, were examined and classified according to the following criteria:

- Location of each element in relation to the overall layout.
- Area of each space.

- Geometric properties of spaces.
- Patterns of unique elements (such as solid walls, doors, windows, or steps).

Each category has different impacts on aspects of social sustainability on both scales: the house, and the cluster/building, as illustrated previously in (Section 4.2) from this chapter.

#### 4.6.2. Space Syntax Analysis

Syntactic relations could be represented visually, through 'justified node-and-connection' graphs that show the hierarchy of the overall layout; or mathematically, such as connectivity, integration, and control values (Hillier *et al.* 1987).

##### a. Visual Representation

Architectural floor plans are an accessible source of information that captures essential characteristics of interior spaces. One of the useful tools for analysing such layouts is to convert areas into abstracted forms without a direct reference to geometrical properties, through representing spaces by circles (nodes), and relationships within the overall configuration by lines (syntactic steps) (Klarqvist 1993). This morphological analysis is used to explore hierarchy of interior environments, analyse the order of relations between users, and evaluate the effect of the layout complexity on residents behaviour (Li and Klippel 2010; Zako 2006; Abu-Ghazze 1997).

For this study, the hierarchical system of spaces in residential units is classified into five types:

- Public spaces: which are linked directly with the outside world with no restrictions on the interaction between guests and the family (e.g. the main entry hall).
- Semi-public spaces: which are dominantly used by visitors to enhance the social interaction with the family (e.g. guest rooms).
- Semi-private spaces: which represent a transitional area between semi-public and private zones (e.g. corridors, courtyards, *iwans*, and galleries).
- Private spaces: this type relates to activities, such as living rooms, kitchen, toilets, and storage areas, that maintain the privacy of the household.
- Intimate spaces: which are controlled directly by the family (e.g. bathrooms and bedrooms).

Similar to the residential unit, common spaces at the scale of the building/neighbourhood could be categorised into three hierarchical zones: Main public spaces; semi-public areas (e.g. alleys and corridors); and semi-private spaces between residential units.

Node-and-connection diagrams show the hierarchy of the overall layout and the depth of each space. In these graphs, a specific space (the root space) is located at the bottom, and all spaces one syntactic step away from it are put on the first level above, all spaces two spaces away on the second level. This offers a visual picture of the overall depth of a layout seen from one of its points. When most of the nodes are located near the root space, then the system is described as shallow.

There are three types of syntactic connections between spaces: linear, fan-shaped or connected (Figure 4.49).

- Linear connection means that there is a separation between spaces, and the overall order of the layout is 'asymmetric'. In other words, there is a high value of depth between spaces.
- Fan connection indicates that spaces are directly connected to the main root space (minimum depth between spaces), with symmetrical order (Mustafa 2010). For example, the transitional space (corridor) between bedrooms (intimate spaces) represents this type of fan-shape connection (Abu-Ghazzeah 1997).
- Connected spaces, which mostly represent the link between private spaces (living room, kitchen and dining room).

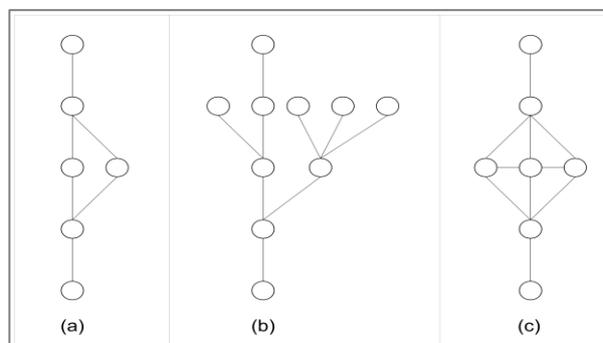


Figure 4.49: Types of connections between spaces: (a) linear, (b) fan-shape, (c) connected  
(Researcher)

## b. Mathematical Representation

Different measurements could be used to quantify syntactic relationships between spatial components of the design. Such measurements include:

- Connectivity (NC<sub>n</sub>): measures the number of immediate neighbours that are directly connected to space. For example, corridors, courtyards, and living rooms have the highest value of connectivity in houses, while storage spaces and services have the lowest value.

- Integration (i): describes the average depth of space to all other spaces in the system, as an indicator of how spaces are quiet or busy (Abu-Ghazze 1997). The highest value indicates the maximum integration.
- Control Value (CV): measures the degree to which space controls access to its immediate neighbours taking into account the number of alternative connections that each of these neighbours has.
- Mean Depth (MD): which is the average depth (or average shortest distance) from node (n) to all other nodes.
- Relative Asymmetry (RA): higher values mean that spaces are more segregated, more controlled in movement, and more private (asymmetric order, linear sequence of movement, and a maximum depth of spaces). In contrast, lower values of RA mean that spaces are more integrated, more accessible, and less private (symmetric order and a minimum depth of spaces).

### c. Tests and Computational Tools for carrying out Space Syntax Analysis

Three types of tests, associated with three computational tools, were used for carrying out space syntax analysis:

#### i. Space Syntax Graphs and Calculations (using AGraph software)

To produce justified graphs and carry out syntactic calculations, 'AGraph 1.14' software was used. AGraph is an open-access software, developed by Bendik Manum, Espen Rusten, and Paul Benze, in 2005, at the Oslo School of Architecture and Design (Manum *et al.* 2005). This 'node-and-connection model' produces different types of justified graphs (Figure 4.50):

- Depth of spaces from the root space, which is in this study the main entrance of the house or the cluster. The diagram represents shallow spaces as 'red' colour nodes, and deepest spaces as 'dark blue' colour nodes.
- Integration of functions with a selected space. Colours of nodes characterise integration values. For instance, the 'red' colour represents a highly integrated space, and the 'dark blue' colour represents the lowest integration value of a space.

Moreover, the following values could be extracted from syntactic calculations:

- $TD_n$ : Total Depth (TD) for each node
- $MD_n$ : Mean Depth (MD) for each node =  $TD/(K-1)$
- $K$ : Number of Nodes

- *NC*: Number of Connections from a Node
- *RA*: Relative Asymmetry =  $2*(MD-1)/(K-2)$
- *i*: Integration Value =  $1/RA$
- *CV*: Control Value

However, the use of *AGraph* software for extracting syntactic values requires drawing the 'node-and-connection' justified graph manually. Thus, errors could easily occur during this process.

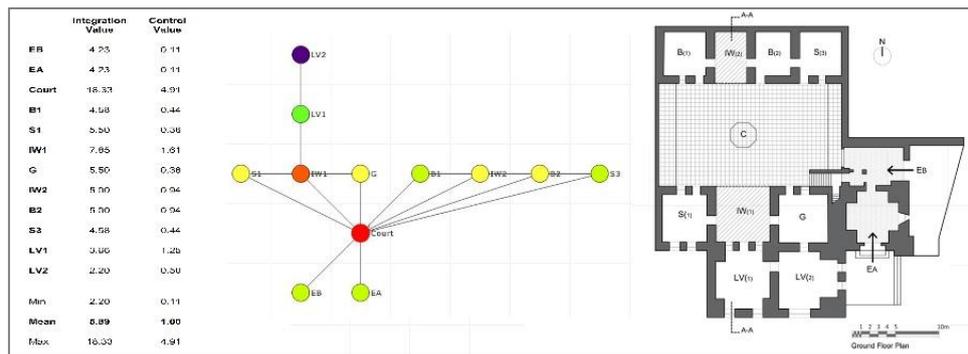


Figure 4.50: A justified graph showing the integration value for each space, produced by *AGraph* software

## ii. *Isovist Analysis (using Syntax2D software)*

*Isovist* analysis addresses the visual access of a person at one location of the environment (Li and Klippel 2010). This type of analysis is executed using open-source software, developed in 2007 at the University of Michigan, which is called '*Syntax2D 1.3.0.7*', (Wineman *et al.* 2007).

To explore the visual privacy inside houses, the *isovist* analysis investigates the visual fields from five locations (Figure 4.51):

- The main entry point of the house.
- The entry point of the main hall.
- The entry point of the guest room.
- The centroid of the guest room.
- Along the movement path of guests inside the house.

Furthermore, the analysis is executed at the scale of the neighbourhood/building. In that case, the process examined the visual fields from two positions (Figure 4.52):

- From the main entry point of the building/neighbourhood).
- From the entry point of each house in the cluster.



Figure 4.51: Samples of isovist analyses for three traditional courtyard houses located in Syria, produced by ‘Syntax2D 1.3.0.7’ software

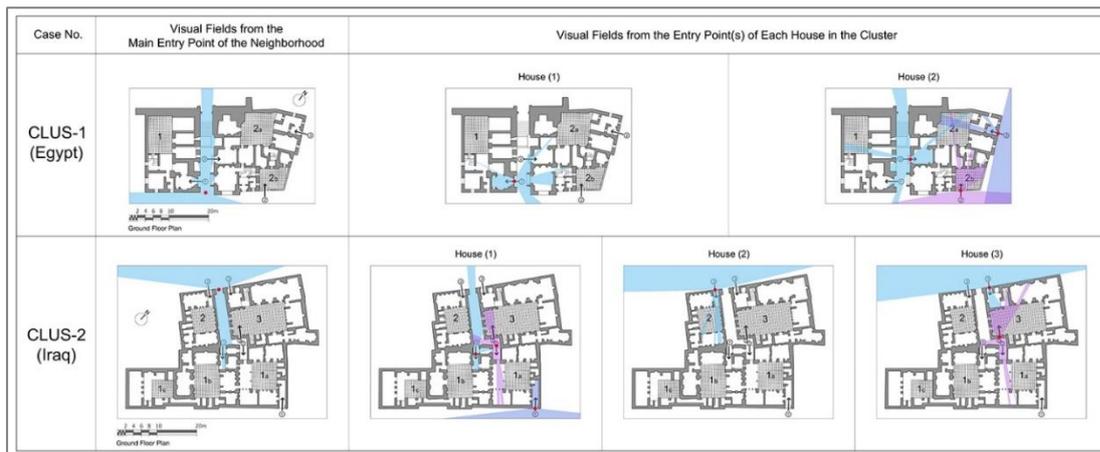


Figure 4.52: Samples of isovist analyses for two cluster of houses (neighbourhoods) located in Egypt and Iraq, produced by ‘Syntax2D 1.3.0.7’ software

**iii. Visibility Graph Analysis (using DepthmapX software)**

‘Visibility Graph Analysis (VGA)’ addresses the visual access to the whole environment at a time. It is based on the study of the reflection of light to determine the pattern of movement of people, to understand the spatial configuration of the environment, and to highlight the differences in experiences.

One computational tool for executing VGA is ‘DepthmapX 0.50’ software, developed firstly in 2000 by Alasdair Turner at the Space Syntax Laboratory, The Bartlett, University College London (UCL), and then by Tasos Varoudis (2011-2015).

*DepthmapX* is a single software platform designed to carry out a set of spatial network analyses on different scales, to understand social processes within the built environment, to derive variables which may have social or experiential significance, and to convey how social organisations occupy spaces. However, this software is only a graph, rather than, geometric analysis tool (Turner 2001).

The 'Visual Graph Analysis (VGA)' includes six types of tests:

- Connectivity analysis, which is the number of points that are connected visually to other spaces.
- Visual integration, which is the representation of potentially core area in the layout, where one can see much of the layout and can be easily seen. The red colour means that those spaces are well integrated (shallow spaces), and the blue colour represents deep and poor integrated locations.
- Through-vision analysis, which looks at how visual fields varies within an environment.
- Visual control: which specifies the degree of the privilege of one point over its immediate neighbours. The high control value means that these spaces might be potentially occupied. Red areas are more convex like, and blue areas are more elongated.
- Depth analysis, which shows changes of direction that would take to get from the selected location to other locations. For this study, depth of spaces (metric steps) is calculated from the main entrance of the house, which has step (0).
- Agent analysis, which indicates patterns of movement, and the frequent use of spaces released from one point. For this study, the selected base point is the main entrance of the house.

In all graphs, the red colour indicates the highest value, and the blue colour represents the lowest values (Figures 4.53, 4.54, and 4.55).

These three tests of space syntax analysis were used to measure the different indicators of social sustainability in contemporary residential buildings, and then compare the results with topological relationships that are extracted from traditional houses and neighbourhoods (Table 4.36).

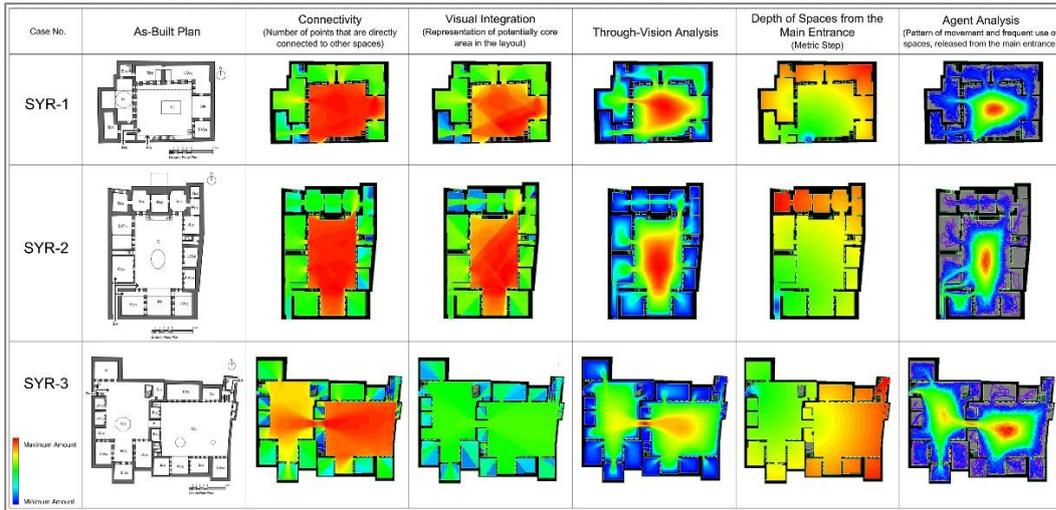


Figure 4.13: Samples of ‘visibility graph analysis’ for three traditional courtyard houses located in Syria, produced by ‘DepthmapX 0.50’ software

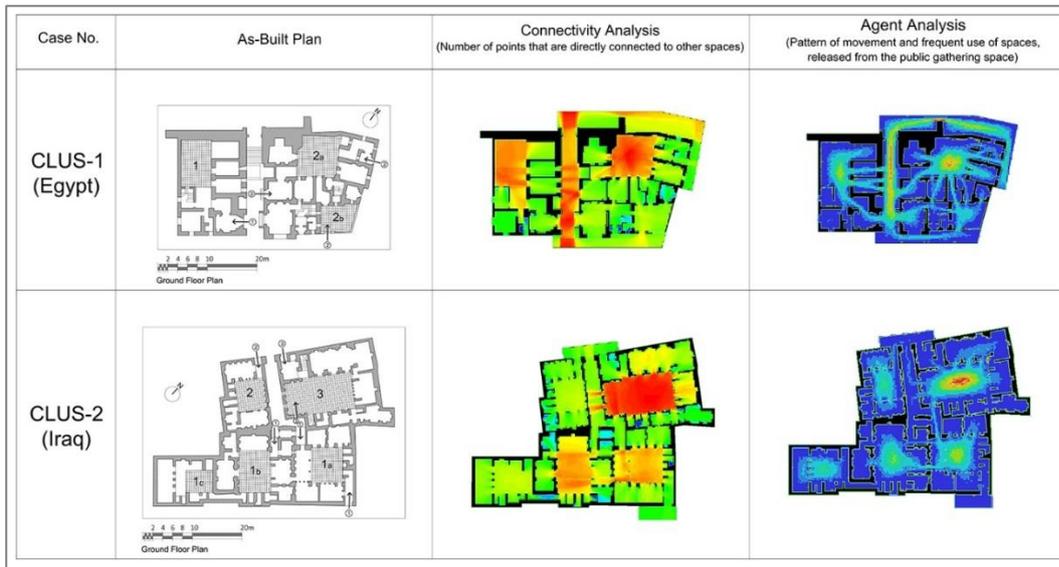


Figure 4.54: Samples of ‘visibility graph analysis’ for two cluster of houses (neighbourhoods) located in Egypt and Iraq, produced by ‘DepthmapX 0.50’ software

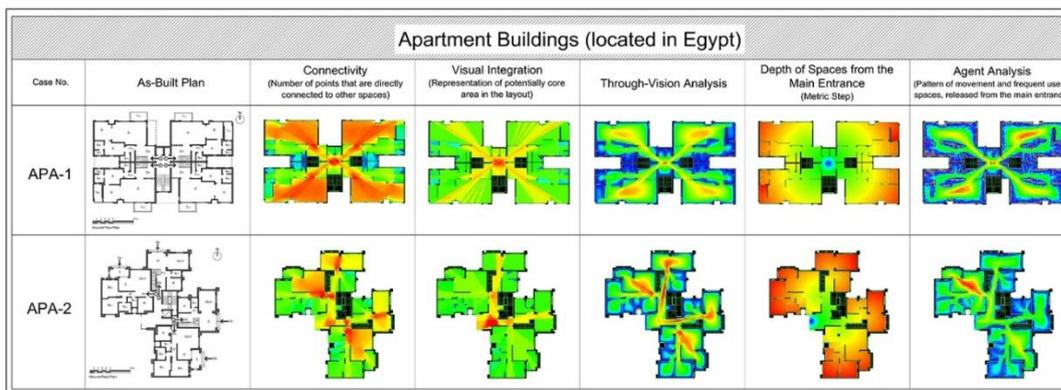


Figure 4.55: Samples of ‘visibility graph analysis’ for two contemporary apartment buildings located in Egypt, produced by ‘DepthmapX 0.50’ software

Table 4.36: Methods and tools of representation for measuring social sustainability

| Methods and Tools for Analysing Social Sustainability in Residential Buildings |  |  |                             |   |  |   |   |  |                      |                          |                          |                              |                             |
|--|--|--|-----------------------------|---|--|---|---|--|----------------------|--------------------------|--------------------------|------------------------------|-----------------------------|
| Approach   | Phenomenological Approach                                      |  |                             | Syntactical Approach  |  |   |   |  |                      | Formal Analysis Approach |                          |                              |                             |
| Methods  | A. Identification of Current Social/Spatial Problems and Needs |  |                             | B. Syntactical Analysis (Integration, Depth, and Control Values)    |  | C. Syntactical Analysis (Integration, Depth, and Connectivity Values, based on Visibility Graph Analysis (VGA)) |   | D. Agent Analysis and Patterns of Movement |                      | E. Isovist Analysis      |                          | F. Geometric Analysis        |                             |
| Tools  | Field Survey (Questionnaire)                                   |  |                             | AGraph Software (Mathematical Calculations and Justified Graphs)    |  | DepthmapX Software  |   | DepthmapX Software                         |                      | Syntax2D Software        |                          | Typological/Spatial Analysis |                             |
| Indicators of Social Sustainability  | 1. Population Density  | 2. Hierarchy of Spaces                     | 3. Social Interaction       | 4. Human Comfort  | 5. Accessibility                             | 6. Visual Privacy   | 7. Acoustical Privacy                     | 8. Olfactory Privacy                       | 9. Spirituality      | 10. Security and Safety  | 11. Views to the Outside | 12. Availability of Services | 13. Hygiene                 |
| Modes of Analysis  | - Numbers (m, m <sup>2</sup> )                                 | - Numbers (syntactic values)<br>- Diagrams | - Numbers (m <sup>2</sup> ) | - Numbers (% , m <sup>2</sup> , m, cm, X:Y)<br>- Diagrams<br>- Text | - Numbers (m <sup>2</sup> , m)<br>- Diagrams | - Diagrams  | - Numbers (m, cm)<br>- Diagrams<br>- Text | - Diagrams                                 | - Diagrams<br>- Text | - Diagrams               | - Diagrams               | - Numbers (%)<br>- Diagrams  | - Numbers (m)<br>- Diagrams |
| Methods  | A  | B C F                                      | A B C F                     | A F   | A B D F                                      | A B C E F   | A F                                       | A F  | A F                  | A F                      | C E F                    | A F                          | A F                         |

#### **d. Developing a Syntactic-Geometric Model for Encoding Social Realities and Spatial Qualities**

In addition to the methods and tools mentioned above, the researcher developed a model of space syntax analysis that adds new aspects to the justified graph of Hillier and Hanson, as a representation of formal and social realities (Figure 4.56). These issues are:

1. Patterns of movement.
2. Metric distance (D1) between the main entrance of the house (N1) and the centre of each space; and between the centre of the main hall (e.g. the courtyard) (N2) and the centre of each space, to analyse accessibility and security inside houses.
3. The actual geometry of each space rather than symbolic nodes. Shapes are arranged to show the following:
  - Hierarchy of spaces (public, semi-public, semi-private, private, and intimate).
  - Orientation (West, East, North, South, North-East, North-West, South-East, and South-West).
  - Type of enclosure (covered, open, semi-open).
  - Shared surfaces between adjacent spaces.
  - Entry point(s) between spaces.

Moreover, the spatial analysis includes geometric proportions for each space (X:Y), where (X) is the width of the space, and (Y) is the length of the space; percentage of space area from the overall area (%All); area of the space in relation to the area of the main hall (e.g. courtyard) (1:C); and the dominant users for each space (male, female, or both).

#### **e. A Computational Toolkit for carrying out Syntactical-Geometric Analyses**

In the field of architecture, computational models are widely used for processing the design in its various stages (analysis, simulation, and generation) efficiently and accurately.

Different levels could be involved in this process (Fathi *et al.* 2016):

- Representational, which includes the use of computers for producing architectural drawings.
- Parametric, which deals with identifying sets of rules and constraints to produce solutions.
- Algorithmic, which is about understanding relationships between inputs and outputs.

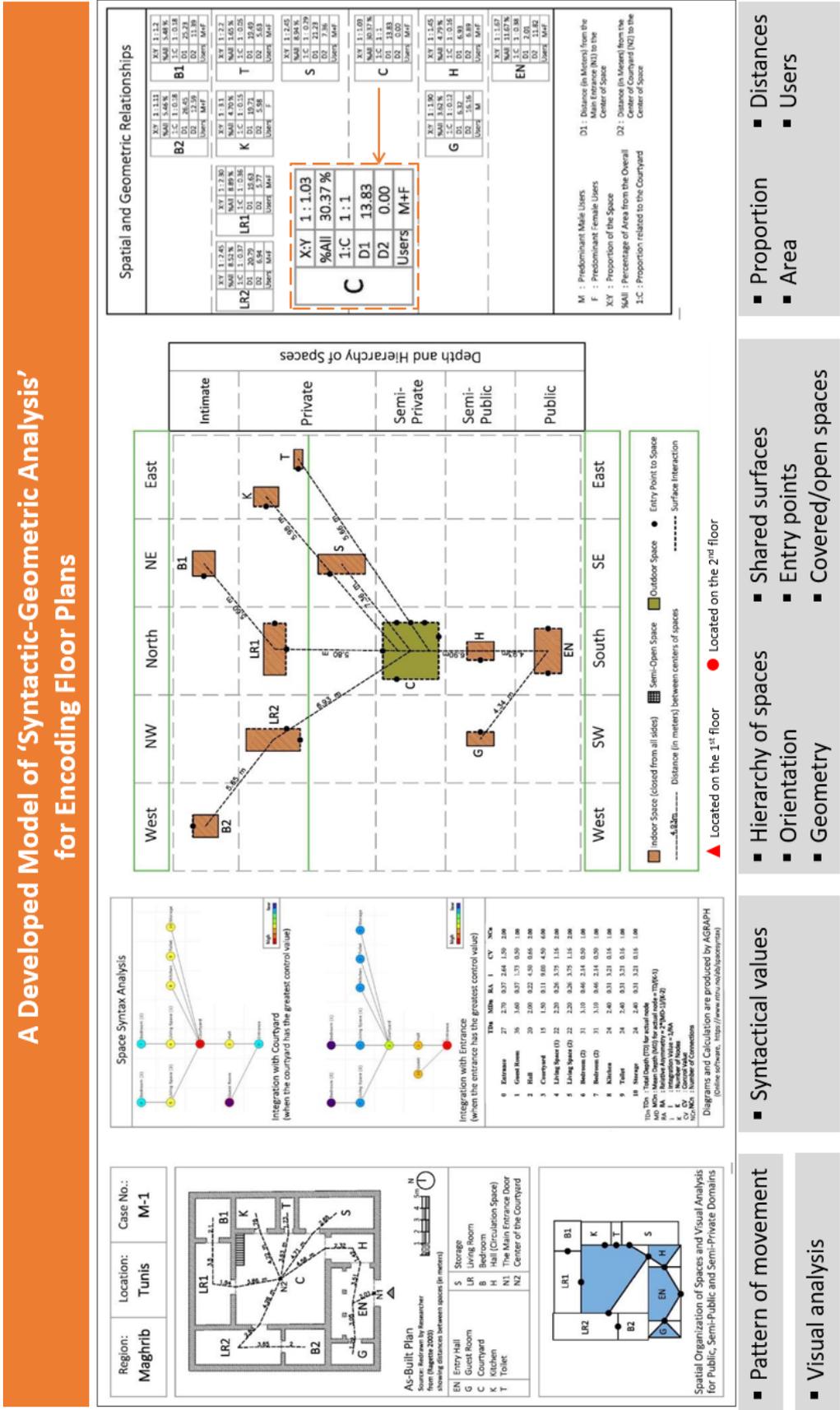


Figure 4.56: A developed model of syntactic-geometric analysis for encoding floor plans to address formal and social realities

The analyses mentioned above require from designers an extra effort to calculate spatial qualities, such as areas and proportions of spaces. Moreover, the use of AGraph software for extracting syntactic values requires drawing the 'node-and-connection' justified graph manually. Thus, errors could easily occur during this process. Therefore, it is useful to develop an automated computational tool for analysing floor plans in a short time of execution, and with a high degree of accuracy that does not require the user to possess an advanced level of knowledge in space syntax analysis.

For this research, Grasshopper, a plugin for Rhinoceros, was used for carrying out the needed analysis. Grasshopper is a visual scripting tool that enables generation and modification of the design by changing the parameters rather than rewriting the code (Oxman and Gu 2015). It allows input data to be passed from one component to another via connecting wires. Several plugins could be downloaded for executing different utilities without leaving the tool itself. The following section illustrates a detailed workflow of the automated model.

#### *i. Model Workflow and the User Interface*

A building is a series of spaces that are connected to each other. In computational models, these spaces are represented as a hierarchical sequence of related spaces through a series of geometrical entities (vertices or points, edges or lines, faces or surfaces, and volumes or shells) (Jabi 2016). The model depends on generating the layout of historical cases according to a 'space partitioning' mechanism (Knecht and Konig 2010). It commences by splitting a region into sub-spaces (cells). This geometric representational technique, using non-manifold topology (NMT), defines topological relations between adjacent spaces without any void (Jabi 2016). The first step requires users to draw the overall layout boundary for the building (as a polyline), internal partitions representing shared surfaces between spaces (as lines), and doors (as rectangles). However, thicknesses of walls are ignored. Once these features are obtained from a 'selection' component, the partitioning process is executed accordingly using NMT. A unique legend number is assigned automatically to each cell. This process could be applied to any layout that is composed of regular or irregular geometries (Figures 4.57 and 4.58).

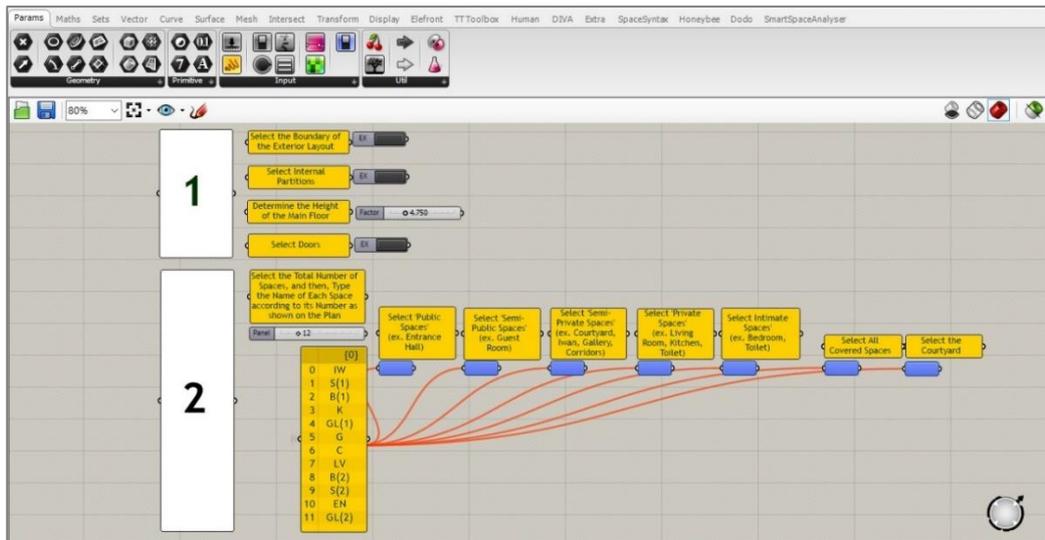


Figure 4.57: A screenshot for the interface in Grasshopper showing the required inputs from the user

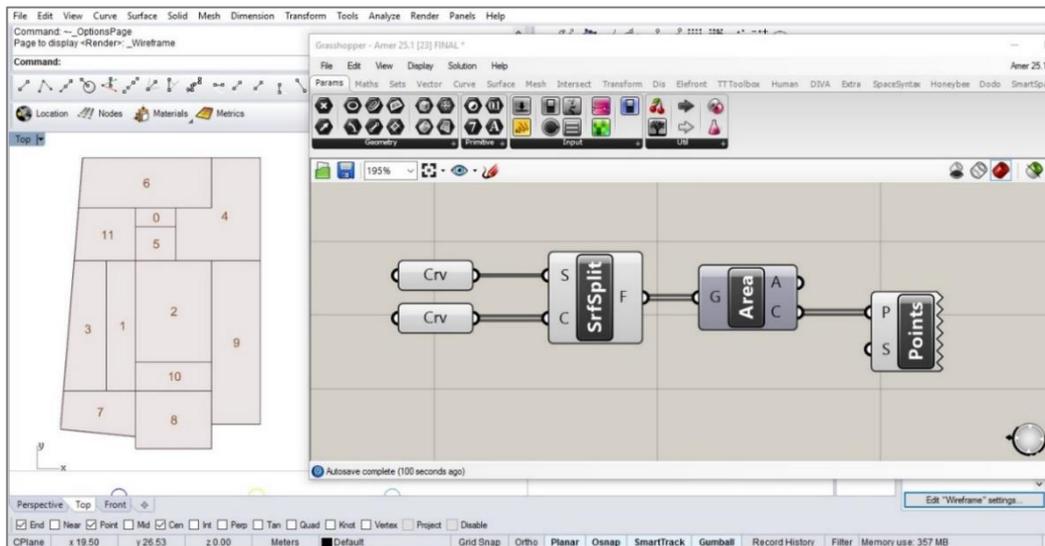


Figure 4.58: A screenshot for the interface in Grasshopper showing functions to carry out the partitioning process, using non-manifold topology (NMT)

The second step involves typing a function label for each cell, and then selecting spaces from lists according to two criteria: hierarchy of spaces (public, semi-public, semi-private, private, or intimate zone); and type of enclosure (open or covered area). A tag component is implemented for each cell (Figure 4.59). The model is then able to compute the following values, which are also delivered in the form of an Excel spreadsheet (Figures 4.60 and 4.61):

1. Area of each space, and the percentage relative to the total area of the house.
2. Total area for each hierarchical zone, and the percentage relative to the total area of the layout.
3. The distance from the centre of each cell to the centre of the main hall (or the courtyard).
4. Color-coded syntactic values for each space, which include:
  - Integration value: describes the average depth of space to other spaces.
  - Control value: measures the degree to which an area controls access to its immediate neighbours taking into account the number of alternative connections that each space has.
  - Entropy value: the difficulty of reaching other areas from that space.
  - Relative asymmetry: values that are closer to 0, means that spaces are more integrated, more accessible, and less private (minimum depth of spaces). In contrast, higher values that are closer to 1, indicate that spaces are more segregated, more controlled in movement, and more private (linear sequence of movement, and a maximum depth of spaces).
  - Difference factor: values that are closer to 0 mean that spaces are more structured, while higher values, i.e. closer to 1, indicate that spaces are more integrated.

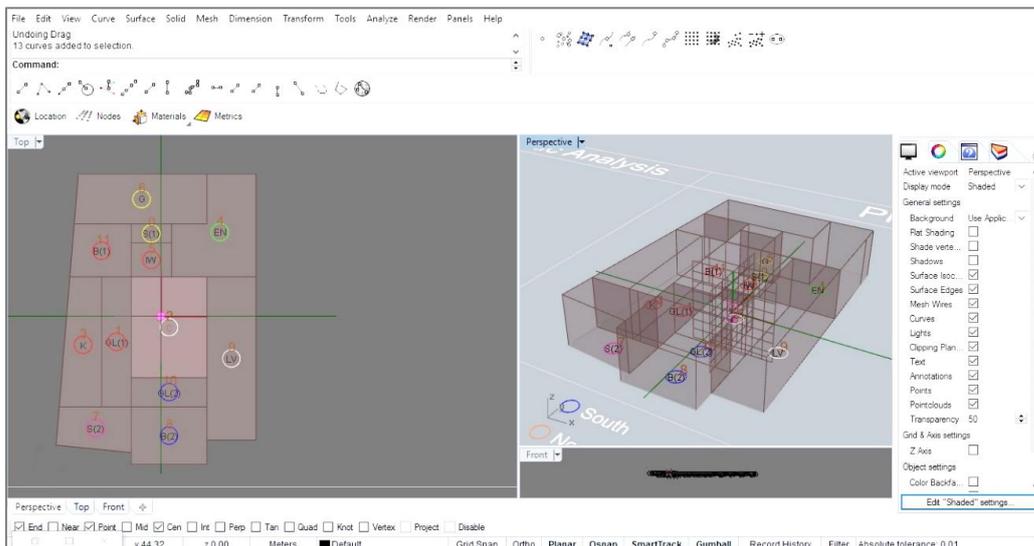


Figure 4.59: A screenshot showing the output of the partitioning process

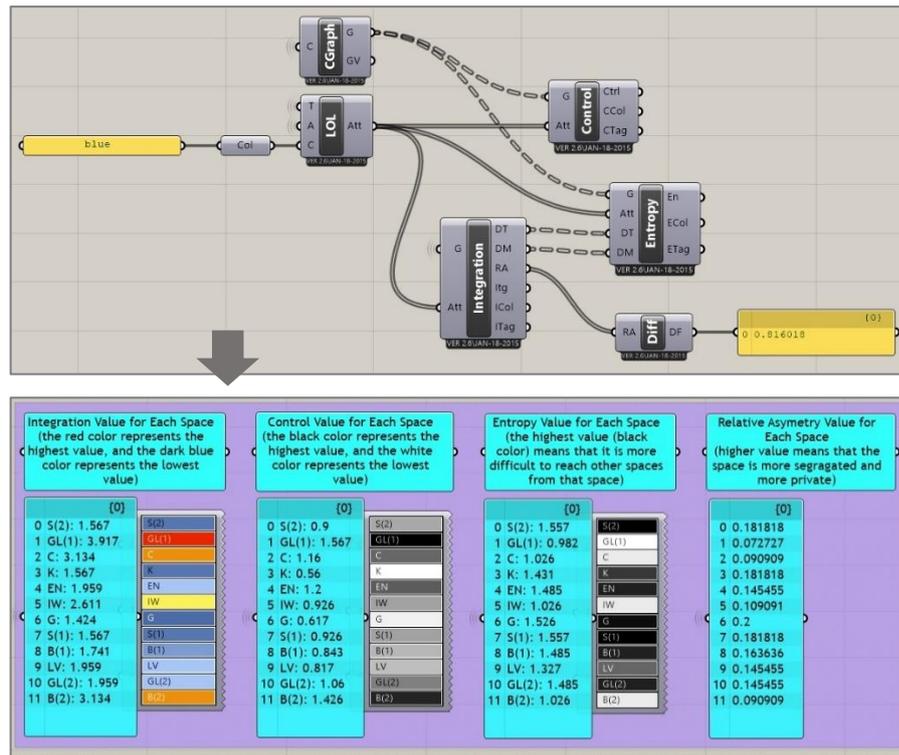


Figure 4.60: A screenshot showing the output of the partitioning process

| Excel Spreadsheet Summary |                        |  |  |                   |               |               |                          |  |  |  |
|---------------------------|------------------------|--|--|-------------------|---------------|---------------|--------------------------|--|--|--|
| Spatial Analysis          |                        | Syntactic Analysis                         |  |                   |               |               |                          |  |  |  |
| Spaces                    | Area (m <sup>2</sup> ) | % of Area from the Total Area of the House | Distance (m) from the Center of the Space to the Center of the Courtyard | Integration Value | Control Value | Entropy Value | Relative Asymmetry Value |  |  |  |
| S(2)                      | 5.63                   | 1.45%                                      | 8.20   | 1.57              | 0.90          | 1.56          | 0.18                     |  |  |  |
| GL(1)                     | 27.78                  | 7.17%                                      | 4.66   | 3.92              | 1.57          | 0.98          | 0.07                     |  |  |  |
| C                         | 56.21                  | 14.52%                                     | 0.00   | 3.13              | 1.16          | 1.03          | 0.09                     |  |  |  |
| K                         | 35.65                  | 9.21%                                      | 7.50   | 1.57              | 0.56          | 1.43          | 0.18                     |  |  |  |
| EN                        | 50.80                  | 13.12%                                     | 9.27   | 1.96              | 1.20          | 1.49          | 0.15                     |  |  |  |
| IW                        | 10.08                  | 2.60%                                      | 5.99   | 2.61              | 0.93          | 1.03          | 0.11                     |  |  |  |
| G                         | 48.25                  | 12.46%                                     | 11.27  | 1.42              | 0.62          | 1.53          | 0.20                     |  |  |  |
| S(1)                      | 22.79                  | 5.89%                                      | 10.70  | 1.57              | 0.93          | 1.56          | 0.18                     |  |  |  |
| B(1)                      | 32.27                  | 8.34%                                      | 9.31   | 1.74              | 0.84          | 1.49          | 0.16                     |  |  |  |
| LV                        | 58.64                  | 15.14%                                     | 5.97   | 1.96              | 0.82          | 1.33          | 0.15                     |  |  |  |
| GL(2)                     | 16.15                  | 4.17%                                      | 5.58   | 1.96              | 1.06          | 1.49          | 0.15                     |  |  |  |
| B(2)                      | 22.94                  | 5.92%                                      | 8.75   | 3.13              | 1.43          | 1.03          | 0.09                     |  |  |  |

Figure 4.61: A screenshot of the Excel spreadsheet showing formal and syntactic calculations produced by the developed model of analysis

Four types of visual diagrams are generated (Figures 4.62 and 4.63):

1. Orientation of spaces based on the coordinates of the centre of each cell in relation to the centre of the layout, and a unique coloured circle that indicates the location assigned to each space.
2. A node-and-connection syntactic diagram that shows the links between spaces. Each link signifies that there is a door/access to the two linked cells.
3. Hierarchy of spaces, with a colour code for each zone.
4. Distances between the centre of the main hall (e.g. the courtyard) and the centre of other spaces.

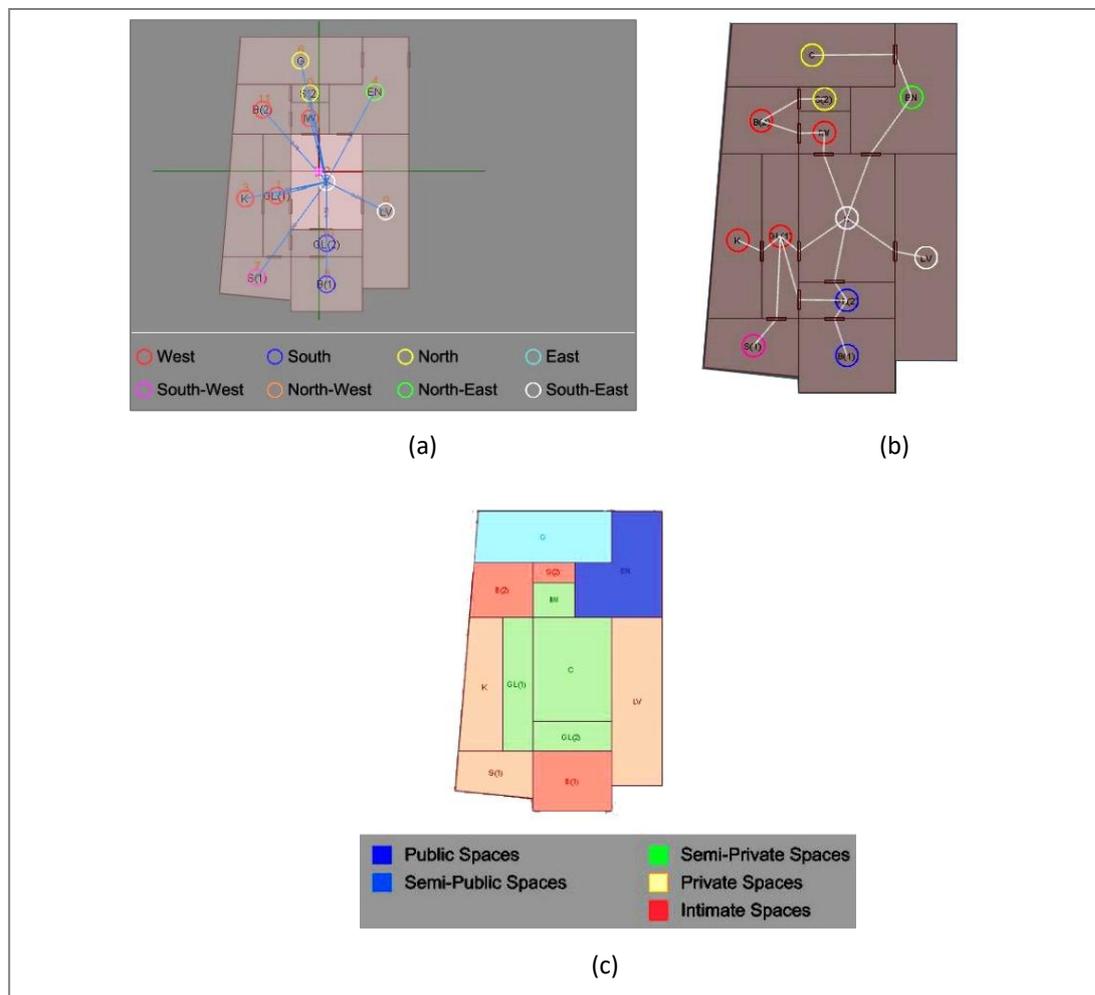


Figure 4.62: Diagrams produced by the developed model of analysis  
 (a) orientation of spaces, and distances between the centre of the main hall and the centre of other spaces; (b) node-and-connection syntactic diagram; (c) hierarchy of spaces

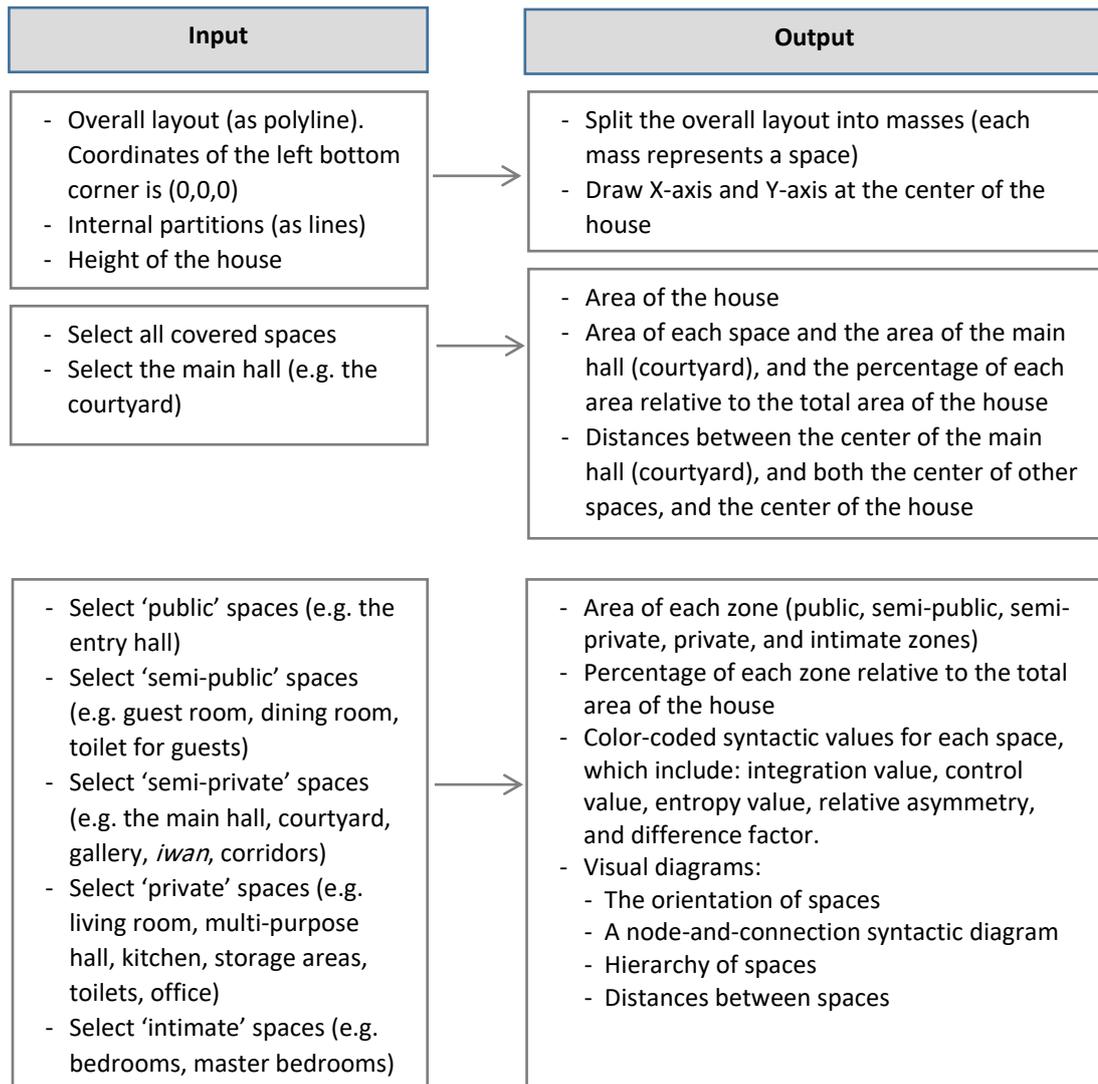


Figure 4.63: Inputs and outputs carried out by the developed model of analysis using Grasshopper

## 4.7. Data Collection

A detailed analysis of residential units and clusters of houses/apartments is useful to examine social and spatial realities, and to develop general statements and regularities for such environments. Data extracted from these cases will be used to establish a comprehensive understanding of social sustainability in contemporary and vernacular dwellings, and a comparison between current vertical developments with historical precedents.

### 4.7.1. Criteria for the Selection of Cases

The study area is distributed on three regions: North Africa; the Gulf Area; and the Middle East, and includes 17 countries. The selection process of historical/contemporary cases from each country depends on the following criteria:

- Regarding vernacular houses, and according to the literature review, the atrium house (with a courtyard at the centre of the house), and the patio house (with several small courtyards cut out the building volume) are the most common typologies of vernacular houses in hot-arid regions. In some countries, such as Lebanon, Yemen, and Saudi Arabia, this element was replaced by a covered main hall. Therefore, all cases have a main hall, or a courtyard.
- Choosing different sizes of houses, buildings, and clusters of houses (neighbourhoods).
- Availability of drawings and illustrations from archives, books, and architectural firms.

Regarding the geographic location of historical cases, there are two types of vernacular houses: (1) town-houses, which are widely distributed in cities; and (2) farm-houses, which are located in villages. Despite similarities between those two types, each one has its characteristics and needs. For instance, residents, who live in farm-houses, need stables and storage areas. Moreover, the area of this type is distributed on large plots, where the family can expand horizontally. In contrast, plot areas in cities are smaller and limited, so the spatial design of town-houses is more condensed, and sometimes distributed on more than one floor. Thus, all case studies and historical precedents have been selected from cities and towns rather than villages. These town-houses are the most suitable type that reflects the preferences of residents who live in urban areas.

Based on these criteria, a sample of 53 layouts for historical and contemporary cases was collected from a variety of periods and places within the study area (Table 4.37). Based on the requirements of computational tools for carrying out space syntax analysis and spatial calculations, all selected layouts were modelled and reproduced using AutoCAD software. These cases are grouped into three main categories:

- Contemporary apartment buildings (Figure 4.64).
- Vernacular houses (Figures 4.65, 4.66, and 4.67).
- Neighbourhoods and clusters of traditional houses (Figure 4.68).

Table 4.37: Number of selected cases from each country

|   | North Africa            |           | The Gulf Area |           | The Middle East |           |
|---|-------------------------|-----------|---------------|-----------|-----------------|-----------|
| <b>Vernacular Houses</b><br>(44 cases)                  | Egypt                   | 4         | KSA           | 5         | Jordan          | 1         |
|   | Algeria                 | 2         | Yemen         | 2         | Lebanon         | 5         |
|   | Tunisia                 | 7         | Kuwait        | 3         | Syria           | 3         |
|   | Morocco                 | 2         | Oman          | 1         | Iraq            | 5         |
|   |                         |           | UAE           | 1         | Palestine       | 3         |
|   |                         | <b>15</b> | <b>12</b>     |           | <b>17</b>       |           |
| <b>Clusters of Houses / Neighbourhoods</b><br>(4 cases) | Egypt                   | 1         |               |           | Syria           | 1         |
|   |                         |           |               |           | Iraq            | 2         |
|   |                         | <b>1</b>  |               | -         |                 | <b>3</b>  |
| <b>Contemporary Apartment Buildings</b><br>(5 cases)    | Egypt                   | 2         | Kuwait        | 1         | Jordan          | 2         |
|   |                         | <b>2</b>  |               | <b>1</b>  |                 | <b>2</b>  |
| <b>TOTAL</b>  |                         | <b>18</b> |               | <b>13</b> |                 | <b>22</b> |
|   | <b>Total cases = 53</b> |           |               |           |                 |           |

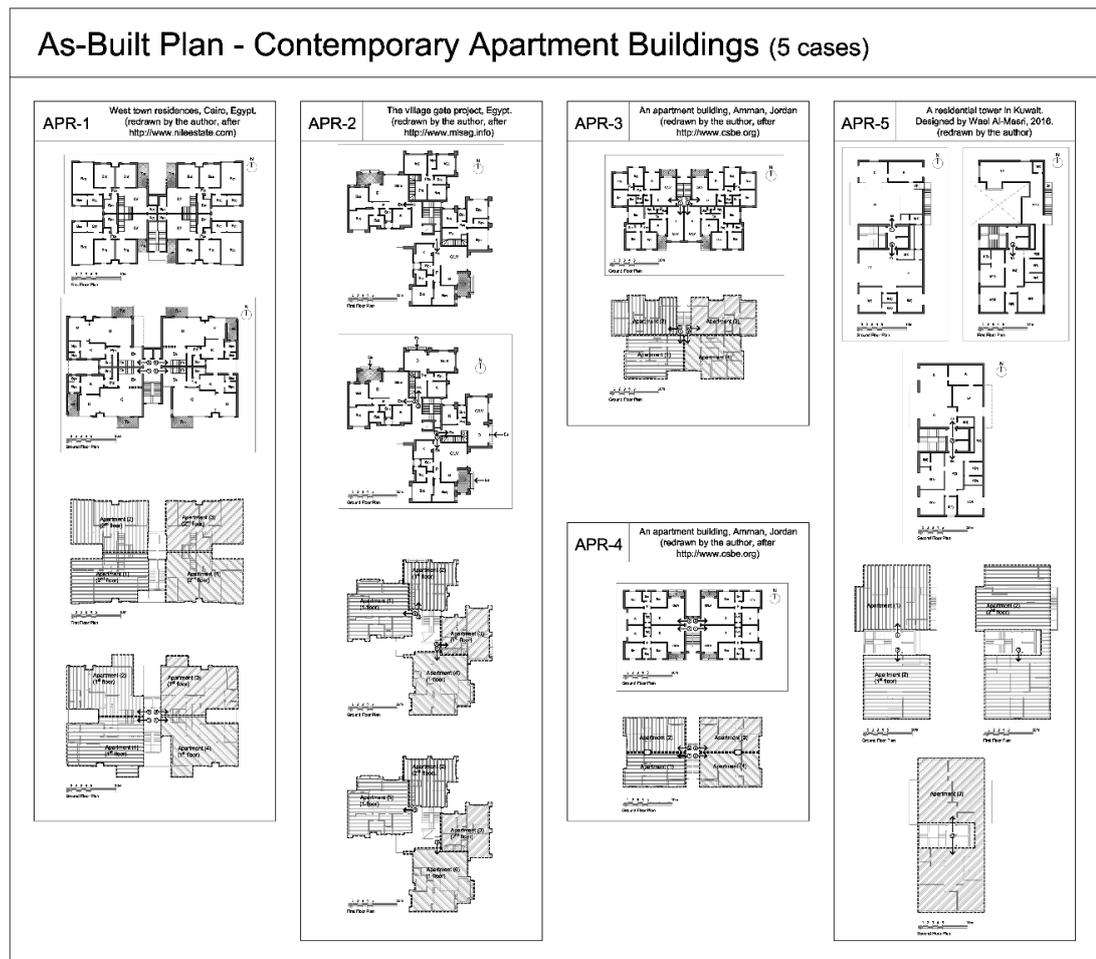


Figure 4.64: As-built architectural drawings for the selected contemporary apartment buildings in MENA region



Figure 4.65: As-built architectural drawings for the selected vernacular houses in the Middle East

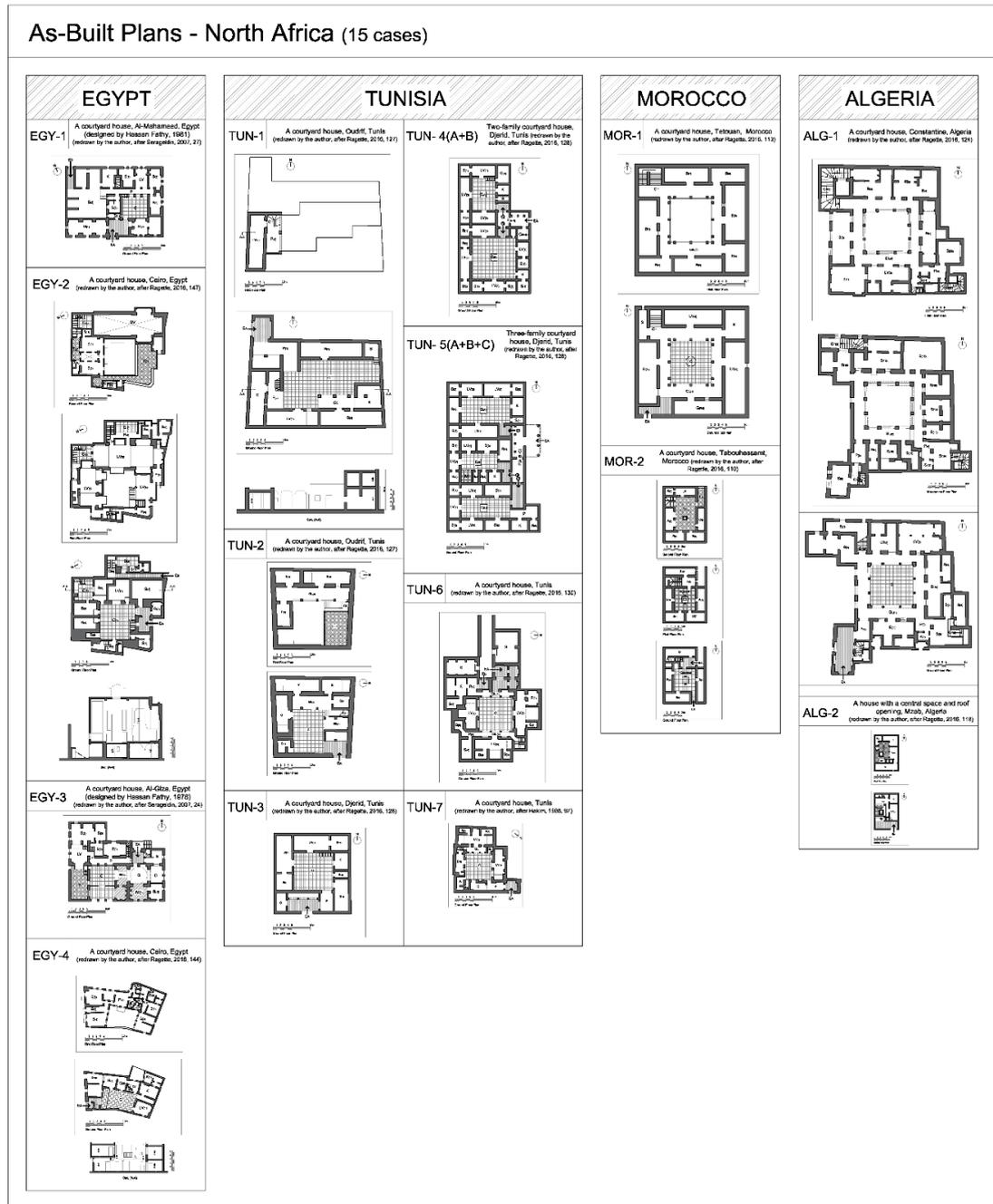


Figure 4.66: As-built architectural drawings for the selected vernacular houses in North Africa

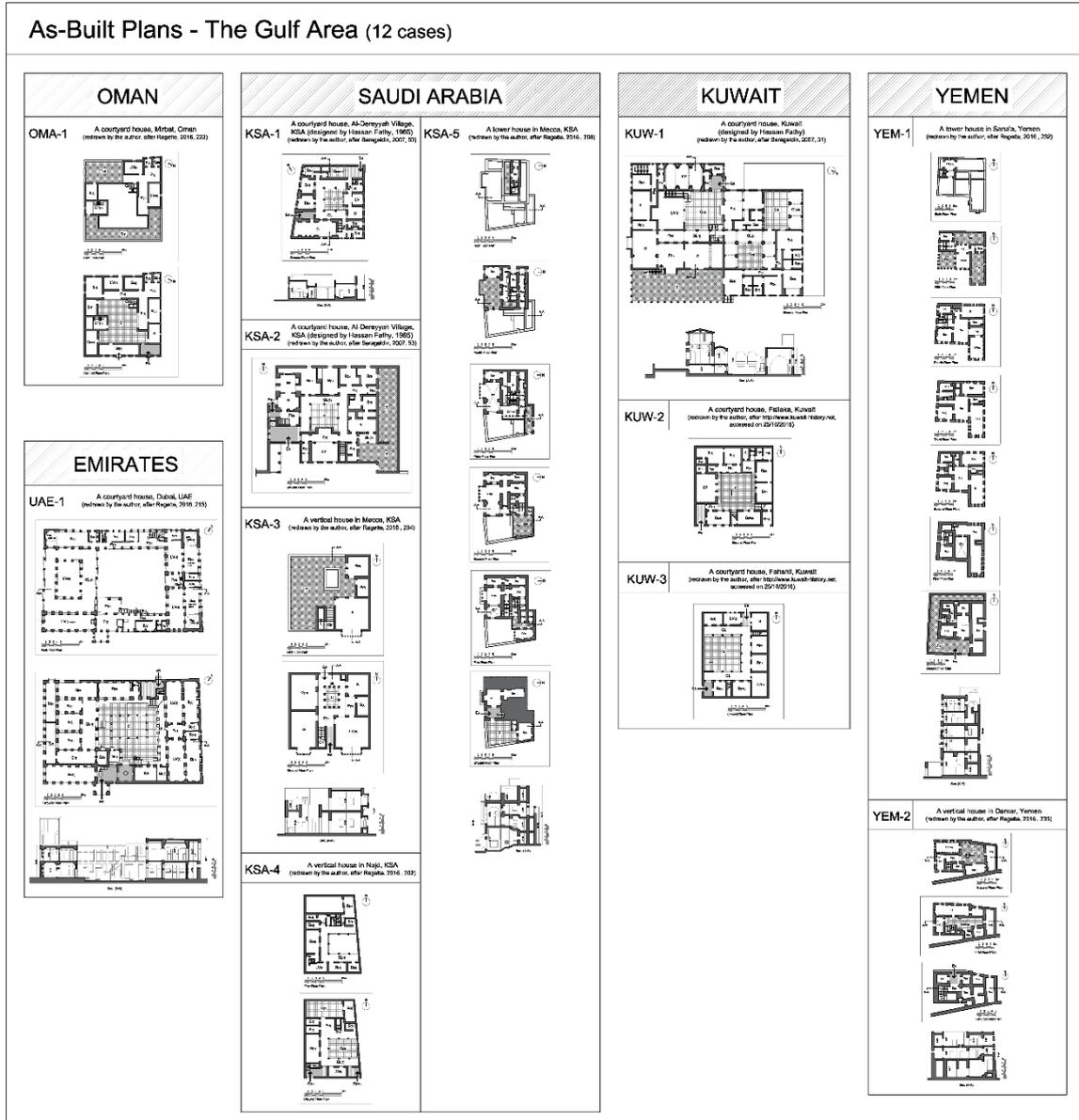


Figure 4.67: As-built architectural drawings for the selected vernacular houses in the Gulf Area



Figure 4.68: As-built architectural drawings for the selected neighbourhoods (clusters of houses) in MENA region

## 4.8. Data Analysis and the Extraction of Socio-Spatial Qualities: Readings from Syntactic and Formal-Geometric Analyses

Studying historical cases and previous documents could inform evidence from the past about specific themes (Groat and Wang 2013; Bryman 2016). However, this method, which does not entail participants, needs from researcher some interpretations to know where to look and how to look. Like natural sciences, analysing cases and thinking casually about the history represent a positivist approach, which could then produce some general concepts.

The following sections illustrate spatial qualities of the different cases, extracting extracted from cases, and show how they could affect social sustainability in residential environments. Spatial elements and topological relationships between spaces (the syntax) are integrated with the social meanings of spaces (semantics). For instance, hierarchy of spaces reflects the concept of privacy, which is an organising mechanism that designated the interaction between people and their choices of movement (Şalgamcıoğlu 2014).

### 4.8.1. Socio-Spatial Qualities of Vernacular Houses

Layouts may be varied in different periods, regions and cultures (Mustafa 2010). However, specific features are used widely in most cases, and remain relatively unchanged in their form and function as they reflect the social and the cultural identity of the region.

Traditional dwellings in the study area are inward-looking with living spaces organised around a central open space (a main hall or a courtyard). This dominant element in most cases is open to the sky, which could maintain a shaded area in summer, and receive solar radiation in winter. Moreover, it acts as a circulation zone, and a recreational living space, which provides security, privacy, and comfort for the family (Moossavi 2014). In some cases, another smaller courtyard could be found, which acts as an entrance open-space, and includes a staircase to upper floors.

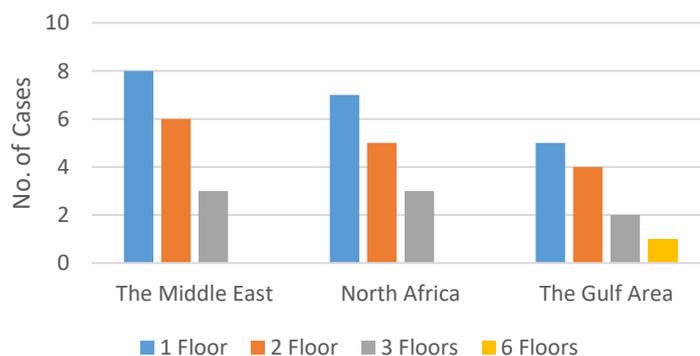
Spaces in most traditional houses are dynamic through using different techniques, such as changes in levels, and various degrees of openness (Ragette 2003). Other features include: (a) reception rooms for male and female guests, which are located adjacent to the main entry hall; (b) *iwan*, which is a sheltered space located in front of the courtyard, and acts as a transitional space between indoor and outdoor spaces; (c) mixed-function rooms, which are used as domestic living spaces; (d) porches and galleries, which connect spatially the indoor environment with the courtyard; (e) bedrooms, which could be located on ground and/or first floor; and (f) kitchen and storage areas surrounding the main hall or the courtyard.

### - Social Indicator (1): Population Density and Crowding

As plot areas in cities are limited, the spatial configuration of town-houses is dense and sometimes distributed on more than one floor (Table 4.38). However, the use of open and semi-open spaces inside the house, which represent approximately 19-28% of the total area, reduces the crowding and offers a comfortable atmosphere for the family. Spatial calculations show that covered spaces form only 70-75% of the total area of the house.

Table 4.38: Number of floors for the selected residential units

| The Middle East |          |               | North Africa |          |               | The Gulf Area |          |                                       |
|-----------------|----------|---------------|--------------|----------|---------------|---------------|----------|---------------------------------------|
| Country         | Case No. | No. of Floors | Country      | Case No. | No. of Floors | Country       | Case No. | No. of Floors                         |
| Syria           | SYR-1    | 2             | Egypt        | EGY-1    | 1             | Oman          | OMN-1    | 2                                     |
|                 | SYR-2    | 3             |              | EGY-2    | 3             | Emirates      | UAE-1    | 2                                     |
|                 | SYR-3    | 1             |              | EGY-3    | 1             | Kuwait        | KUW-1    | 1                                     |
| Lebanon         | LBN-1    | 1             |              | EGY-4    | 2             |               | KUW-2    | 1                                     |
|                 | LBN-2    | 1             | Tunisia      | TUN-1    | 2             |               | KUW-3    | 1                                     |
|                 | LBN-3    | 2             |              | TUN-2    | 2             | Yemen         | YEM-1    | 6                                     |
|                 | LBN-4    | 1             |              | TUN-3    | 1             |               | YEM-2    | 3                                     |
|                 | LBN-5    | 1             |              | TUN-4    | 1             | Saudi Arabia  | KSA-1    | 1                                     |
| Palestine       | PAL-1    | 1             |              | TUN-5    | 1             |               | KSA-2    | 1                                     |
|                 | PAL-2    | 1             |              | TUN-6    | 1             |               | KSA-3    | 2                                     |
|                 | PAL-3    | 1             |              | TUN-7    | 1             |               | KSA-4    | 2                                     |
| Jordan          | JOR-1    | 2             | Morocco      | MOR-1    | 2             |               | KSA-5    | 3 main floors<br>(6 different levels) |
| Iraq            | IRQ-1    | 2             |              | MOR-2    | 3             |               |          |                                       |
|                 | IRQ-2    | 2             | Algeria      | ALG-1    | 3             |               |          |                                       |
|                 | IRQ-3    | 2             |              | ALG-2    | 2             |               |          |                                       |
|                 | IRQ-4    | 3             |              |          |               |               |          |                                       |
|                 | IRQ-5    | 3             |              |          |               |               |          |                                       |



Another feature that reduces the feeling of crowding inside the house is the use of terraces and balconies on the first level of two-floor houses. This reduces the built-up area of the house, and therefore, offers the penetration of natural ventilation and lighting inside spaces. Results of the spatial analysis show that the area of the first level ranges between 36% and 93%, and terraces represent 11-16% from the total area of the house (Figure 4.69).

| The Layout of the Ground Floor                            | For MC-S |     | For MC-C                 |                          |     |                          |     | For MC-E                 |     | For MC-W |
|---|----------|-----|--------------------------|--------------------------|-----|--------------------------|-----|--------------------------|-----|----------|
| The Layout of the First Floor                             |          |     |                          |                          |     |                          |     |                          |     |          |
| % of the 1 <sup>st</sup> Floor Area from the Ground Floor | 87%      | 36% | 73% ↔ 93%<br>(AVG = 83%) | 34% ↔ 65%<br>(AVG = 47%) | 37% | 26% ↔ 46%<br>(AVG = 36%) | 47% | 52% ↔ 93%<br>(AVG = 73%) | 71% | 74%      |

Figure 4.69: Diagrams showing the layout of the first level in two-floor houses

**- Social Indicator (2): Hierarchy of Spaces**

Traditional houses are distinguished by a hierarchical system of movement that offers privacy for the family (Tables 4.39 and 4.40). Spaces are categorised into five main zones:

- (1) Public spaces, such as entrances (E).
- (2) Semi-public zone, which includes guest rooms (G).
- (3) Semi-private spaces, such as courtyards/main halls (C) and corridors (P).
- (4) Private zone, which includes living areas (LV), kitchen (K), storage spaces, services and toilets (S).
- (5) Intimate spaces, such as bedrooms (B) and bathrooms (S).

Spatial calculations show that the percent of public and semi-public spaces relative to the total area of the house is only 13-15%. The average areas of private, semi-private and intimate zones represent 32%, 38%, and 16% respectively (Table 4.41).

Table 4.39: Hierarchy of spaces and movement patterns for guests in traditional houses

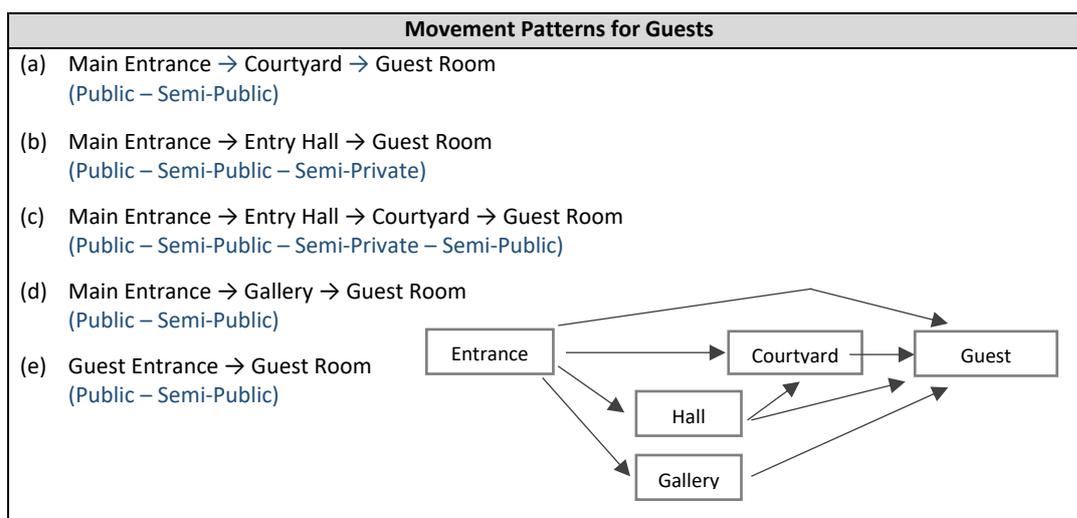


Table 4.40: Hierarchy of spaces and movement patterns for family members in traditional houses

| Movement Pattern for Family Members |  |
|-------------------------------------|--|
| (a)                                 | Main Entrance → Courtyard → Iwan → Living Room<br>Public – Semi-Public – Semi-Private – Private  |
| (b)                                 | Main Entrance → Stair → Corridor → Bedrooms<br>Public – Semi-Public – Semi-Private – Intimate  |
| (c)                                 | Main Entrance → Entry Hall → Courtyard → Iwan → Living Rooms, Kitchen, Services<br>Public – Semi-Public – Semi-Private – Private                                       |
| (d)                                 | Main Entrance → Entry Hall → Courtyard → Stair → Terrace → Gallery → Bedrooms<br>Public – Semi-Public – Semi-Private – Private – Intimate                              |
| (e)                                 | Main Entrance → Entry Hall → Courtyard → Corridor → Family Courtyard → Iwan → Bedrooms<br>Public – Semi-Public – Semi-Private – Private – Private – Intimate           |
| (f)                                 | Main Entrance → Entry Hall → Courtyard → Gallery → Bedrooms<br>Public – Semi-Public – Semi-Private – Private – Intimate  |
| (g)                                 | Main Entrance → Entry Hall → Courtyard → Iwan → Bedrooms<br>Public – Semi-Public – Semi-Private – Private – Intimate   |
| (h)                                 | Main Entrance → Entry Hall → Courtyard → Living Rooms<br>Public – Semi-Public – Semi-Private – Private   |
| (i)                                 | Main Entrance → Entry Hall → Courtyard → Living Rooms → Corridor → Bedrooms<br>Public – Semi-Public – Semi-Private – Private – Intimate                                |
| (j)                                 | Main Entrance → Gallery → Courtyard → Gallery → Living Rooms, Services<br>Public – Semi-Public – Semi-Private – Private  |
| (k)                                 | Main Entrance → Gallery → Courtyard → Gallery → Stair → Terrace → Gallery → Iwan → Bedrooms<br>Public – Semi-Public – Semi-Private – Semi-Private – Private – Intimate |
| (l)                                 | Service Entrance → Corridor → Kitchen → Corridor → Courtyard<br>Semi-Public – Semi-Private – Private – Semi-Private – Private  |
| (m)                                 | Service Entrance → Service Courtyard → Kitchen → Courtyard<br>Semi-Public – Semi-Private – Private – Semi-Private  |
| (n)                                 | Service Entrance → Service Courtyard → Kitchen → Gallery → Courtyard<br>Semi-Public – Semi-Private – Private – Semi-Private  |

```

graph LR
    EA[EA] --> C[C]
    EA --> Hall[Hall]
    EA --> GL[GL]
    C --> IW[IW]
    C --> P1[P]
    C --> LV[LV]
    Hall --> C
    GL --> C
    IW --> LV
    P1 --> LV
    LV --> K[K]
    LV --> S[S]
    LV --> P2[P]
    P2 --> B[B]
    
```

**Pattern (A)**

Where:  
**EA:** Main Entrance, **C:** Main Courtyard, **C(s):** Service courtyard, **IW:** Iwan, **GL:** Gallery,  
**EB:** Service Entrance **P:** Passage/corridor, **LV:** Living room, **K:** Kitchen, **S:** Services,  
**B:** Bedrooms

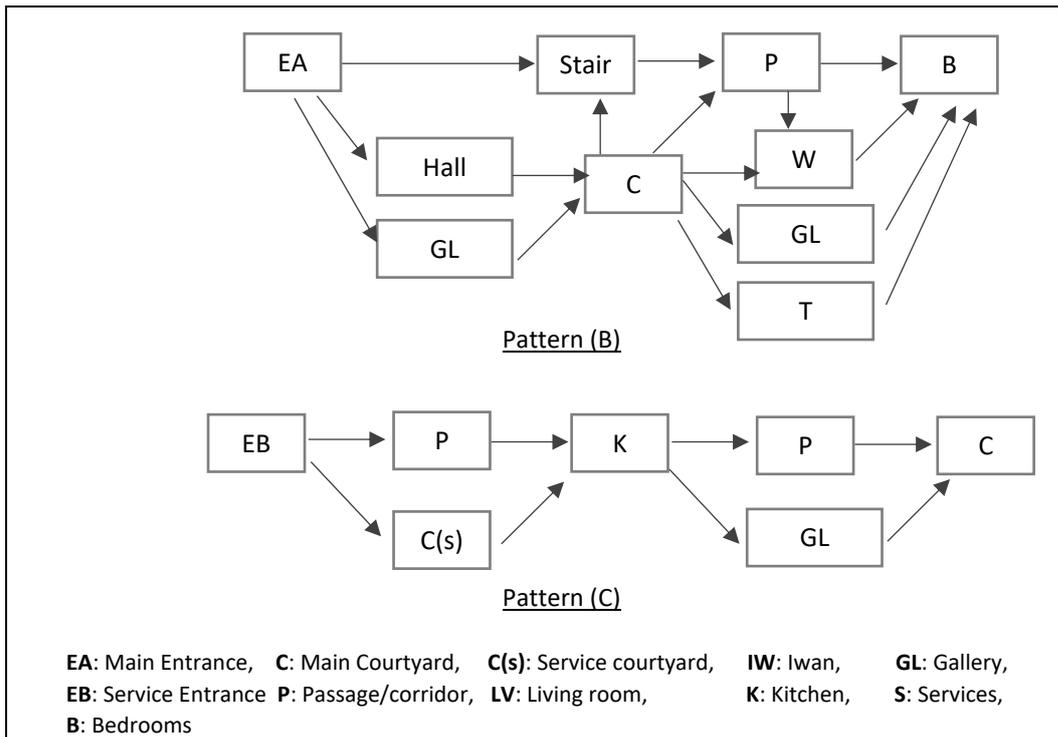


Table 4.41: Percentages of hierarchical zones relative to the area of the house<sup>1</sup>

| Region                      | % of Public Spaces | % of Semi-public Spaces | % of Semi-Private Spaces | % of Private Spaces | % of Intimate Spaces |
|-----------------------------|--------------------|-------------------------|--------------------------|---------------------|----------------------|
| <b>The Middle East (ME)</b> |                    |                         |                          |                     |                      |
| Syria                       | 1.3 %              | 8.5 %                   | 46.9 %                   | 30.5 %              | 12.8 %               |
| Lebanon                     | 4.2 %              | 6.1 %                   | 41.0 %                   | 34.6 %              | 14.2 %               |
| Jordan                      | 2.1 %              | 17.7 %                  | 43.8 %                   | 23.5 %              | 12.8 %               |
| Palestine                   | 3.2 %              | 12.2 %                  | 34.3 %                   | 22.0 %              | 28.2 %               |
| Iraq                        | 2.9 %              | 4.8 %                   | 41.8 %                   | 33.6 %              | 16.9 %               |
| AVG                         | <b>2.7 %</b>       | <b>9.8 %</b>            | <b>41.6 %</b>            | <b>28.9 %</b>       | <b>17 %</b>          |
| <b>North Africa (NA)</b>    |                    |                         |                          |                     |                      |
| Egypt                       | 4.8 %              | 15.5 %                  | 20.8 %                   | 36.8 %              | 22.2 %               |
| Tunisia                     | 7.3 %              | 7.04 %                  | 38.0 %                   | 37.4 %              | 12.4 %               |
| Morocco                     | 2.6 %              | 7.8 %                   | 22.4 %                   | 45.9 %              | 21.4 %               |
| Algeria                     | 1.2 %              | 10.5 %                  | 25.6 %                   | 42.6 %              | 12.6 %               |
| AVG                         | <b>4.0 %</b>       | <b>10.2 %</b>           | <b>26.7 %</b>            | <b>40.7 %</b>       | <b>17.1 %</b>        |
| <b>The Gulf Area (GA)</b>   |                    |                         |                          |                     |                      |
| KSA                         | 4.4 %              | 14.8 %                  | 26.7 %                   | 40.7 %              | 13.4 %               |
| UAE                         | 2.1 %              | 4.0 %                   | 28.4 %                   | 50.8 %              | 14.7 %               |
| Oman                        | 3.0 %              | 10.1 %                  | 21.9 %                   | 53.3 %              | 11.6 %               |
| Kuwait                      | 3.8 %              | 12.1 %                  | 38.2 %                   | 24.4 %              | 21.6 %               |
| Yemen                       | 3.6 %              | 13.3 %                  | 13.4 %                   | 58.6 %              | 11.0 %               |
| AVG                         | <b>3.4 %</b>       | <b>10.8 %</b>           | <b>25.7 %</b>            | <b>45.6 %</b>       | <b>14.5 %</b>        |
| AVG (Study Area)            | <b>3.4 %</b>       | <b>10.3 %</b>           | <b>31.7 %</b>            | <b>38.4 %</b>       | <b>16.2 %</b>        |

<sup>1</sup> Detailed geometric and spatial calculations for all cases are shown in (Volume 2- Appendix (4-B-8): Spatial and Geometric Calculations for the Selected Vernacular Houses).

Furthermore, observations from space syntax analysis and ‘visibility graph analysis (VGA)’ for traditional houses reflect certain social and cultural meanings. The courtyard and the gallery have the highest integration and control values, and the lowest depth value (Figures 4.70 to 4.73)<sup>2</sup>. This suits with the main function of these spaces as a transitional zone that controls the overall layout of the house, and provides a suitable area for family gatherings. In contrast, services, terraces, bedrooms and guest rooms, have the lowest integration and control values, and the highest depth value. This means that those spaces are mostly private zones, and they are controlled and accessed through the central space of the house (Tables 4.42, 4.43, 4.44).

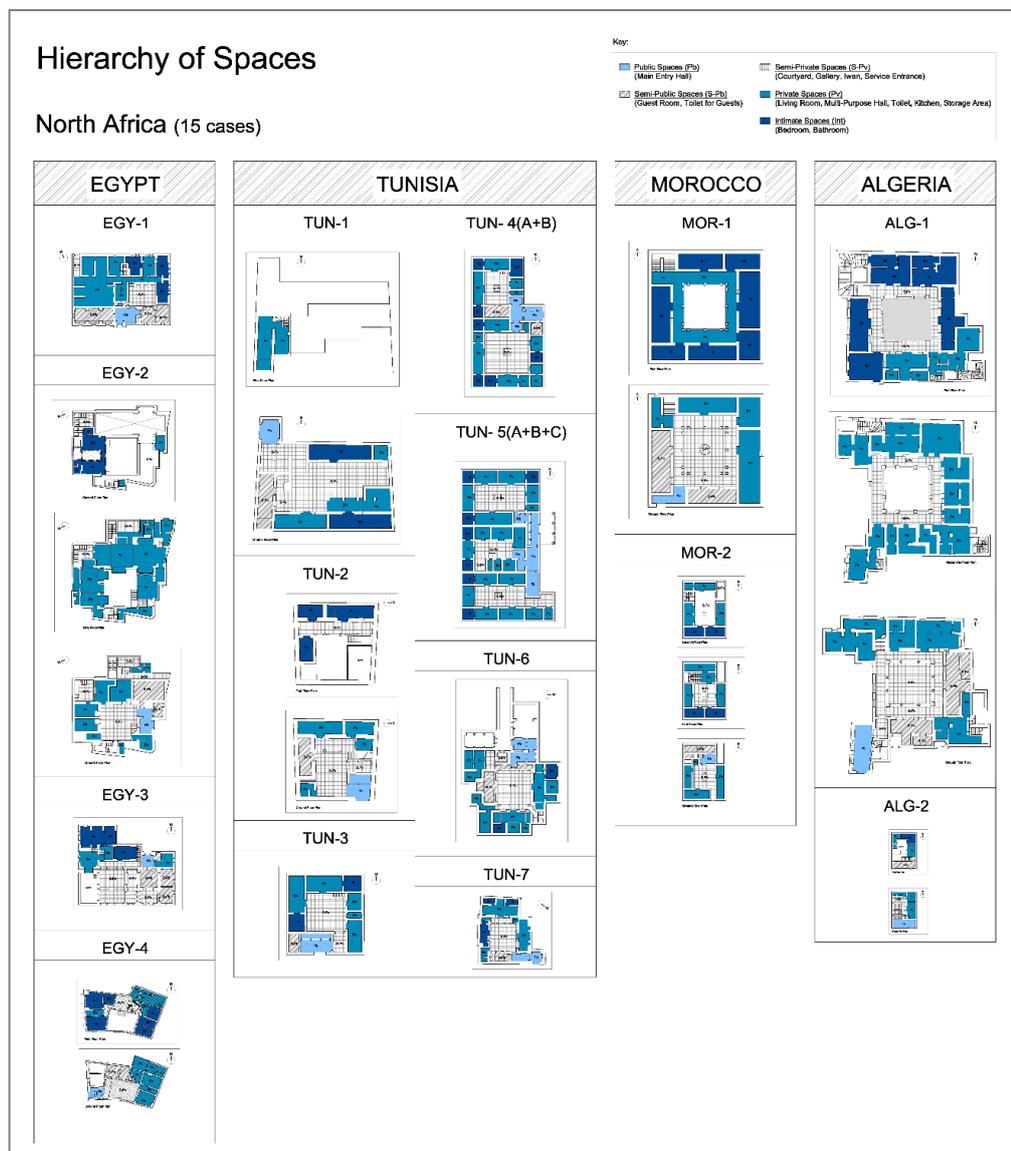


Figure 4.70: Diagrams showing hierarchy of spaces for traditional courtyard houses located in North Africa

<sup>2</sup> Analytical drawings for other cases are shown in (Volume 2 - Appendix (4-B-7): Syntactic Diagrams for the Selected Vernacular Houses; and Appendix (4-B-4): Visibility Graph Analysis).

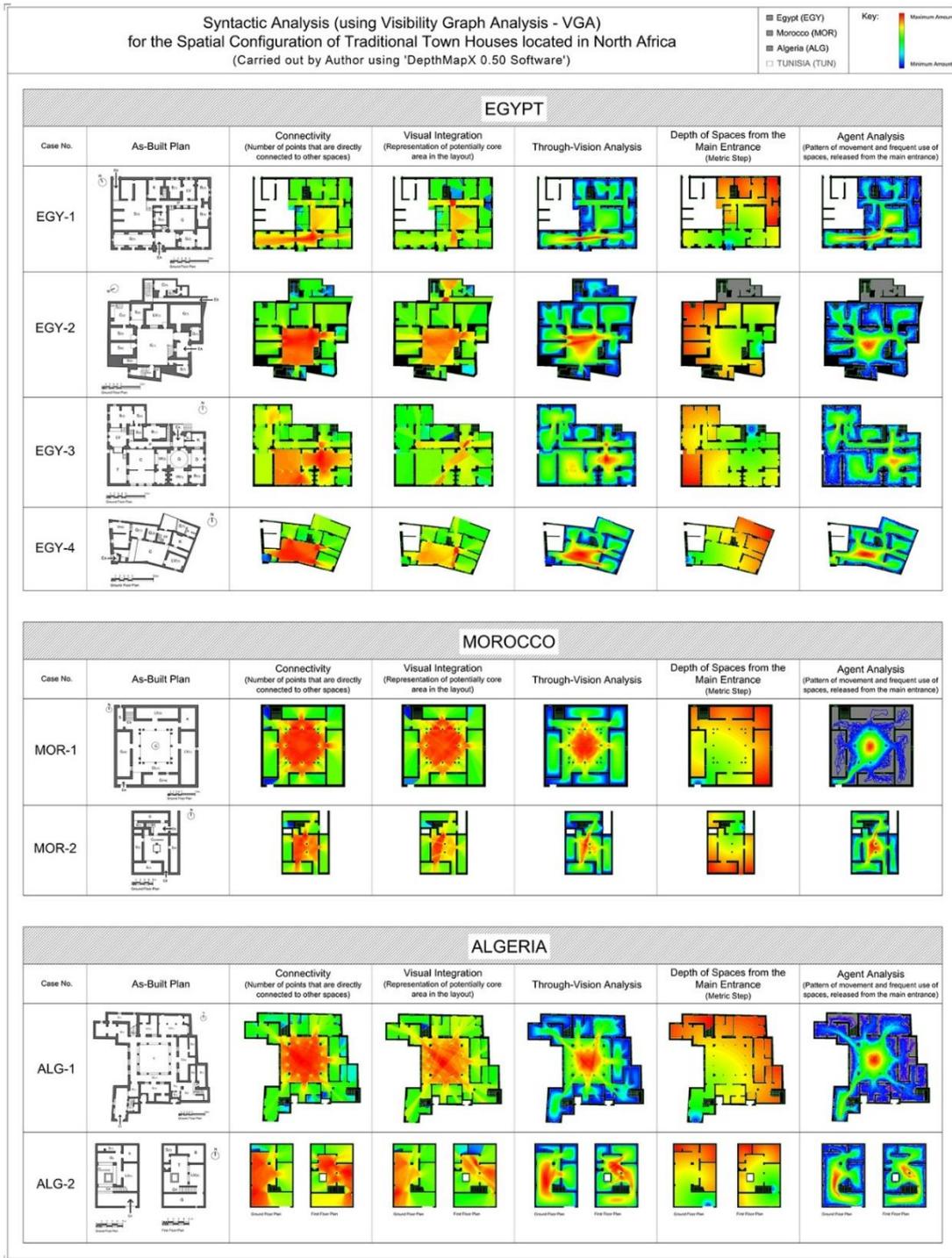


Figure 4.71: 'Visibility graph analysis' for traditional courtyard houses located in North Africa, produced by 'DepthmapX 0.50' software

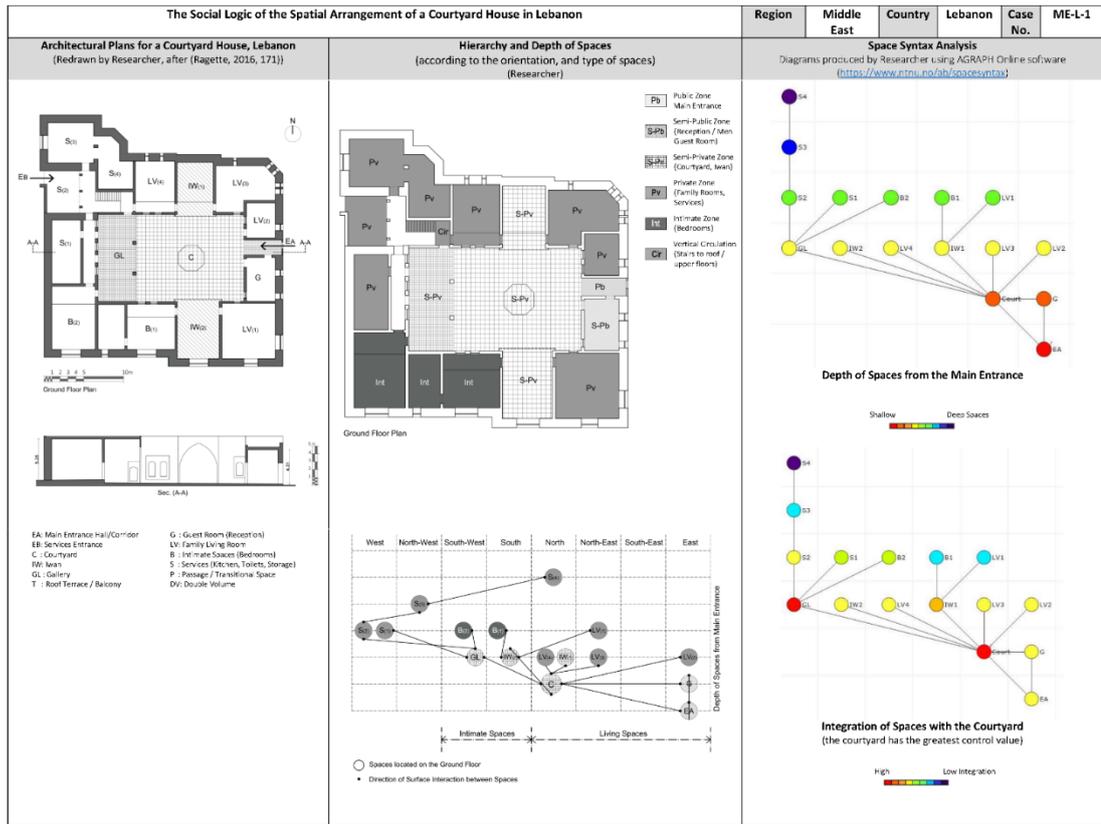


Figure 4.72: Sample of space syntax diagrams for a courtyard house located in Syria

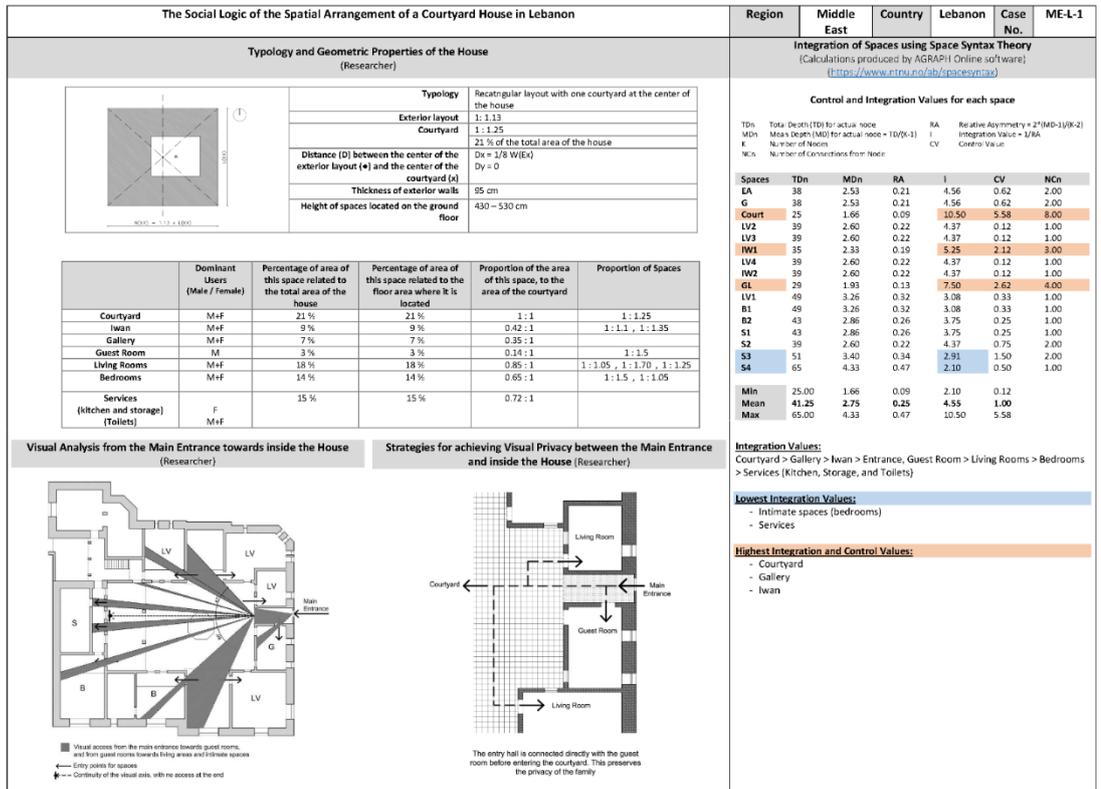


Figure 4.73: Sample of space syntax and geometric calculations for a courtyard house located in Syria

Table 4.42: Spaces that have the highest integration values in traditional houses

| Region                      | Spaces that have the Highest Integration Value (*)<br>(with identifying spaces that are connected with it) |
|-----------------------------|--|
| <b>The Middle East (ME)</b> |  |
| Syria                       | Courtyard → LV, Cir, S, IW, G  |
| Lebanon                     | Courtyard → LV, IW, GL, G  |
| Jordan                      | Gallery → LV, T, B, S, P, C, IW  |
| Palestine                   | Gallery → LV, K, B, C, EB, S   |
| Iraq                        | Courtyard → IW, B, K, Cir, GL  |
| <b>North Africa (NA)</b>    |  |
| Egypt                       | Gallery → C, K, LV, B, S   |
| Tunisia                     | Courtyard → LV, K, S, P  |
| Morocco                     | Gallery → G, C, E, LV, K, CIR  |
| Algeria                     | Courtyard → LV, GL, EA   |
| <b>The Gulf Area (GA)</b>   |  |
| KSA                         | Courtyard → LV, D, K, GL, P, S   |
| UAE                         | Courtyard → P, GL, B   |
| Oman                        | Courtyard → G, CIR, S, P, EA   |
| Kuwait                      | Courtyard → GL, LV, G, B, P  |
| Yemen                       | Courtyard → CIR, LV, G, K, S   |

(\*) based on space syntax analysis carried out using *DepthmapX* and *AGraph* software

EA: Main Entrance, C: Main Courtyard, C(s): Service courtyard, IW: Iwan, GL: Gallery, CIR: Stair  
EB: Service Entrance P: Passage/corridor, LV: Living room, K: Kitchen, S: Services, B: Bedrooms

Table 4.43: Hierarchy of spaces based on depth values for traditional houses

| Region                      | Depth of Spaces based on the Relative Asymmetry Value (*)          |
|-----------------------------|--|
| <b>The Middle East (ME)</b> |  |
| Syria                       | T > B > S > GL > LV > G > E > IW > P > C                           |
| Lebanon                     | S > B > LV > IW > E > G > IW > GL > C                              |
| Jordan                      | S > T > LV > S > EB > S > GL > E > G > B > IW > C > GL             |
| Palestine                   | E > C > S > LV > B > G > EB > G > K > GL                           |
| Iraq                        | G > S > B > LV > S > E > T > IW > B > K > GL > Cir > C             |
| <b>North Africa (NA)</b>    |  |
| Egypt                       | B > G > S > K > S > LV > EA > C > GL                               |
| Tunisia                     | G > B > EA > K > S > LV > P > C                                    |
| Morocco                     | B > EA > G > C > LV > K > S > GL > CIR                             |
| Algeria                     | B > S > K > S > LV > G > T > GL > LV > C > EA > CIR                |
| <b>The Gulf Area (GA)</b>   |  |
| KSA                         | EB > C(SER) > S > B > EA > G > LV > D > K > S > P > GL > C         |
| UAE                         | S > G > S > B > EA > LV > S > GL > LV > P > C > GL                 |
| Oman                        | S > K > LV > T > P > B > LV > P > S > G > EA > P > T > P > CIR > C |
| Kuwait                      | G > S > EA > B > S > K > B > LV > P > GL > P > C                   |
| Yemen                       | S > K > B > LV > EA > B > T > P > LV > G > S > P > CIR > C         |

(\*) based on space syntax analysis carried out using *DepthmapX* and *AGraph* software

EA: Main Entrance, C: Main Courtyard, C(s): Service courtyard, IW: Iwan, GL: Gallery, CIR: Stair  
EB: Service Entrance P: Passage/corridor, LV: Living room, K: Kitchen, S: Services, B: Bedrooms

Table 4.44: Hierarchy of spaces based on control values for traditional courtyard houses

| Region                      | Spaces that have the Highest Control Value (*)               |
|-----------------------------|--|
| <b>The Middle East (ME)</b> |  |
| Syria                       | C > Cir > IW > B > E > S > GL > G > LV > S > B > LV          |
| Lebanon                     | C > GL > IW > S > E > G > LV > B > LV > IW                   |
| Jordan                      | GL > P > G > IW > B > S > LV > T > C > S > Cir > E           |
| Palestine                   | GL > G > K > B > LV > EB > G > E > C > S                     |
| Iraq                        | C > GL > T > IW > E > GL > IW > B > G > Cir > S > B > LV > K |
| <b>North Africa (NA)</b>    |  |
| Egypt                       | GL > EA > LV > B > C > G > S > K > B > S                     |
| Tunisia                     | C > EA > LV > P > G > B > K > S                              |
| Morocco                     | GL > C > B > EA > G > C > LV > K > S                         |
| Algeria                     | T > GL > CIR > C > LV > EA > B > S > K > G                   |
| <b>The Gulf Area (GA)</b>   |  |
| KSA                         | C > GL > C(SER) > EA > G > P > EB > S > B > LV > D > K > S   |
| UAE                         | C=EA > P > GL > B > LV > S > P > GL > G > S > B              |
| Oman                        | C > P > T > EA > CIR > S > K > LV > B > S > G                |
| Kuwait                      | C > P > GL > EA > LV > P > G(M) > S > B > S > K > G(FM) > B  |
| Yemen                       | C > T > EA > P > CIR > S > K > B > LV > G > K > S            |

(\*) based on space syntax analysis carried out using *DepthmapX* and *AGraph* software

EA: Main Entrance, C: Main Courtyard, C(s): Service courtyard, IW: Iwan, GL: Gallery, CIR: Stair  
EB: Service Entrance P: Passage/corridor, LV: Living room, K: Kitchen, S: Services, B: Bedrooms

### - Social Indicator (3): Social Interaction and Living Spaces

Different spaces inside the house considered as active architectural elements that facilitate social gathering between the family members. Traditional houses offer a half area of the house for social interaction, and more than the third area of the house with a variety of seasonal semi-private and private spaces (Table 4.45). These living spaces are ranged from closed areas, such as living rooms, which represent 12% of the total area of the house; to semi-open spaces, such as *iwans*, which represent 7% from the total area; and open spaces, including courtyards, terraces, and balconies that represent 16% from the total area. Moreover, the amount of living spaces in comparison to the area of guest rooms is a significant aspect that accommodates the daily living activities, and at the same time encourages the interaction between the family members. The spatial analysis of cases shows that guest rooms accommodate approximately 7-8% of the total area of the house, which represents only the quarter of living rooms' area.

The courtyard, which is an open-to-sky private space for the family, represents the main feature of traditional houses in MENA region. In most cases, it is located at the centre of the layout and surrounded by rooms. However, it could be located adjacent to the southern, eastern, or western edges of the house (Figure 4.74).

In some countries, such as Lebanon, Saudi Arabia, and Yemen, the courtyard is replaced by a covered main hall. Yet, this hall has the same function of the courtyard as a transitional

area and gathering space. Such variations are due to the need for protection against the cold weather and the heavy rainfalls produced, or due to the vertical expansion of houses.

Table 4.45: Types and percentages of living spaces in comparison to the area of guest room(s)

| Region                                       | % of Area for Covered Living Space | % of Area for Iwan (Semi-open Living Space) | % of Area for Courtyard (Open Living Space) | % of Area for Terraces and Balconies | % of Area for Guest Rooms |
|--|------------------------------------|---|---|--------------------------------------|---------------------------|
| <b>The Middle East (ME)</b>                  |                                    |   |   |                                      |                           |
| Syria  | 15.5 %                             | 5.1 %                                       | 22.2 %                                      | 16.5 %                               | 6.5 %                     |
| Lebanon                                      | 16.1 %                             | 5.8 %                                       | 25.5 %                                      | 8.5 %                                | 5.1 %                     |
| Jordan                                       | 7.6 %                              | 2.5 %                                       | 12.9 %                                      | 25.8 %                               | 13.1 %                    |
| Palestine                                    | 7.1 %                              | 3.4 %                                       | 17.4 %                                      | 22.2 %                               | 7.4 %                     |
| Iraq   | 13.1 %                             | 7.9 %                                       | 13.1 %                                      | 6.0 %                                | 4.5 %                     |
| AVG  | <b>11.88 %</b>                     | <b>4.94 %</b>                               | <b>18.22 %</b>                              | <b>15.8 %</b>                        | <b>7.32 %</b>             |
| <b>North Africa (NA)</b>                     |                                    |   |   |                                      |                           |
| Egypt  | 8.8 %                              | 12.7 %                                      | 14.3 %                                      | 6.7 %                                | 11.8 %                    |
| Tunisia                                      | 20.6 %                             | 5.9 %                                       | 29.8 %                                      | 10.1 %                               | 4.6 %                     |
| Morocco                                      | 7.9 %                              | -   | 10.4 %                                      | 13.0 %                               | 7.3 %                     |
| Algeria                                      | 11.7 %                             | -   | 9.4 %                                       | 14.9 %                               | 8.4 %                     |
| AVG  | <b>12.25 %</b>                     | <b>9.30 %</b>                               | <b>15.98 %</b>                              | <b>11.2 %</b>                        | <b>8.03 %</b>             |
| <b>The Gulf Area (GA)</b>                    |                                    |   |   |                                      |                           |
| KSA  | 9.8 %                              | -   | 8.8 %                                       | 24.9 %                               | 9.8 %                     |
| UAE  | 17.6 %                             | -   | 17.5 %                                      | 0.5 %                                | 3.3 %                     |
| Oman   | 7.9 %                              | -   | 15.8 %                                      | 21.7 %                               | 7.9 %                     |
| Kuwait                                       | 9.2 %                              | -   | 20.6 %                                      | 16.8 %                               | 9.3 %                     |
| Yemen  | 10.5 %                             | -   | 6.4 %                                       | 15.9 %                               | 6.7 %                     |
| AVG  | <b>11.00 %</b>                     | -   | <b>13.82 %</b>                              | <b>16.0 %</b>                        | <b>7.40 %</b>             |
| AVG (Study Area)                             | <b>11.71 %</b>                     | <b>7.12 %</b>                               | <b>16.00 %</b>                              | <b>14.33 %</b>                       | <b>7.58 %</b>             |
| <b>Total Area of Social Spaces = 49.16 %</b> |                                    |   |   |                                      |                           |

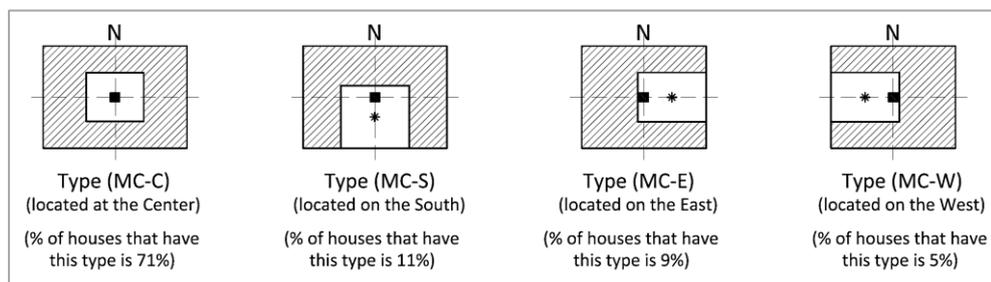


Figure 4.74: Diagrams showing location of the courtyard in vernacular houses

*Iwan* is a double-volume summer living room, with an openly shared surface with the courtyard. The analysis shows that this spatial element does not exist in the Gulf area, due to the harsh climate. In contrast, it is a central feature in traditional houses in the Middle East and North Africa. Mostly, it is located on the southern side of the courtyard, and opens

to the north. However, other locations of *iwan* have been traced from the analysis of courtyard houses in MENA region (Figure 4.75).

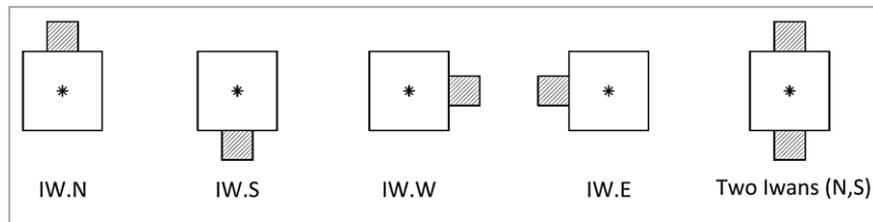


Figure 4.75: Diagrams showing location of *iwan* in vernacular houses

#### - Social Indicator (4): Human Comfort

Human comfort inside houses could be divided into two types: thermal comfort, and psychological comfort. Thermal comfort depends on different spatial factors: availability of open spaces, the orientation of spaces, size of windows, and height of the ceiling. Psychological wellbeing inside the house is associated with geometric properties of spaces, especially living areas.

Regarding the geometric properties of spaces, courtyards and *iwans* have a square-shape with an average proportion equals to 1:1.24 and 1:1.28, respectively. Living spaces and guest rooms have more elongated shape, with an average proportion equals 1:1.88 and 1:2.70, respectively. Another observation is that most private spaces are facing the courtyard, and have approximately the same distance between the centre of the courtyard and the entry point of those spaces. This depth, which ranges between 5.65 and 7.30 meters, provides a suitable distance for the residents to live in a comfortable atmosphere (Table 4.46). However, most intimate spaces (bedrooms) should be accessed through private spaces to achieve more privacy.

Based on the spatial analysis of traditional houses in MENA region, results show that courtyards represent 20%, approximately, from the total area of the house. Moreover, semi-open spaces, with a percent of 14% relative to the total area, offer a comfortable living summer spaces for the family (Tables 4.47 and 4.48). Furthermore, the availability of high ceilings (423 cm, as an average) plays an essential role in achieving moderate atmosphere inside the house in comparison to the harsh outside climate (Table 4.49).

Table 4.46: Geometric properties and the orientation of main spaces

| Region                      | Courtyard       |                   | <i>Iwan</i>     |                   | Living Room     |                    | Guest Room      |                    |
|-----------------------------|-----------------|-------------------|-----------------|-------------------|-----------------|--------------------|-----------------|--------------------|
|                             | Proportion      | Orientation       | Proportion      | Orientation       | Proportion      | Orientation        | Proportion      | Orientation        |
| <b>The Middle East (ME)</b> |                 |                   |                 |                   |                 |                    |                 |                    |
| Syria                       | 1 : 1.10        | S, N, CEN.        | 1 : 1.19        | E, S              | 1 : 2.09        | N, W, SE           | 1 : 1.38        | W, S, NW           |
| Lebanon                     | 1 : 1.51        | CEN., E, W        | 1 : 1.35        | S, N              | 1 : 1.29        | SE, S, SW,<br>N, W | 1 : 1.39        | E, N, SE, NW       |
| Jordan                      | 1 : 1.19        | CEN.              | 1 : 1.33        | W                 | 1 : 2.05        | W                  | 1 : 4.57        | E                  |
| Palestine                   | 1 : 1.08        | E, S              | 1 : 1.8         | W                 | 1 : 1.17        | N, E, W            | 1 : 1.17        | NE, NW, W          |
| Iraq                        | 1 : 1.28        | CEN., N.          | 1 : 1.34        | S, E, N,<br>NW, W | 1 : 2.35        | S, W, SW,<br>NE    | 1 : 1.92        | S, E, SE           |
| AVG                         | <b>1 : 1.23</b> |                   | <b>1 : 1.40</b> |                   | <b>1 : 1.79</b> |                    | <b>1 : 2.09</b> |                    |
| <b>North Africa (NA)</b>    |                 |                   |                 |                   |                 |                    |                 |                    |
| Egypt                       | 1 : 1.35        | S, SE, CEN.       | 1 : 1           | S                 | 1 : 1.24        | E                  | 1 : 1.60        | SW, S, N           |
| Tunisia                     | 1 : 1.50        | E, CEN.           | 1 : 1.32        | S, N, E           | 1 : 2.58        | S, W, N, E         | 1 : 2.22        | SE, S, W,<br>NE, E |
| Morocco                     | 1 : 1.09        | CEN.              |                 |                   | 1 : 3.25        | E, N               | 1 : 3.86        | W, N               |
| Algeria                     | 1 : 1.13        | W                 |                 |                   | 1 : 1.72        | E, N               | 1 : 2.78        | S                  |
| AVG                         | <b>1 : 1.27</b> |                   | <b>1 : 1.16</b> |                   | <b>1 : 2.20</b> |                    | <b>1 : 3.40</b> |                    |
| <b>The Gulf Area (GA)</b>   |                 |                   |                 |                   |                 |                    |                 |                    |
| KSA                         | 1 : 1.22        | CEN., N, E,<br>SE |                 |                   | 1 : 1.52        | S, E, SE           | 1 : 1.64        | SE, SW, W, S       |
| UAE                         | 1 : 1           | CEN.              |                 |                   | 1 : 1.58        | W                  | 1 : 3.32        | W                  |
| Oman                        | 1 : 1.15        | CEN.              |                 |                   | 1 : 1.57        | W                  | 1 : 3.77        | E                  |
| Kuwait                      | 1 : 1.03        | CEN., E           |                 |                   | 1 : 1.21        | S, W, SE           | 1 : 1.48        | S, E               |
| Yemen                       | 1 : 1.66        | CEN.              |                 |                   | 1 : 2.31        | SE, NW             | 1 : 2.88        | SE, NW             |
| AVG                         | <b>1 : 1.21</b> |                   |                 |                   | <b>1 : 1.64</b> |                    | <b>1 : 2.62</b> |                    |
| AVG<br>(Study<br>Area)      | <b>1 : 1.24</b> |                   | <b>1 : 1.28</b> |                   | <b>1 : 1.88</b> |                    | <b>1 : 2.70</b> |                    |

Table 4.47: Spatial and geometric properties of courtyards in traditional houses

| Region                      | Main Courtyard      |                 |   | Service Courtyard   |                 |   |
|-----------------------------|---------------------|-----------------|---|---------------------|-----------------|---|
|                             | % of the Total Area | Proportions     | Distance (between the centre of the courtyard and the centre of the overall layout) | % of the Total Area | Proportions     | Distance (between the centre of the courtyard and the centre of the overall layout) |
| <b>The Middle East (ME)</b> |                     |                 |   |                     |                 |   |
| Syria                       | 22.2 %              | 1 : 1.10        | (1.51, 0.81)  |                     |                 |   |
| Lebanon                     | 25.5 %              | 1 : 1.51        | (0.83, -0.43)   | 1 %                 | 1 : 1           | (2.2, 0.15)   |
| Jordan                      | 12.9 %              | 1 : 1.19        | (-0.28, -0.78)  |                     |                 |   |
| Palestine                   | 17.4 %              | 1 : 1.08        | (2.89, -0.93)   |                     |                 |   |
| Iraq                        | 13.1 %              | 1 : 1.28        | (-0.98, 0.95)   | 2 %                 | 1 : 1.09        | (3.95, 5.58)  |
| AVG                         | <b>18.22 %</b>      | <b>1 : 1.23</b> |   | <b>1.5 %</b>        | <b>1 : 1.05</b> |   |
| <b>North Africa (NA)</b>    |                     |                 |   |                     |                 |   |
| Egypt                       | 14.3 %              | 1 : 1.35        | -0.41, -2.78  | 1.8 %               | 1 : 1.17        | (-8.83, 3.71)   |
| Tunisia                     | 29.8 %              | 1 : 1.50        | 1.19, 1.55  |                     |                 |   |
| Morocco                     | 10.4 %              | 1 : 1.09        | 0.20, -0.46   |                     |                 |   |
| Algeria                     | 9.4 %               | 1 : 1.13        | 0.63, 0.22  |                     |                 |   |
| AVG                         | <b>15.98 %</b>      | <b>1 : 1.27</b> |   | <b>1.8 %</b>        | <b>1 : 1.17</b> |   |
| <b>The Gulf Area (GA)</b>   |                     |                 |   |                     |                 |   |
| KSA                         | 8.8 %               | 1 : 1.22        | (0.55, 0.10)  | 9.2 %               | 1 : 1.99        |   |
| UAE                         | 17.5 %              | 1 : 1           | (1.84, 0.39)  |                     |                 |   |
| Oman                        | 15.8 %              | 1 : 1.15        | (-1.48, -1.48)  |                     |                 |   |
| Kuwait                      | 20.6 %              | 1 : 1.03        | (-2.10, 1.39)   | 5.8 %               | 1 : 1.55        |   |
| Yemen                       | 6.4 %               | 1 : 1.66        | (-0.38, 0.00)   |                     |                 |   |
| AVG                         | <b>13.82 %</b>      | <b>1 : 1.21</b> |   | <b>7.5 %</b>        | <b>1 : 1.77</b> |   |
| AVG (Study Area)            | <b>16 %</b>         | <b>1 : 1.24</b> |   | <b>3.6 %</b>        | <b>1 : 1.33</b> |   |

Table 4.48 Percentages of open, semi-open and covered spaces relative to the total area of the house

| Region                      | % of the Area from the Total Area of the House |                       |                     |
|-----------------------------|--|-----------------------|---------------------|
|                             | % of Open Spaces                               | % of Semi-open Spaces | % of Covered Spaces |
| <b>The Middle East (ME)</b> |  |                       |                     |
| Syria                       | 27.5 %   | 10.7 %                | 61.8 %              |
| Lebanon                     | 21.0 %   | 13.3 %                | 65.7 %              |
| Jordan                      | 14.3 %   | 18.3 %                | 67.4 %              |
| Palestine                   | 15.5 %   | 22.3 %                | 62.2 %              |
| Iraq                        | 10.3 %   | 23.8 %                | 65.9 %              |
| AVG                         | <b>17.7 %</b>                                  | <b>17.68 %</b>        | <b>64.62 %</b>      |
| <b>North Africa (NA)</b>    |  |                       |                     |
| Egypt                       | 11.4 %   | 12.7 %                | 75.9 %              |
| Tunisia                     | 22.8 %   | 13.6 %                | 63.6 %              |
| Morocco                     | 7.9 %  | 29.2 %                | 62.9 %              |
| Algeria                     | 7.3 %  | 8.8 %                 | 83.9 %              |
| AVG                         | <b>12.35 %</b>                                 | <b>16.08 %</b>        | <b>71.85 %</b>      |
| <b>The Gulf Area (GA)</b>   |  |                       |                     |
| KSA                         | 10.5 %   | 12.7 %                | 76.8 %              |
| UAE                         | 13.6 %   | 12.5 %                | 73.9 %              |
| Oman                        | 20.3 %   |                       | 79.7 %              |
| Kuwait                      | 19.0 %   | 12.3 %                | 68.7 %              |
| Yemen                       | 4.7 %  |                       | 95.3 %              |
| AVG                         | <b>13.62 %</b>                                 | <b>12.5 %</b>         | <b>78.88 %</b>      |
| AVG (Study Area)            | <b>14.56 %</b>                                 | <b>13.66 %</b>        | <b>71.78 %</b>      |

Table 4.49: Height of ceiling

| Region                  | Height of Ceiling (cm) |
|-------------------------|------------------------|
| The Middle East         | 433                    |
| North Africa            | 412                    |
| The Gulf Area           | 423                    |
| <i>AVG (Study Area)</i> | <b>423</b>             |

#### - Social Indicator (5): Accessibility

Different types of entrances could be found in traditional courtyard houses. These include a separate entrance for guests; an entrance for the family members; and a service entrance, which is connected directly to the kitchen and storage spaces. All of these types are usually connected with an entry hall, and then with transitional spaces, such as a courtyard, gallery, or stair that leads to the first floor of the house. Regarding the circulation system inside the house, observations show that transitional spaces, which are connected with private and intimate spaces, are small halls rather than narrow corridors. The total area of such areas, in addition to the area of vertical stairs leading to upper floors, represents approximately 10% relative to the area of the house (Table 4.50).

In vertical houses, stairs are private spaces and connected with courtyards. In some cases, when the guest room is located on the first floor, the stair is connected directly to the main entry hall. On upper floors, the landing is connected with semi-private areas, which include terraces, galleries or transitional spaces (Figure 4.76, and Table 4.51).

Another issue, which is related to the accessibility, is that most spaces on each floor have the same level, except *iwans*, which are usually raised one to two steps from the courtyard. Moreover, some private spaces, such as living rooms, have a sunken floor at the entry space, where shoes and tools are placed, and to protect such spaces from the dust entered from the courtyard. However, this could have negative impact on the movement of people, especially the elderly and children. The same problem is in vertical houses where functions are distributed on floors.

Table 4.50: Entrances and transitional spaces inside the house

| Region                      | The Main Entry Hall |  | Service Entrance |  | Transitional Spaces (stairs, corridors) |  |
|-----------------------------|---------------------|--|------------------|--|---|--|
|                             | % of Area           | Spaces that are connected with Entry Hall(s) | % of Area        | Spaces that are connected with Service Entrance(s) | % of Area                               | Spaces that are connected with Transitional Spaces |
| <b>The Middle East (ME)</b> |                     |  |                  |  |   |  |
| Syria                       | 1.2 %               | EA → C, G                                    | 1.7 %            | EB → C, S  | 4.4 %                                   | P/Cir → B, T                                       |
| Lebanon                     | 2.9 %               | EA → C, G, LV                                | 2.7 %            | EB → S   | 4.3 %                                   | P/Cir → S, LV, G                                   |
| Jordan                      | 1.6 %               | EA → G, GL                                   |                  |  | 4.6 %                                   | P/Cir → GL, T                                      |
| Palestine                   | 2.6 %               | EA → GL, G, P                                | 1.2 %            | EB → GL, K   | 10.0 %                                  | P/Cir → LV, B, S, EA                               |
| Iraq                        | 2.9 %               | EA → GL, G                                   | 0.5 %            | EB → C(S)  | 8.4 %                                   | P/Cir → C, GL                                      |
| AVG                         | <b>2.2 %</b>        |  | <b>1.5 %</b>     |  | <b>6.3 %</b>                            |  |
| <b>North Africa (NA)</b>    |                     |  |                  |  |   |  |
| Egypt                       | 4.5 %               | EA → G, C, S                                 | 1.8 %            | EB → S   | 14 %                                    | P/Cir → LV, C, B, EA,                              |
| Tunisia                     | 6.5 %               | EA → P, C, GL                                | 2.2 %            | EB → P, S  | 7.7 %                                   | P/Cir → C, GL, LV, S, G, EA, EB                    |
| Morocco                     | 2.7 %               | EA → GL, C, G, CIR                           | 1.2 %            | EB → C   | 5.8 %                                   | P/Cir → S, GL, C, T. EA                            |
| Algeria                     | 7.7 %               | EA → CIR, P, GL                              |                  |  | 9.0 %                                   | P/Cir → GL, S, LV, G. EA                           |
| AVG                         | <b>5.3 %</b>        |  | <b>1.7 %</b>     |  | <b>9.1 %</b>                            |  |
| <b>The Gulf Area (GA)</b>   |                     |  |                  |  |   |  |
| KSA                         | 4.1 %               | EA → GL, G                                   | 3.4 %            | EB → C(S), GL, K, P                                | 11.1 %                                  | P/Cir → S, LV, C, EB                               |
| UAE                         | 1.1 %               | EA → G, S                                    | 1.3 %            | EB → C   | 13.6 %                                  | P/Cir → S, LV, C                                   |
| Oman                        | 2.4 %               | EA → C                                       |                  |  | 26.3 %                                  | P/Cir → B, LV, C, S, T                             |
| Kuwait                      | 3.8 %               | EA → P, G, GL                                | 1.6 %            | EB → P, S, C, GL, LV                               | 6.6 %                                   | P/Cir → C, B, S, EA, EB                            |
| Yemen                       | 2.9 %               | EA → T, P                                    |                  |  | 18.3 %                                  | P/Cir → EA, S, B                                   |
| AVG                         | <b>2.8 %</b>        |  | <b>2.1 %</b>     |  | <b>15.2 %</b>                           |  |
| <b>AVG (Study Area)</b>     | <b>3.43 %</b>       |  | <b>1.77 %</b>    |  | <b>10.2 %</b>                           |  |

EA: Main Entrance, C: Main Courtyard, C(s): Service courtyard, IW: Iwan, GL: Gallery, CIR: Stair  
 EB: Service Entrance P: Passage/corridor, LV: Living room, K: Kitchen, S: Services, B: Bedrooms

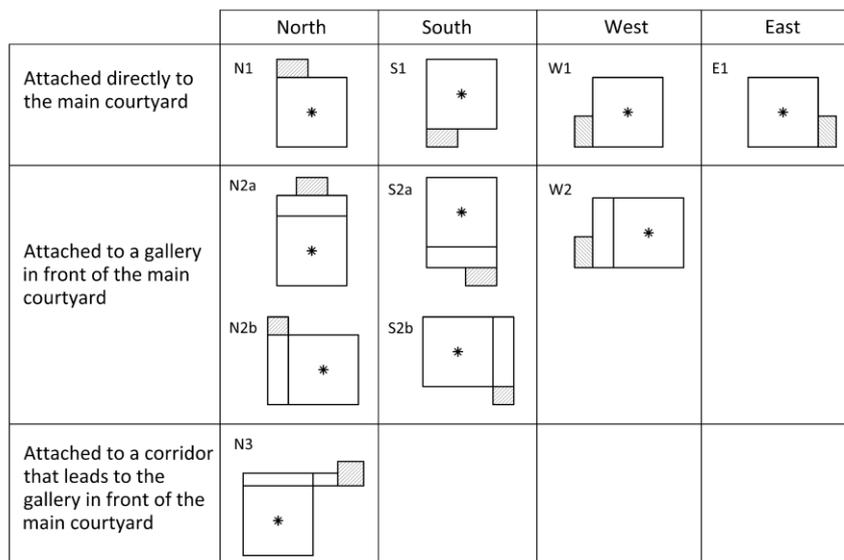


Figure 4.76: Diagrams showing location of the main entry hall in vernacular houses

Table 4.51: Arrangement of functions in vertical houses

| Region                      | Functions located on the Ground Floor | Functions located on Upper Floors |
|-----------------------------|---------------------------------------|-----------------------------------|
| <b>The Middle East (ME)</b> |                                       |                                   |
| Syria                       | EA, EB, C, IW, G, LV, S               | B, T, LV, S                       |
| Lebanon                     | EA, EB, C, GL, G, LV, S, B            | B, T, LV, GL, IW, S               |
| Jordan                      | EA, EB, C, GL, G, S                   | B, T, LV, GL, IW, S               |
| Palestine                   | -                                     | -                                 |
| Iraq                        | EA, EB, C, IW, GL, G, LV, S           | B, T, LV, GL, IW, S               |
| <b>North Africa (NA)</b>    |                                       |                                   |
| Egypt                       | EA, EB, C, IW, GL, G, LV, S           | B, T, LV, GL, IW, S               |
| Tunisia                     | EA, EB, C, IW, GL, G, LV, S           | B, T, LV, GL, IW, S               |
| Morocco                     | EA, EB, C, IW, GL, G, LV, S           | B, T, LV, GL, IW, S               |
| Algeria                     | EA, EB, C, IW, GL, G, LV, S           | B, T, LV, GL, IW, S               |
| <b>The Gulf Area (GA)</b>   |                                       |                                   |
| KSA                         | EA, EB, C, GL, S, LV                  | B, T, LV(M), S                    |
| UAE                         | EA, G, S, B, LV, C                    | LV, S, T                          |
| Oman                        | EA, G, S, B, LV, C                    | LV, S, T                          |
| Kuwait                      | -                                     | -                                 |
| Yemen                       | EA, S                                 | G, C, S, LV                       |

EA: Main Entrance, C: Main Courtyard, C(s): Service courtyard, IW: Iwan, GL: Gallery, CIR: Stair  
 EB: Service Entrance P: Passage/corridor, LV: Living room, K: Kitchen, S: Services, B: Bedrooms

#### - Social Indicator (6): Visual Privacy

Based on the spatial analysis of courtyard houses, the following are the main strategies that have been used for achieving the privacy of the family:

- Guest rooms are located adjacent to the main entry hall (Figure 4.77).
- The use of spatial barriers (such as solid walls, and bent entrances) in front of main doors (Figures 4.78 and 4.79).
- The guest room has a direct access from the main entry hall before entering the courtyard.
- In most cases, bedrooms and living rooms, which are private/intimate spaces and used dominantly by women, need to be entered from *iwan* (a semi-private space), and not from the courtyard (Figure 4.80).
- Visual fields from doors of guest rooms or along the path of guests towards private spaces are protected (Figures 4.81 and 4.82).
- The use of narrow windows in semi-public spaces (guest room) when they are connected with courtyards.

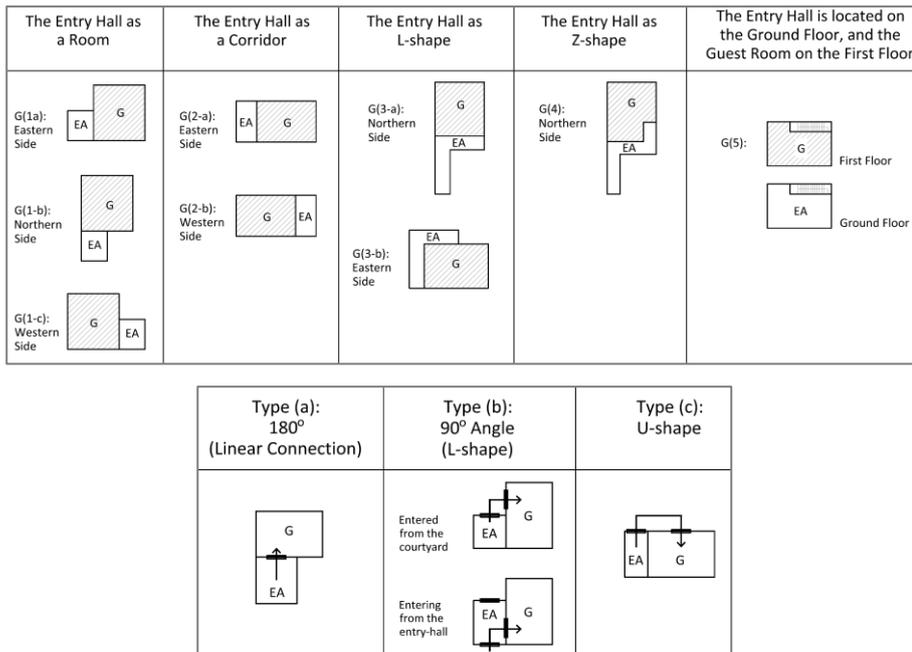


Figure 4.77: Diagrams showing movement patterns and location of guest rooms in relation to the main entry hall in vernacular houses

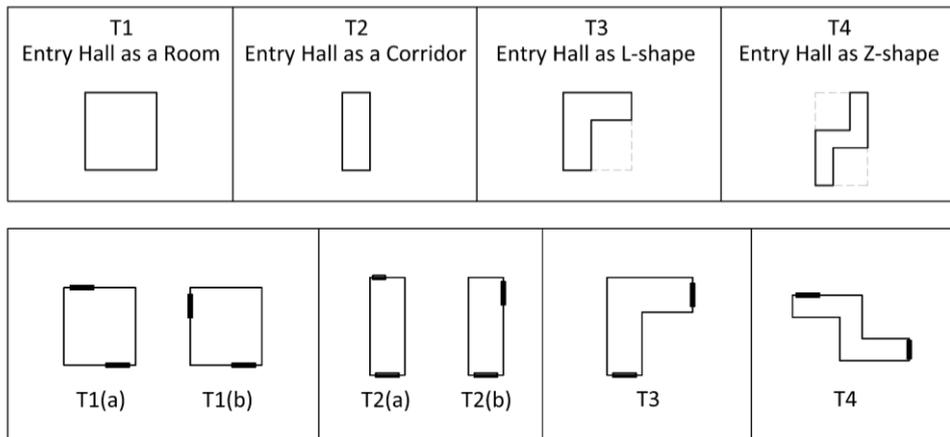


Figure 4.78: Diagrams showing location of openings for the main entry hall in vernacular houses

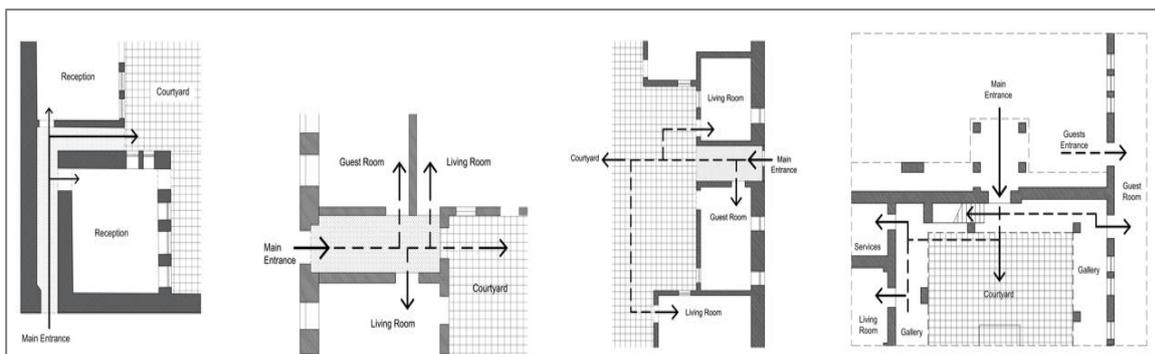


Figure 4.79: Diagrams showing the direct access from the main entry hall to guest room in vernacular houses

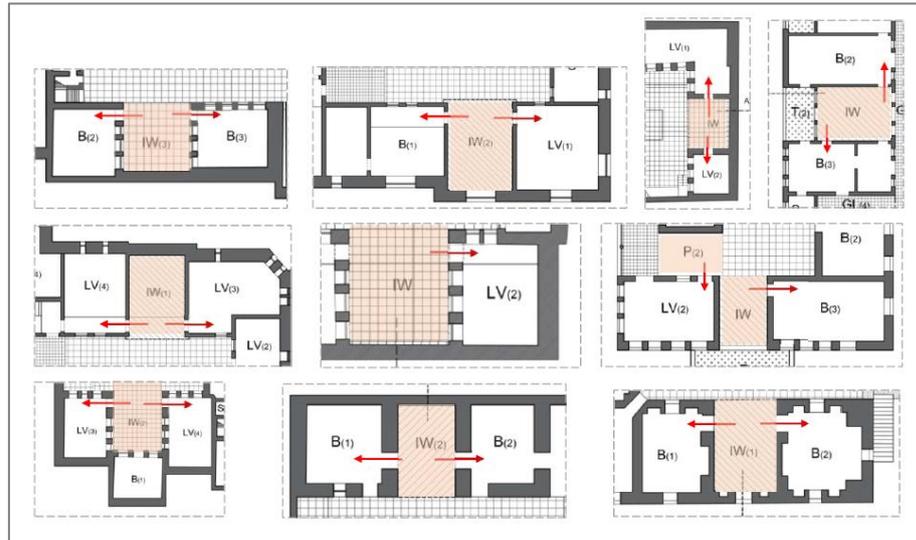


Figure 4.80: Diagrams showing the movement access from *iwan* to bedrooms and living rooms

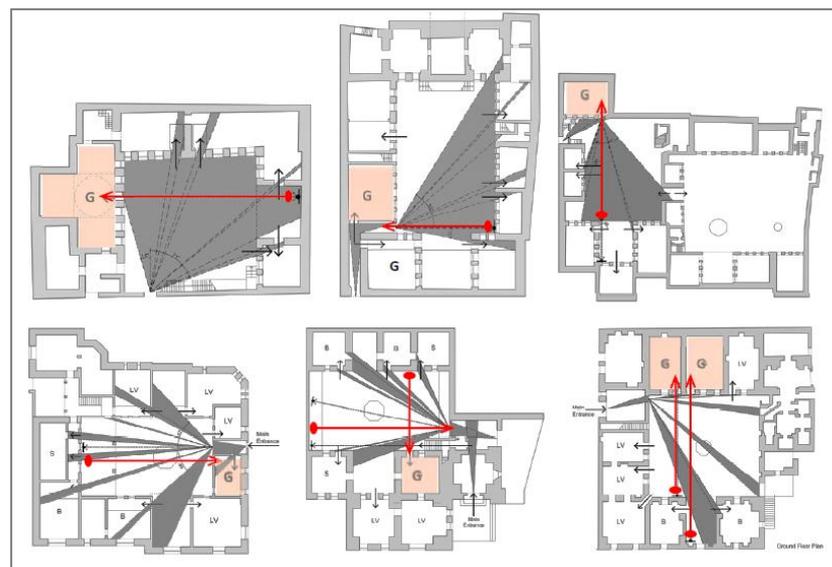


Figure 4.81: Visual fields from doors of guest rooms toward private spaces

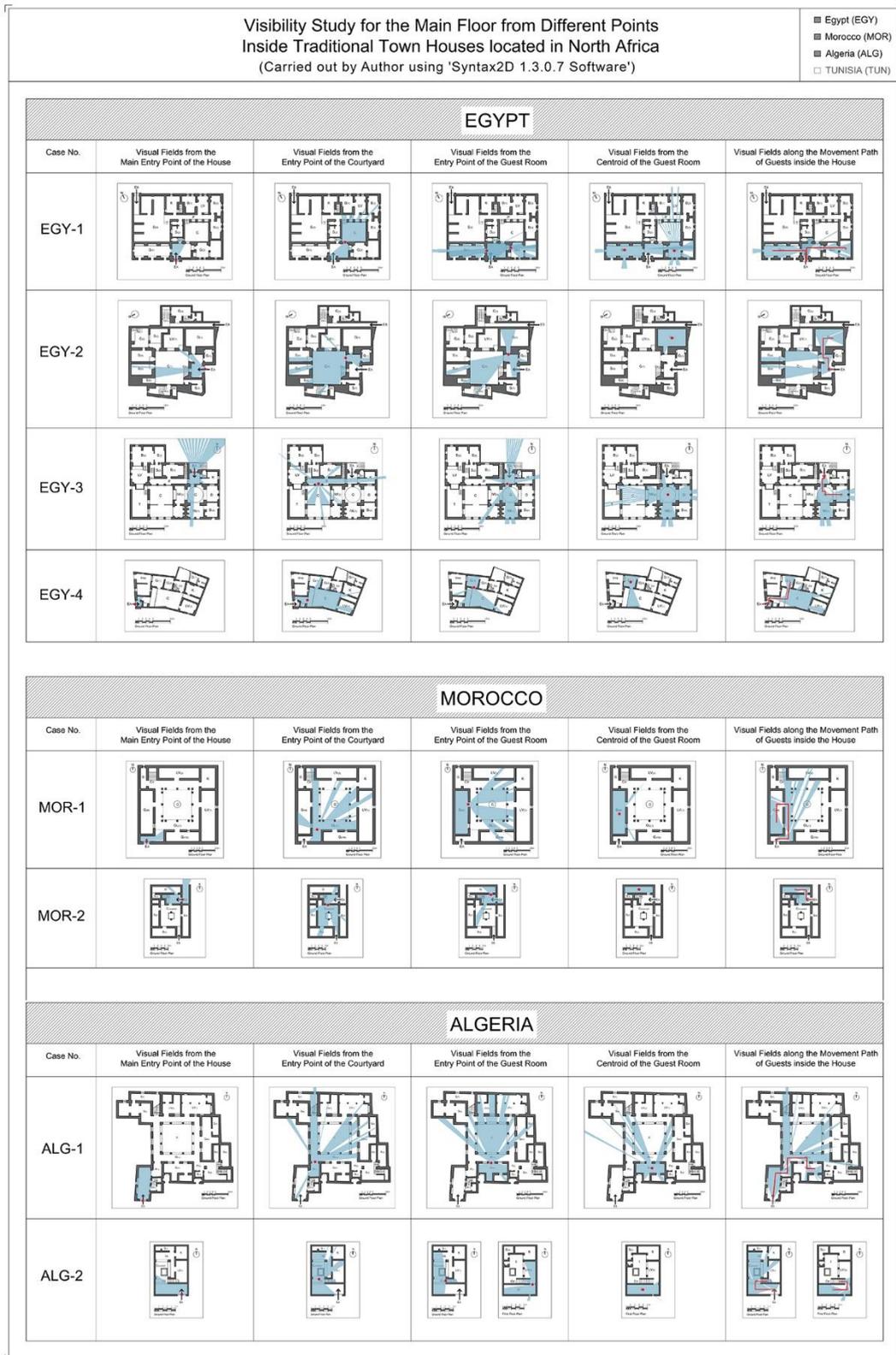


Figure 4.82: *Isovist* analysis for traditional courtyard houses located in North Africa, produced by 'Syntax2D 1.3.0.7' software

### - Social Indicator (7): Acoustical Privacy

Four strategies are used for achieving acoustical privacy inside traditional houses:

- The vertical separation between living rooms, which are active spaces, and intimate spaces, which are the quiet zone in the house, through allocating bedrooms on upper floors (Figure 4.83).
- The horizontal separation between living rooms and bedrooms through the courtyard as a transitional space that reduces noise (Figure 4.84).
- Thick exterior walls, which vary between 37 cm and 83 cm (Table 4.52).
- The use of soft landscaping, such as trees and water features in courtyards.

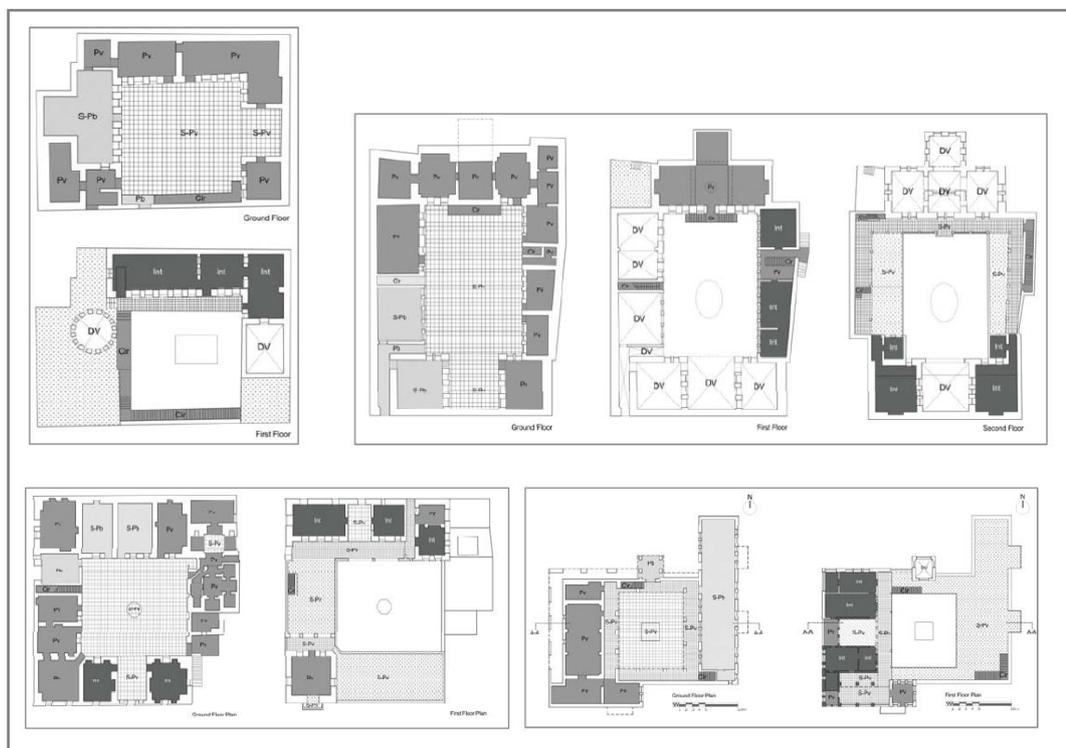


Figure 4.83: Vertical separation between living rooms (private spaces) and bedrooms (intimate spaces) in two-floor houses

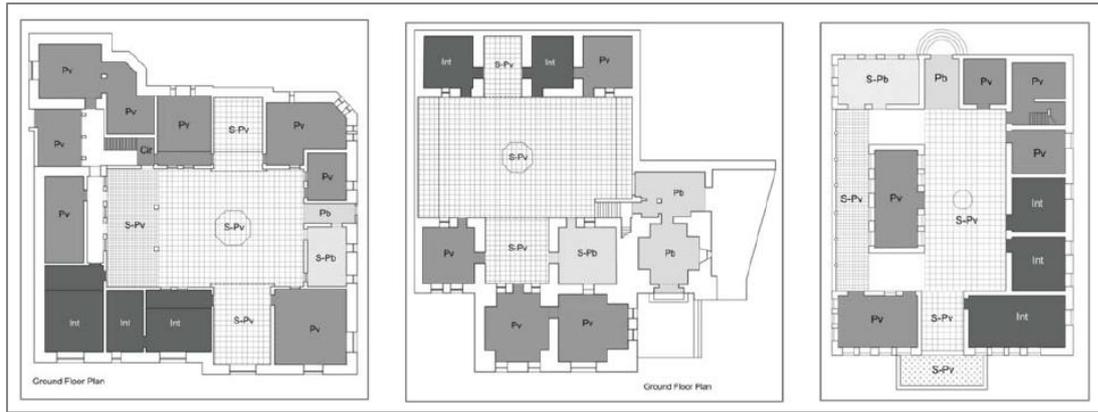


Figure 4.84: Horizontal separation between living rooms and bedrooms through courtyards in single-floor houses

Table 4.52: Thickness of exterior walls and shared surfaces between adjacent houses

| Region                      | Thickness of Exterior Walls (cm) |
|-----------------------------|----------------------------------|
| <b>The Middle East (ME)</b> |                                  |
| Syria                       | 82                               |
| Lebanon                     | 83                               |
| Jordan                      | 50                               |
| Palestine                   | 76                               |
| Iraq                        | 70                               |
| AVG                         | <b>72</b>                        |
| <b>North Africa (NA)</b>    |                                  |
| Egypt                       | 60                               |
| Tunisia                     | 66                               |
| Morocco                     | 75                               |
| Algeria                     | 55                               |
| AVG                         | <b>64</b>                        |
| <b>The Gulf Area (GA)</b>   |                                  |
| KSA                         | 48                               |
| UAE                         | 65                               |
| Oman                        | 40                               |
| Kuwait                      | 37                               |
| Yemen                       | 75                               |
| AVG                         | <b>53</b>                        |
| <b>AVG (Study Area)</b>     | <b>63</b>                        |

#### - Social Indicator (8): Olfactory Privacy

Orientation and location of open spaces and services play an essential role in achieving olfactory privacy. In traditional houses, most terraces are oriented towards east and west directions. Location of courtyards at the centre of the house, or at the south or east sides prevents the transition of cooking smells to neighbours. Moreover, location of kitchen windows toward south or east directions in most cases, considered as a successful strategy for achieving this issue (Table 4.53).

Table 4.53: Orientation of kitchen, courtyard and terraces

| Region                      | Orientation of Kitchen | Orientation of Courtyard | Orientation of Terraces |
|-----------------------------|------------------------|--------------------------|-------------------------|
| <b>The Middle East (ME)</b> |                        |                          |                         |
| Syria                       | N                      | S, N, CEN.               | W, E                    |
| Lebanon                     | NW, SW, N, E           | CEN., E, W               | W, S                    |
| Jordan                      | W                      | CEN.                     | E                       |
| Palestine                   | SW, SE, W              | E, S                     | W, N, E                 |
| Iraq                        | NW, N                  | CEN., N.                 | N                       |
| <b>North Africa (NA)</b>    |                        |                          |                         |
| Egypt                       | W, N, E                | S, SE, CEN.              | W, E                    |
| Tunisia                     | NW, S, E               | E, CEN.                  | N                       |
| Morocco                     | NE, S, N               | CEN.                     |                         |
| Algeria                     | NW, NE                 | W                        | W                       |
| <b>The Gulf Area (GA)</b>   |                        |                          |                         |
| KSA                         | SE, NE, S, E           | CEN., N, E, SE           | W, E                    |
| UAE                         | S                      | CEN.                     |                         |
| Oman                        | N                      | CEN.                     | W, E                    |
| Kuwait                      | NE, N, E               | CEN., E                  |                         |
| Yemen                       | S, N                   | CEN.                     | W, N, E                 |

#### - Social Indicator (9): Spirituality

Sometimes, orientation of spaces inside dwellings to '*qibla*' (which is the direction that should be faced when a Muslim prays) has a symbolic and specific meaning of spiritual focus (Oliver 2003). Moreover, availability of open spaces, which represents 15% from the total area of the house, and the use of water features, plants, and trees in courtyards and terraces add a spiritual atmosphere to the residential environment (Table 4.54).

Table 4.54: Percentage of open spaces relative to the total area of the house

| Region                      | Percentages of Open Spaces relative to the Total Area of the House |
|-----------------------------|--|
| <b>The Middle East (ME)</b> |  |
| Syria                       | 27.5 %   |
| Lebanon                     | 21.0 %   |
| Jordan                      | 14.3 %   |
| Palestine                   | 15.5 %   |
| Iraq                        | 10.3 %   |
| AVG                         | <b>17.7 %</b>  |
| <b>North Africa (NA)</b>    |  |
| Egypt                       | 11.4 %   |
| Tunisia                     | 22.8 %   |
| Morocco                     | 7.9 %  |
| Algeria                     | 7.3 %  |
| AVG                         | <b>12.35 %</b>   |
| <b>The Gulf Area (GA)</b>   |  |
| KSA                         | 10.5 %   |
| UAE                         | 13.6 %   |
| Oman                        | 20.3 %   |
| Kuwait                      | 19.0 %   |
| Yemen                       | 4.7 %  |
| AVG                         | <b>13.62 %</b>   |
| <b>AVG (Study Area)</b>     |  |
|                             | <b>14.56 %</b>   |

- **Social Indicator (10): Security and Safety**

Availability of safe play areas for children and secured open spaces for the family considered a critical factor for achieving social sustainability in residential environments. Moreover, the transition from the outside context (the public zone) to private spaces should accommodate safety for the family. Such criteria have been achieved in traditional houses through courtyards and secured open areas. For instance, the courtyard is surrounded by galleries, and by rooms from three sides at least. Also, this open area is connected with the outside context through covered transitional spaces, such as corridors. Moreover, the location of terraces on upper floors offers privacy and security for the family. Space syntax analysis for the different cases showed that courtyards and terraces have a high depth value when it is measured from the main entrance of the house (Table 4.55, and Figures 4.85 and 4.86).

Table 4.55: Spatial relationships between open spaces and other functions

| Types of Open Spaces | Spaces that are connected with Open and Semi-open Spaces   |
|----------------------|--|
| Courtyard            | $C \rightarrow EA$<br>$C \rightarrow P \rightarrow EA$<br>$C \rightarrow GL \rightarrow EA$<br>$C \rightarrow Cir \rightarrow P \rightarrow EA$<br>$C \rightarrow P \rightarrow S \rightarrow EB$<br>$C \rightarrow S \rightarrow EB$<br>$\rightarrow$ Outside Context   |
| Terraces             | $T \rightarrow IW \rightarrow GL \rightarrow Cir \rightarrow GL \rightarrow EA$<br>$T \rightarrow GL \rightarrow Cir \rightarrow EA$<br>$T \rightarrow LV \rightarrow Cir \rightarrow C \rightarrow EA$<br>$T \rightarrow P \rightarrow Cir \rightarrow C \rightarrow P \rightarrow EA$<br>$T \rightarrow Cir \rightarrow C \rightarrow EA$<br>$\rightarrow$ Outside Context |
| <i>Iwan</i>          | $IW \rightarrow C, GL, T$<br>$IW \rightarrow LV, S$<br>$IW \rightarrow B$  |
| Gallery              | $GL \rightarrow EA$<br>$GL \rightarrow C, IW, Cir, P$<br>$GL \rightarrow LV, S$<br>$GL \rightarrow B$  |

EA: Main Entrance, C: Main Courtyard, C(s): Service courtyard,  
 EB: Service Entrance, P: Passage/corridor, LV: Living room,  
 IW: Iwan, GL: Gallery, CIR: Stair,  
 K: Kitchen, S: Services, B: Bedrooms



Figure 4.85: Depth of spaces in four traditional courtyard houses located in Lebanon, produced by 'DepthmapX 0.50' software

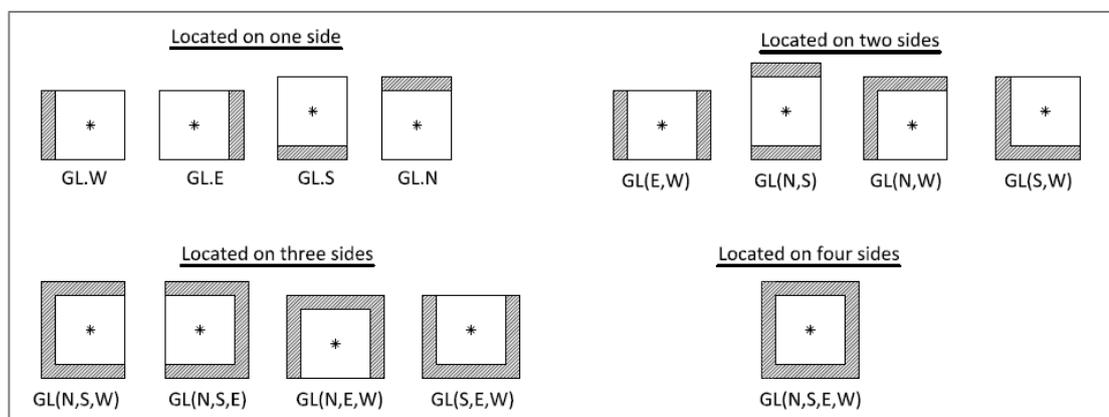


Figure 4.86: Diagrams showing location of galleries (semi-open spaces) in relation to the courtyard

- **Social Indicator (11): Viewing the outside Context**

Traditional houses in MENA region have introverted courtyards that preserve the privacy of the family. However, availability of roof terraces and balconies offers the potential of seeing the outside context. These spaces could be found in single-floor and multi-floor houses. In both cases, terraces are connected with living rooms or bedrooms, and represent 11-16% from the total area of the house (Figures 4.87 and 4.88, and Table 4.56).

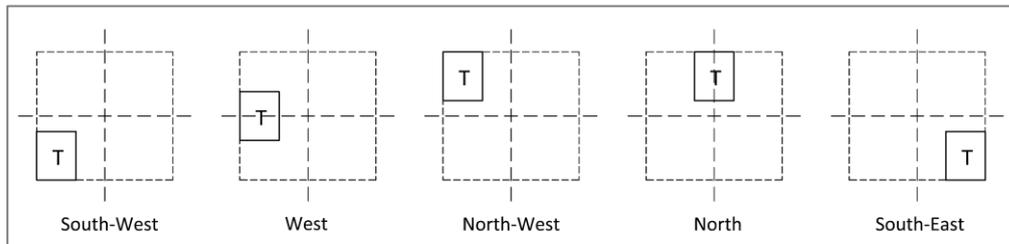


Figure 4.87: Location of terraces in relation to the layout of the ground floor

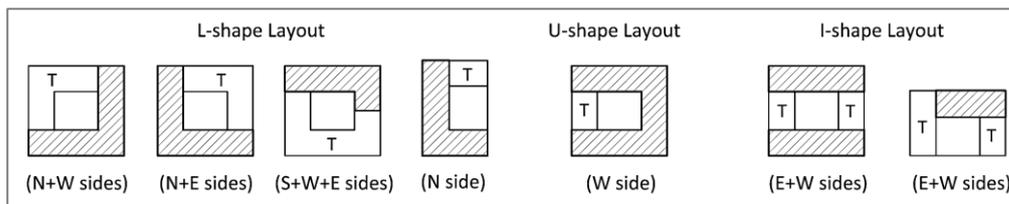


Figure 4.88: Location of terraces in relation to the layout of upper floors

Table 4.56: Percentages of open spaces relative to the total area of the house functions

| Region                      | Percentages of Open/Semi-open Spaces from the Total Area of the House |                    |               |                |
|-----------------------------|---|--------------------|---------------|----------------|
|                             | Courtyard   | Terraces/Balconies | <i>Iwan</i>   | Gallery        |
| <b>The Middle East (ME)</b> |   |                    |               |                |
| Syria                       | 27.5 %  | 16.5 %             | 5.1 %         | 5.6 %          |
| Lebanon                     | 21.0 %  | 8.5 %              | 5.8 %         | 7.5 %          |
| Jordan                      | 14.3 %  | 25.8 %             | 2.5 %         | 15.8 %         |
| Palestine                   | 15.5 %  | 22.2 %             | 3.4 %         | 18.9 %         |
| Iraq                        | 10.3 %  | 6.0 %              | 7.9 %         | 15.9 %         |
| AVG                         | <b>17.7 %</b>   | <b>15.8 %</b>      | <b>4.9 %</b>  | <b>12.7 %</b>  |
| <b>North Africa (NA)</b>    |   |                    |               |                |
| Egypt                       | 11.4 %  | 6.7 %              | 12.7 %        | -              |
| Tunisia                     | 22.8 %  | 10.1 %             | 5.9 %         | 7.7 %          |
| Morocco                     | 7.9 %   | 13.0 %             | -             | 29.2 %         |
| Algeria                     | 7.3 %   | 14.9 %             | -             | 8.8 %          |
| AVG                         | <b>12.35 %</b>  | <b>11.2 %</b>      | <b>9.3 %</b>  | <b>15.2 %</b>  |
| <b>The Gulf Area (GA)</b>   |   |                    |               |                |
| KSA                         | 10.5 %  | 24.9 %             | -             | 12.7           |
| UAE                         | 13.6 %  | 0.5 %              | -             | 12.5           |
| Oman                        | 20.3 %  | 21.7 %             | -             | -              |
| Kuwait                      | 19.0 %  | 16.8 %             | -             | 12.3           |
| Yemen                       | 4.7 %   | 15.9 %             | -             | -              |
| AVG                         | <b>13.62 %</b>  | <b>16.0 %</b>      | -             | <b>12.5 %</b>  |
| AVG (Study Area)            | <b>14.56 %</b>  | <b>14.33 %</b>     | <b>7.10 %</b> | <b>13.47 %</b> |

### - Social Indicator (12): Availability of Services

Residents need storage spaces and separate entrances that are connected with services and kitchen. In traditional houses, such issues are one of the leading features that achieve the requirements of users. Kitchens and storage areas represent 11-20% of the total area of the house (Table 4.57). Moreover, these spaces are connected with a service entrance, which is a semi-private space that is used only by the family. This entrance could be located adjacent or opposite to the main entrance of the house. Services are categorised into three types (Figure 4.89):

- Kitchen and storage area, which are connected with living rooms or service entrances.
- Toilets, which are connected with living spaces or guest rooms.
- Bathrooms, which are connected with bedrooms.

Table 4.57: Percentages of services relative to the total area of the house

| Region                      | % of services  |
|-----------------------------|----------------|
| <b>The Middle East (ME)</b> |                |
| Syria                       | 7.5 %          |
| Lebanon                     | 15.5 %         |
| Jordan                      | 7.5 %          |
| Palestine                   | 10.0 %         |
| Iraq                        | 12.8 %         |
| AVG                         | <b>10.7 %</b>  |
| <b>North Africa (NA)</b>    |                |
| Egypt                       | 16.4 %         |
| Tunisia                     | 15.2 %         |
| Morocco                     | 22.8 %         |
| Algeria                     | 26.4 %         |
| AVG                         | <b>20.2 %</b>  |
| <b>The Gulf Area (GA)</b>   |                |
| KSA                         | 15.3 %         |
| UAE                         | 19.9 %         |
| Oman                        | 8.9 %          |
| Kuwait                      | 9.2 %          |
| Yemen                       | 30.1 %         |
| AVG                         | <b>16.7 %</b>  |
| <b>AVG (Study Area)</b>     | <b>15.87 %</b> |

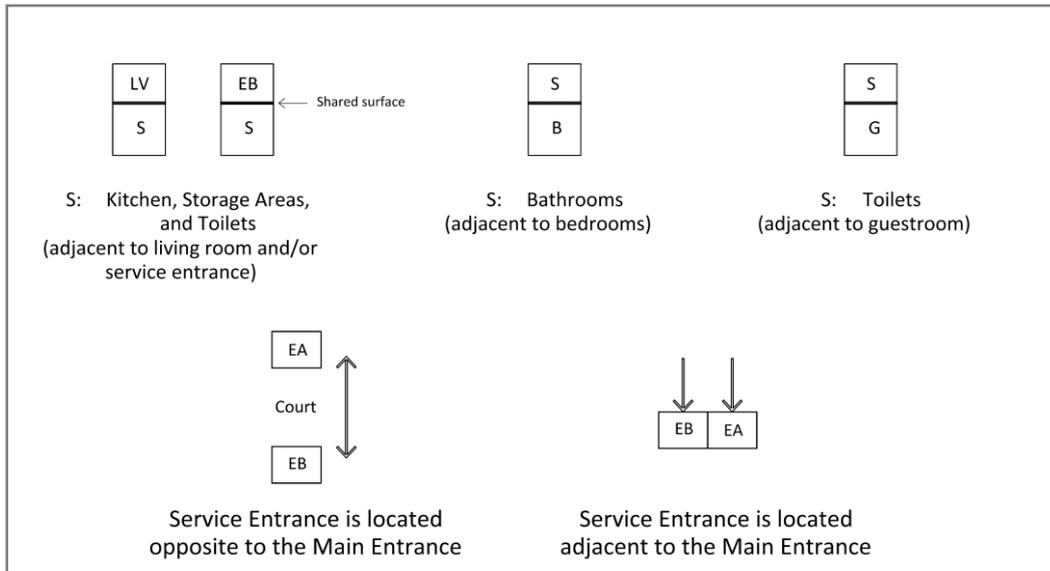


Figure 4.89: Location of services and service entrance in relation to other spaces

- **Social Indicator (13): Hygiene**

In most residential units, gates and thresholds define the private zones. This change in level protects houses from dust. Inside the house, steps that separate services and clean sitting areas from depressed floors where shoes and tools are placed, is also a response to that requirement (Figure 4.90).

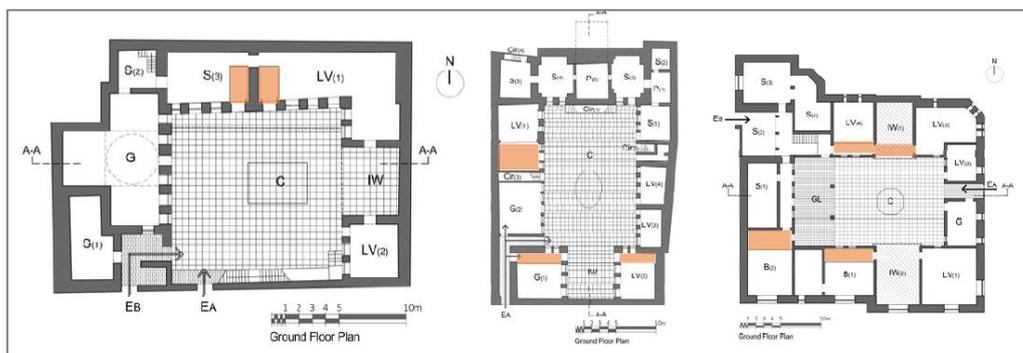


Figure 4.90: Sunken area separating living zones and services from the outside

#### 4.8.2. Socio-Spatial Qualities of Traditional Neighbourhoods

The layout of traditional neighbourhoods in the study area has an irregular pattern, and more than one focal centre. However, the organic spatial configuration of these quarters produces a homogeneous urban fabric and balanced townscapes that are determined by specific social and religious principles (Bianca 2000). Different layouts, located in Egypt (such as Cairo); Syria (such as Aleppo); Iraq (such as Baghdad and Ur); Saudi Arabia (such as Al-Medina and Al-Hasa); Morocco (such as Fez and Marrakech); Tunisia; and Algeria, have been investigated. A detailed spatial-syntactical evaluation for four neighbourhoods located in Egypt; Iraq; and Syria, has been conducted to examine geometrical properties and topological relationships of such layouts in relation to the different indicators of social sustainability.

##### - Social Indicators (1) and (3): Population Density and Social Interaction

One of the most prominent features of traditional residential quarters in MENA region is the dense and physical cohesion structure. However, open areas, which constitute approximately half area of the cluster (39-54%), offer a valuable element in such harsh environments (Figure 4.91). The spatial analysis shows that open public spaces constitute 21-38% of the cluster's area. Moreover, the percent of private courtyards relative to the total ground floor area of residential units represents 18-28% (Table 4.58).

These open areas invite the gathering of residents at various times of the day, and at different levels. This issue allows social interaction at the family level in private courtyards; social interaction among women and children in cul-de-sacs and semi-private alleyways between residential units; and mixed interaction in public spaces (Eben Saleh 1997). Therefore, residents had a sense of community and belonging towards their residential quarter (Al-Masri 2010; Ramezani and Hamidi 2010; Eben Saleh 1998).

Table 4.58: Percentages of open spaces for the selected residential neighbourhoods

| Case No. and Location | Total Area of the Cluster (m <sup>2</sup> ) | Open Spaces                  |      | Public Spaces                |   | Total Area of Houses (m <sup>2</sup> ) | Total Area of Covered Spaces (m <sup>2</sup> ) | Private Courtyards           |  |
|-----------------------|---|------------------------------|------|------------------------------|---|--|--|------------------------------|--|
|                       |   | Total Area (m <sup>2</sup> ) | %    | Total Area (m <sup>2</sup> ) | % (relative to the Total Area of the Cluster) |  |  | Total Area (m <sup>2</sup> ) | % (relative to the Total Area of Houses) |
| CLUS-1 (Egypt)        | 1185  | 616                          | 52 % | 454                          | 38 %  | 731                                    | 569  | 162                          | 22 %                                     |
| CLUS-2 (Iraq)         | 1642  | 885                          | 54 % | 622                          | 38 %  | 1020                                   | 757  | 263                          | 26 %                                     |
| CLUS-3 (Iraq)         | 1929  | 755                          | 39 % | 499                          | 26 %  | 1430                                   | 1174   | 256                          | 18 %                                     |
| CLUS-4 (Syria)        | 4525  | 1856                         | 42 % | 929                          | 21 %  | 2757                                   | 1998   | 759                          | 28 %                                     |



Figure 4.91: Types of open spaces in traditional residential quarters located in MENA region

- **Social Indicators (2) and (5): Hierarchy of Spaces and Accessibility**

The access from public areas to residential quarters is usually controlled and broken into hierarchical sections. Each group of courtyard houses are clustered around a semi-private open space (a cul-de-sac), where the most rates of social interaction among immediate neighbours, especially women and children took place (Ramezani and Hamidi 2010). These spaces are connected with main public spaces and streets through narrow-secondary alleys and pedestrian walkways. Syntactical analysis of such clusters shows that open spaces have the highest integration and control values (Figures 4.92, 4.93, 4.94, and Table 4.59).

Such a pattern of semi-public and semi-private spaces prevents conflicts with the public realm, makes residents able to manage their desired rate of social contact, increases degrees of privacy and security, and at the same time maintains a balance between isolation and social interaction (Crouch and Johnson 2001; Mortada 2003; Bianca 2000).

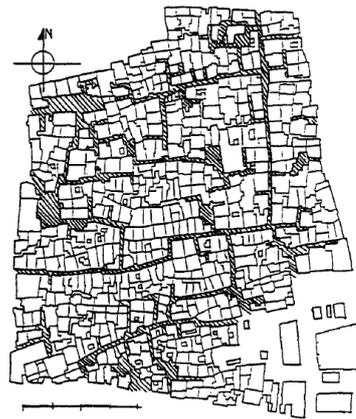


Figure 4.92: A traditional residential neighbourhood in Al-Hasa, KSA, showing hierarchy of streets and open spaces (Eben Saleh 1997)

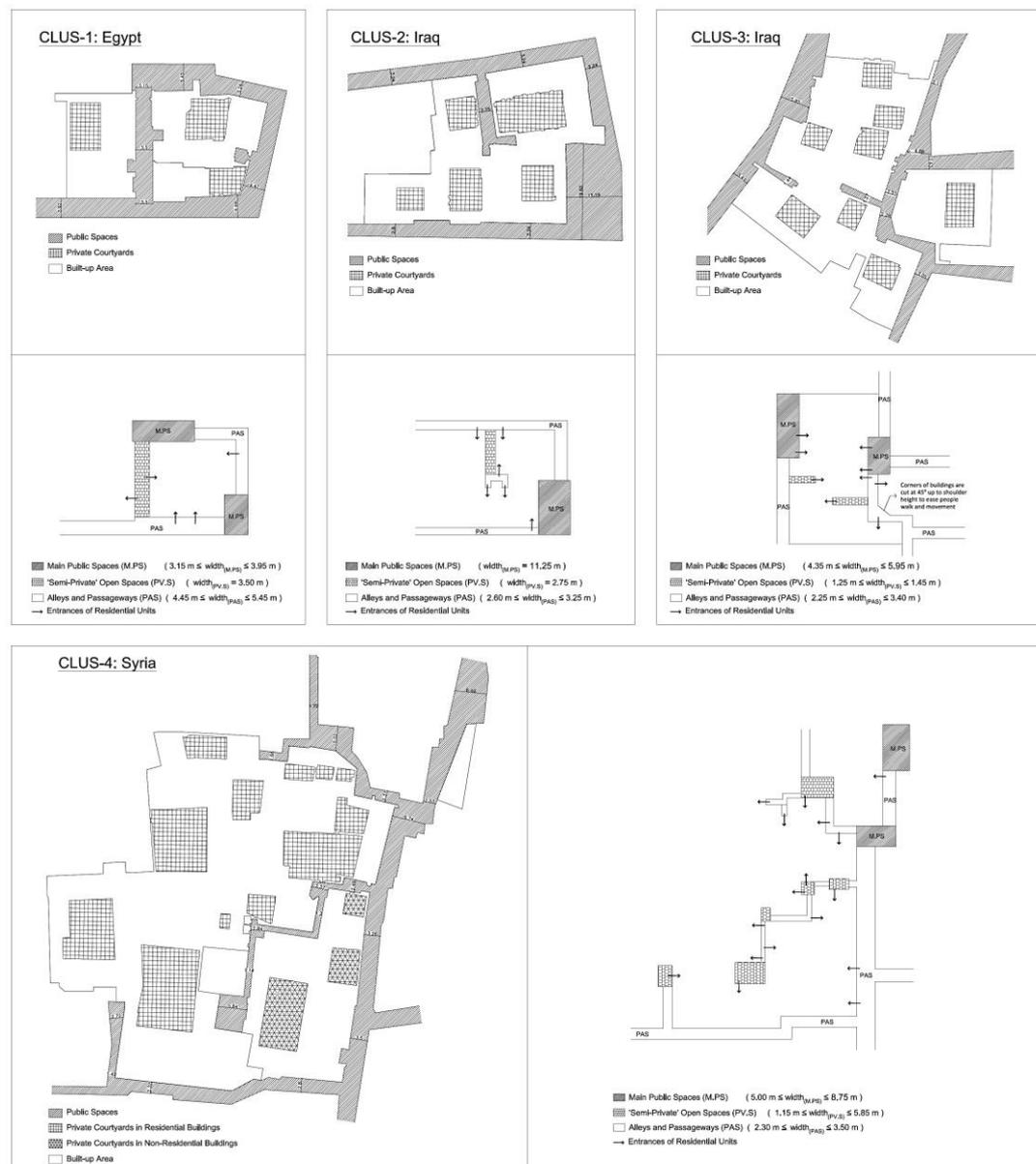


Figure 4.93: Hierarchy of open spaces in traditional residential neighbourhoods located in MENA region

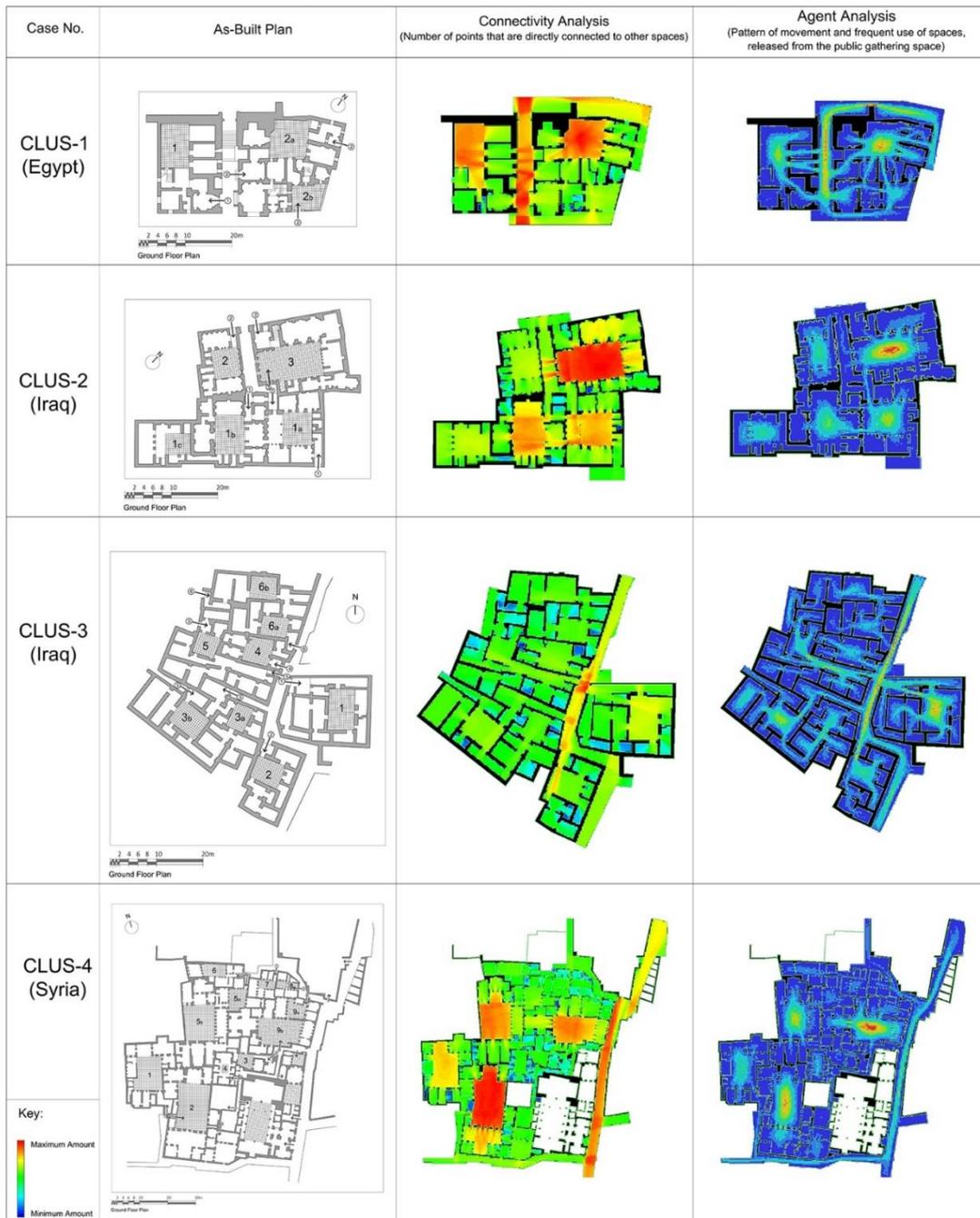


Figure 4.94: Connectivity and agent analyses for traditional neighbourhoods located in MENA region, produced by 'DepthmapX 0.50' software

Table 4.59: Width of open spaces for the selected residential neighbourhoods

| Case No. and Location | Width of Main Public Spaces | Width of Semi-private Open Spaces | Width of Secondary Passageways |
|-----------------------|-----------------------------|-----------------------------------|--------------------------------|
| CLUS-1 (Egypt)        | 3.15 – 3.95 m               | 3.50 m                            | 4.45 – 5.45 m                  |
| CLUS-2 (Iraq)         | 11.25 m                     | 2.75 m                            | 2.60 – 3.25 m                  |
| CLUS-3 (Iraq)         | 4.35 – 5.95 m               | 1.25 – 5.95 m                     | 2.25 – 3.40 m                  |
| CLUS-4 (Syria)        | 5.00 – 8.75 m               | 1.15 – 5.85 m                     | 2.30 – 3.50 m                  |

#### - **Social Indicator (4): Thermal Comfort**

Availability of open spaces, and the pattern of narrow pedestrian walkways in traditional neighbourhoods reduce external heat gain or loss (Ragette 2003; Maleki 2011; Moossavi 2014). Moreover, projections from houses, and the use of covered pathways play an essential role in creating a comfortable zone for residents (Figure 4.95). However, thermal comfort in open spaces depends on the width of such areas, the height of adjacent houses, and the orientation.

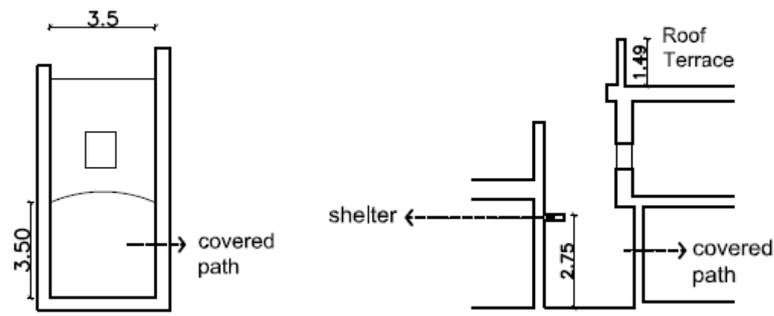


Figure 4.95: Sections showing the use of covered pathways and shelters in open spaces

#### - **Social Indicator (6): Visual Privacy**

The respect of visual privacy in outdoor spaces is of extreme concern in traditional neighbourhoods (Ragette 2003; Bianca 2000; Mortada 2003). The privacy of family is preserved (Figures 4.96, 4.97, and 4.98), through different visual barriers, such as:

- Avoiding entrances facing each other, by using the principle of staggered entrances, which maintains the private life of the family,
- The use of solid walls in front of main entrances, which prevents a direct view towards private spaces inside the house,
- Entrances are connected with semi-private open spaces instead of main public spaces,
- The use of high walls and setbacks between houses,
- Minimal and small openings are located on exterior facades, and placed above eye level,
- No windows overlooking neighbour's courtyards or roof terraces,
- In the case of linear passageways, entrances are usually lead to a corner of the house, where there are no private activities (Ramezani and Hamidi 2010).

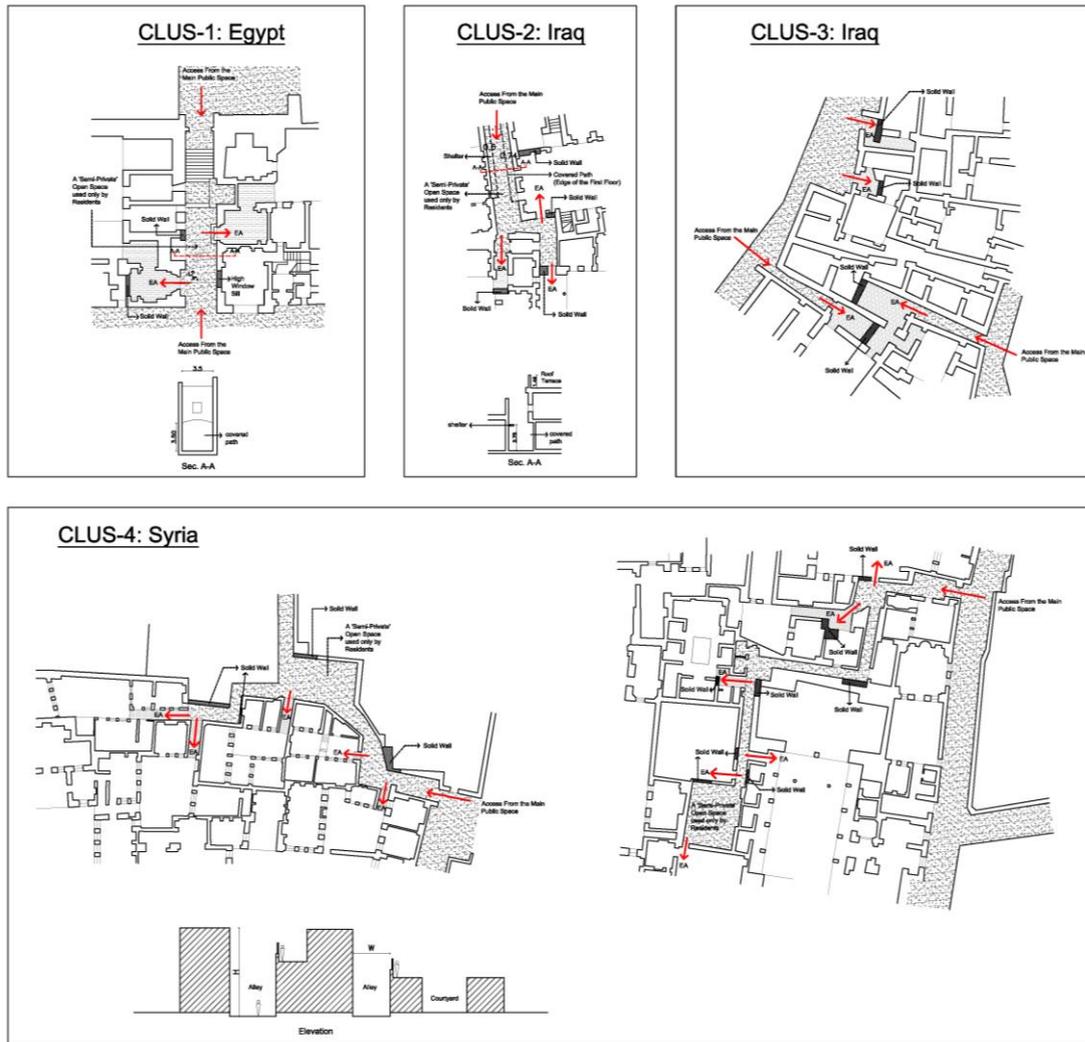


Figure 4.96: Analysing visual privacy in traditional neighbourhoods

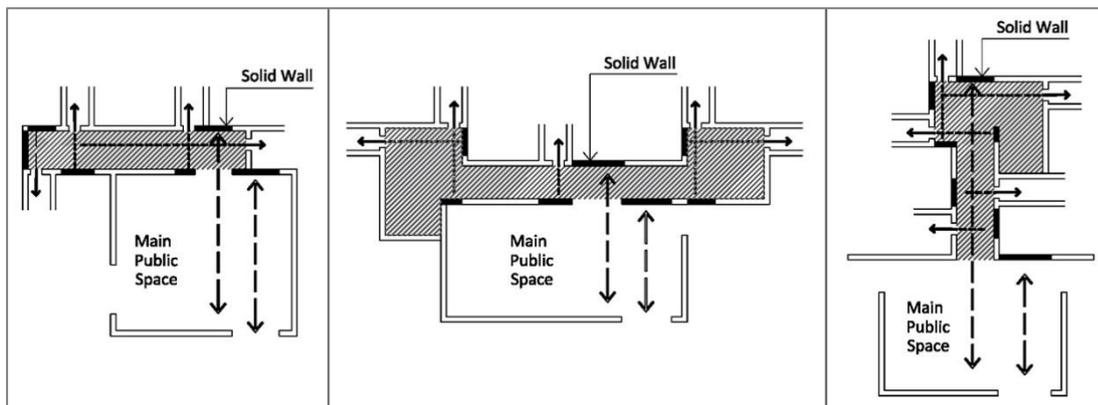


Figure 4.97: Strategies for achieving visual privacy in traditional neighbourhoods



Figure 4.98: *Isovist* analysis for traditional neighbourhoods, produced by ‘Syntax2D 1.3.0.7’ software

- **Social Indicator (7): Acoustical Privacy**

Thick walls between adjacent houses, which are ranged between 40 and 90 cm, and the use of landscaping in public spaces play a role in reducing the transition of noise between houses. Moreover, increasing the width of alleys preserves the acoustical privacy for the family in the residential quarter (Figure 4.99 and Table 4.60).



Figure 4.99: Shared walls and alleys between adjacent houses in traditional residential quarters

Table 4.60: Thickness of shared walls and width of alleys between adjacent houses in the selected residential neighbourhoods

| Case No., and Location | Thickness of Shared Walls | Width of Alleys |
|------------------------|---------------------------|-----------------|
| CLUS-1 (Egypt)         | 70 cm                     | 315 – 350 cm    |
| CLUS-2 (Iraq)          | 46 - 91 cm                | 276 cm          |
| CLUS-3 (Iraq)          | 57 – 71 cm                | 91 – 275 cm     |
| CLUS-4 (Syria)         | 39 – 85 cm                | 114 – 280 cm    |

- **Social Indicator (10): Safety and Security**

The hierarchical system of open spaces, and the morphology of courtyard houses in residential quarters offer the residents a sense of security (Eben Saleh 1997). Availability of semi-private spaces for women and children allows a secure place to meet, talk, and play with nearby neighbours in front of their houses. Moreover, the introverted design of houses towards courtyards, with openings restricted to doors and small windows at street level, provide safety and security for the family.

### - Social Indicator (13): Hygiene

Achieving a hygienic atmosphere in open spaces needs specific environmental solutions. In traditional neighbourhoods, the low-rise and medium-rise of residential units allow the sun to penetrate these spaces, and therefore, reduce rates of moisture. Furthermore, changes in directions between public spaces and alleys block the excessive air movement that carries sand and dust (Ragette 2003; Maleki 2011; Crouch and Johnson 2001; Moossavi 2014). Another treatment is the use of steps between public spaces and semi-private open spaces or the entrance of residential units (Figure 4.100).



Figure 4.100: Strategies for achieving hygiene in residential quarters

The other four social indicators; (8) Olfactory Privacy, (9) Spirituality, (11) Views to the Exterior, and (12) Availability of Services, have not been addressed in the spatial analysis of neighbourhoods, due to the lack of information about the context and the surrounding. Yet, advantages and impacts of the layout of neighbourhoods on these four indicators have been mentioned in Part (A) of Chapter 2: Literature Review.

### 4.8.3. A Comparative Socio-Spatial Analysis between Vernacular Houses/ Neighbourhoods and Contemporary Residential Buildings in MENA Region

A total number of five contemporary residential buildings located in the three regions of the study area have been analysed using the same process of spatial and syntactical analyses. Each building represents a vertical cluster of residential units. Results and measurements obtained from these evaluations are used to conduct a comparative analysis between traditional houses/neighbourhoods and contemporary residential buildings.

#### a. Readings from Space Syntax Analysis

Space syntax analysis for contemporary apartments showed that the overall layout is more segregated and have a linear sequence of movement. In other words, spaces in new buildings are more controlled and they are not easily accessible. This is supported by a low 'mean depth' value (MD = 2.71), and a high 'relative asymmetry' value (RA = 0.36). In contrast, a higher MD value (= 3.49), and a lower RA value (= 0.225) for traditional houses, mean that spaces are more integrated, connected, and more accessible from the main core of the house (Figure 4.101).

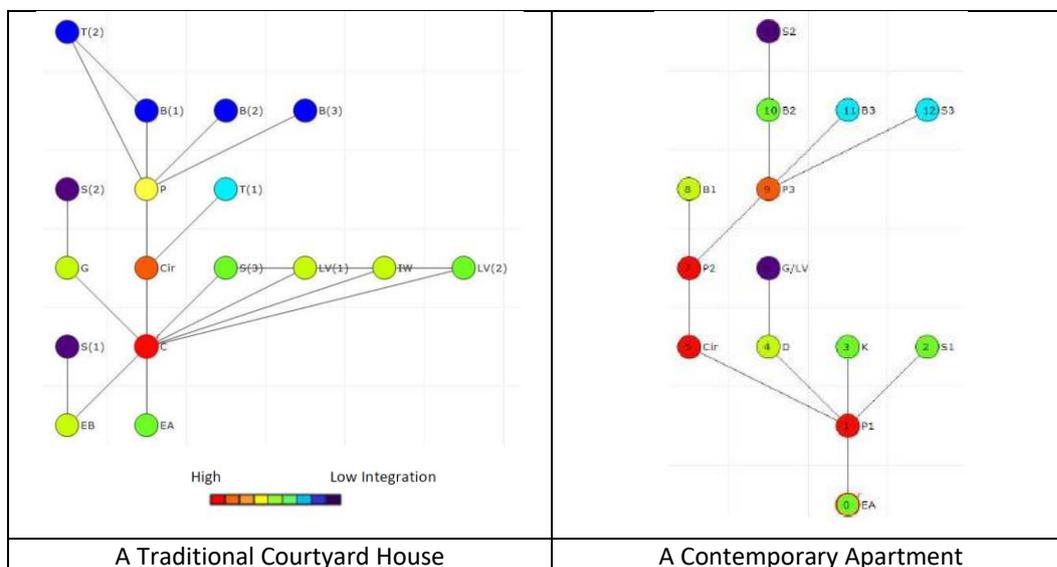


Figure 4.101: Node-and-connection diagrams for a traditional courtyard house and a contemporary apartment, showing the overall arrangement of spaces and the integration value for each space, produced by *AGraph* software

Moreover, space syntax measurements show that entry halls, corridors and vertical circulation elements have the highest integration value in contemporary apartments. Such values indicate that the privacy of the family is not protected from public and semi-public zones. On the other hand, lowest integration values are associated with services and

terraces, which mean that these spaces are more isolated. However, the guest room, which is used as a living space in most cases, has a high integration value.

In contrast, measurements extracted from traditional houses show that the courtyard has the highest integration value. This suits with its primary function as a transitional zone that controls the overall layout. Services, terraces, bedrooms and guest rooms, have the lowest integration value, which reflects the dominant characteristic of such areas as they are more isolated and more private. For instance, bedrooms in traditional houses have a lower RA value (= 0.24) than contemporary residential units (RA = 0.35). Table (4.61) shows the integration value for some cases from the study area.

Table 4.61: Hierarchy of spaces in contemporary apartments and traditional courtyard houses based on the integration value

|          | Integration Values for Contemporary Apartments   | Integration Values for Different Traditional Houses   |
|----------|--|---|
| AP-1     | <b>Vertical Circulation</b> > Entrance, Living Area > Corridors > <b>Guest Room</b> > Kitchen > Dining Room > <b>Bedrooms</b> > Terraces > <b>Services (Toilets)</b>     | <b>Courtyard</b> > Vertical Circulation > Entrance, <b>Guest Room</b> > Living Rooms, <i>Iwan</i> > <b>Bedrooms</b> > <b>Services (Kitchen, Storage, and Toilets)</b>                             |
| AP-2 (a) | <b>Entrance, Corridors</b> > <b>Guest Room</b> > Kitchen > <b>Bedrooms</b> > Dining Room > Services (Toilets) > <b>Terrace</b>   | <b>Courtyard</b> > Vertical Circulation, Service > Entrance > Living Rooms, <i>Iwan</i> > , <b>Guest Room</b> > <b>Bedrooms</b> > Services (Kitchen, Storage, and Toilets) > <b>Terraces</b>      |
| AP-2 (b) | <b>Vertical Circulation</b> > Corridors > Dining Room > <b>Bedroom (1)</b> > Entrance > Kitchen > <b>Bedrooms (2, 3)</b> > <b>Guest Room</b> > <b>Services (Toilets)</b> | <b>Courtyard</b> > Main Entrance and Service Entrance > Gallery and <i>Iwan</i> > Living Rooms > <b>Guest Room</b> > <b>Bedrooms</b> > Services (Kitchen, Storage, and Toilets) > <b>Terraces</b> |
| AP-3     | <b>Corridors</b> > Dining Room > Services, Kitchen > <b>Bedroom (1)</b> > <b>Guest Room, Bedrooms (2, 3)</b> > Entrance > Services (Toilets) > <b>Terrace</b>            | <b>Corridor</b> > Courtyard > Living Room > Entrance > <b>Bedrooms</b> > Services (Kitchen, Storage, and Toilets) > <b>Guest Room</b>   |
| AP-4     | <b>Corridors</b> > Dining Room > Entrance > Services, Kitchen, <b>Bedrooms</b> > <b>Guest Room, Terrace</b>  | <b>Gallery</b> > Vertical Circulation > Courtyard > Living Rooms, <i>Iwan</i> > <b>Guest Room</b> > <b>Bedrooms, Terraces</b> > <b>Services (Kitchen, Storage, and Toilets)</b>                   |
|          |  Highest Integration Value  |  Lowest Integration Value  |

A further syntactic test that is important for understanding the spatial arrangement of spaces is the connectivity analysis. In current developments, the highest connectivity is found in living rooms and circulation passageways, while bedrooms, bathrooms, kitchen and terraces have the lowest values (Figure 4.102). In contrast, connectivity is maximal for courtyards and galleries, and minimal for services in traditional houses.

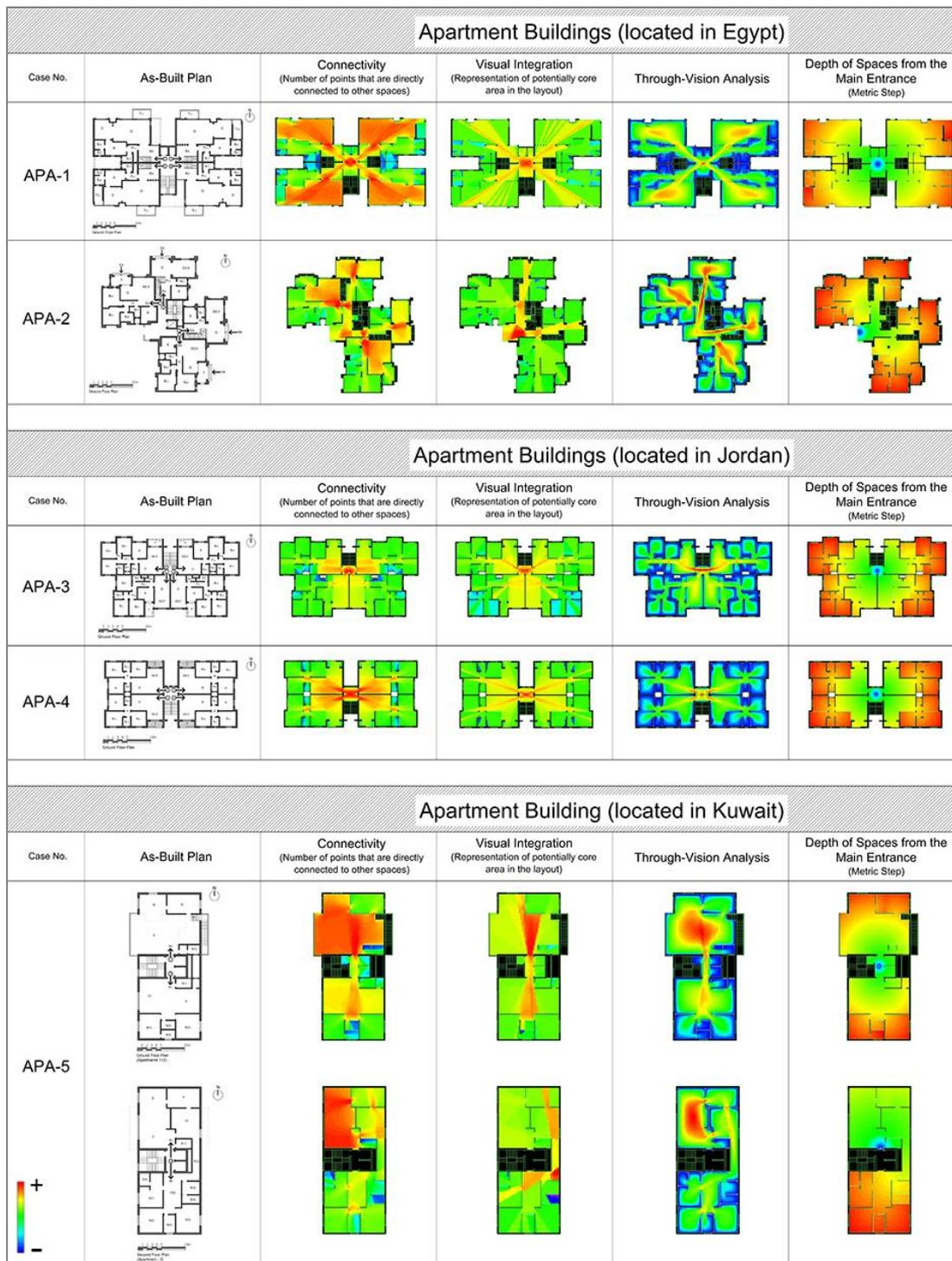


Figure 4.102: Connectivity and visual integration analyses for contemporary apartment buildings located in MENA region, produced by 'DepthmapX 0.50' software

**b. Readings from Spatial Analysis**

A morphological study that deals with topological relationships between spaces in contemporary residential developments have been conducted. As there are major differences in four indicators of social sustainability (social interaction, hierarchy of spaces, accessibility, and visual proivacy) between current developments and traditional

houses/neighbourhoods, spatial-geometric analyses are used to test these aspects in both models.

- *Social Indicator (3): Social Interaction*

At the level of the cluster, semi-public and semi-private spaces in front of apartments in contemporary buildings are limited to circulation paths. Therefore, social interaction among neighbours decreases accordingly. Going inside the house, the percentage of social gathering spaces - including living rooms, terraces and balconies – constitutes only 22% of the total area of the house. In contrast, availability of courtyards and *iwan* (as semi-open living area) increases the area of living spaces to 51%, and therefore, social interaction between the family (Table 4.62).

Table 4.62: Percentage of area for living spaces in contemporary buildings

| Case No.                             | Location | Living Rooms | Terraces / Balconies | Courtyards  | <i>Iwans</i> (semi-open living area) | TOTAL % of Social Gathering Spaces |
|--------------------------------------|----------|--------------|----------------------|-------------|--------------------------------------|------------------------------------|
| AP-1                                 | Egypt    | 6 %          | 8 %                  | -           | -                                    | 14 %                               |
| AP-2 (a)                             | Egypt    | 21 %         | 7 %                  | -           | -                                    | 28 %                               |
| AP-2 (b)                             | Egypt    | 14 %         | -                    | -           | -                                    | 14 %                               |
| AP-3                                 | Jordan   | 12 %         | 6 %                  | -           | -                                    | 18 %                               |
| AP-4                                 | Jordan   | 23 %         | 5 %                  | -           | -                                    | 28 %                               |
| AP-5 (a)                             | Kuwait   | 33 %         | -                    | -           | -                                    | 33 %                               |
| AP-5 (b)                             | Kuwait   | 15 %         | -                    | -           | -                                    | 15 %                               |
| AP-5 (c)                             | Kuwait   | 30 %         | -                    | -           | -                                    | 30 %                               |
| <b>AVG (Contemporary Apartments)</b> |          | <b>19 %</b>  | <b>3 %</b>           | <b>0 %</b>  | <b>0 %</b>                           | <b>22 %</b>                        |
| <b>AVG (Traditional Houses)</b>      |          | <b>13 %</b>  | <b>8 %</b>           | <b>25 %</b> | <b>5 %</b>                           | <b>51 %</b>                        |

- *Social Indicators (2) and (4): Hierarchy of Spaces and Accessibility*

As shown previously, there is a hierarchical movement pattern in traditional houses that preserves the privacy of the family. For instance, entering the private zone of a house needs to pass from an entry hall, which is a public zone, through a passageway to reach the courtyard. Private spaces, including living rooms and kitchen, are connected directly with courtyards, or indirectly, through *iwans* or corridors.

In modern houses, the spatial analysis indicated that there is a sudden transition from public spaces (entrances) to private zones (living rooms and kitchen) due to the lack of semi-private spaces (such as courtyards, galleries, or *iwans*) (Figure 4.103 and Table 4.63). However, there is no spatial or visual separation (such as transitional spaces, walls or doors) between living areas and guest/dining rooms in most cases. Investigations at the scale of contemporary clusters showed the same observation, which is the lack of semi-

private spaces between residential units. Entrances of houses are opened directly on a transitional space in front of the vertical circulation zone (Figure 4.104). Such issues have negative impacts on aspects of social sustainability, including interaction, security and privacy.

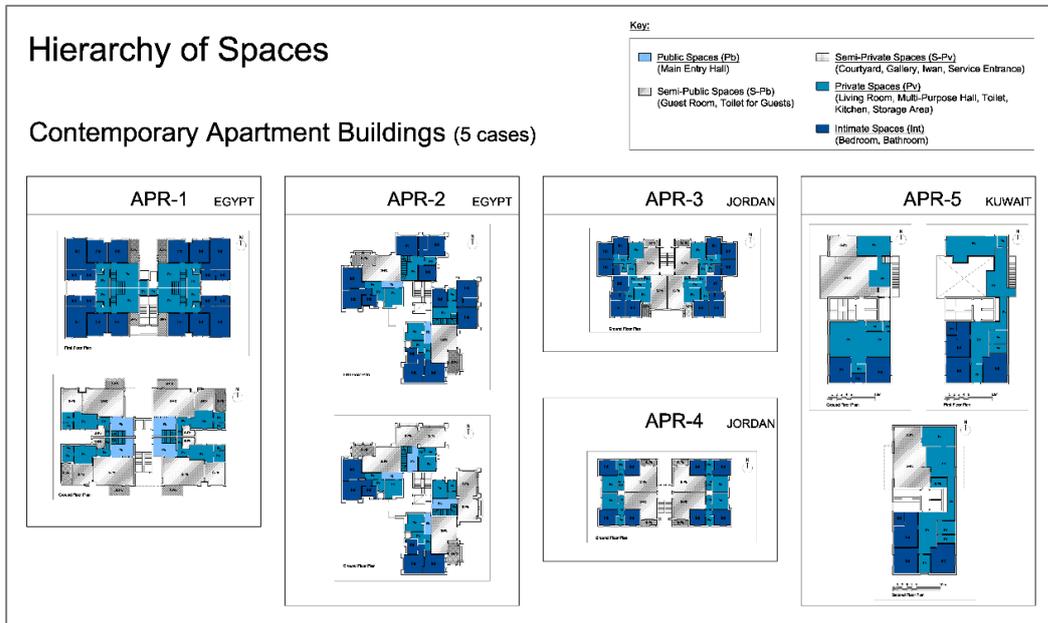


Figure 4.103: Hierarchy of spaces in contemporary apartment buildings

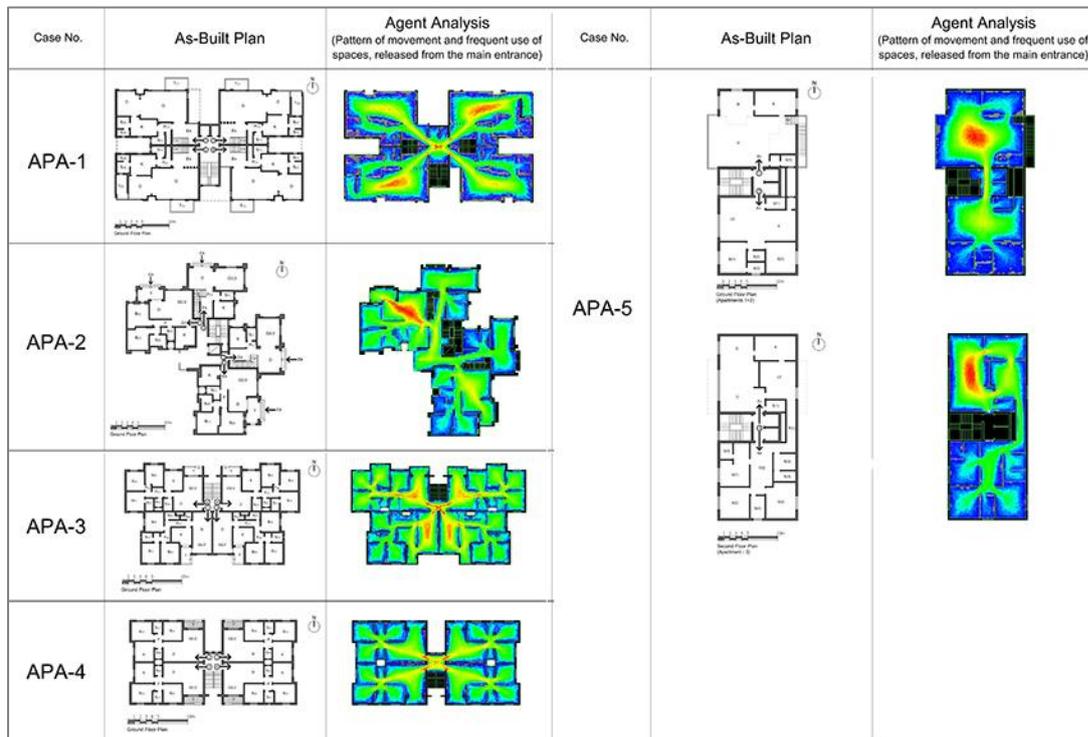


Figure 4.104: Agent analysis and patterns of movement in contemporary apartment buildings

Table 4.63: Movement patterns for guests and family members in contemporary houses

| <b>Contemporary Apartment Buildings</b> |  |
|---|--|
| AP-1                                    | <p><u>Movement Pattern for Guests:</u><br/>(a) Entrance → Entry Hall → Guest room → Dining Room → Terrace<br/><b>Public – Semi-Public</b></p> <p><u>Movement Pattern for Family Members:</u><br/>(b) Entrance → Entry Hall → Corridor → Kitchen → Service<br/><b>Public – Semi-Public – Semi-Private – Private</b><br/>(c) Entrance → Entry Hall → Stair → Living Room → Corridor → Bedrooms<br/><b>Public – Semi-Public – Semi-Private – Private – Intimate</b></p> |
| AP-2 (a)                                | <p><u>Movement Pattern for Guests:</u><br/>(a) Entrance → Entry Hall → Guest Room → Dining Room → Terrace<br/><b>Public – Semi-Public</b></p> <p><u>Movement Pattern for Family Members:</u><br/>(b) Entrance → Entry Hall → Kitchen<br/><b>Public – Semi-Public – Semi-Private – Private</b><br/>(c) Entrance → Entry Hall → Corridor → Bedrooms<br/><b>Public – Semi-Public – Semi-Private – Private – Intimate</b></p>  |
| AP-2 (b)                                | <p><u>Movement Pattern for Guests:</u><br/>(a) Entrance → Entry Hall → Corridor → Dining Room → Guest Room<br/><b>Public – Semi-Public</b></p> <p><u>Movement Pattern for Family Members:</u><br/>(b) Entrance → Entry Hall → Corridor → Services and Kitchen<br/><b>Public – Semi-Public – Semi-Private – Private</b><br/>(c) Entrance → Entry Hall → Stair → Corridor → Bedrooms<br/><b>Public – Semi-Public – Semi-Private – Private – Intimate</b></p>           |
| AP-3                                    | <p><u>Movement Pattern for Guests:</u><br/>(a) Entrance → Dining Room → Guest Room → Terrace<br/><b>Public – Semi-Public</b></p> <p><u>Movement Pattern for Family Members:</u><br/>(b) Entrance → Dining Room → Kitchen and Services → Corridor → Bedrooms<br/><b>Public – Semi-Public – Semi-Private – Private – Intimate</b></p>  |
| AP-4                                    | <p><u>Movement Pattern for Guests:</u><br/>(a) Entrance → Guest Room → Terrace<br/><b>Public – Semi-Public</b></p> <p><u>Movement Pattern for Family Members:</u><br/>(b) Entrance → Dining Room → Corridor → Bedrooms<br/><b>Public – Semi-Public – Semi-Private – Private – Intimate</b></p>   |

- *Social Indicator (6): Visual Privacy*

Visual privacy could be defined as ‘the ability to carry out everyday activities hidden from the eye of outsiders or without fear of being observed by them’ (Al-Kodmany 1999). Spatial designs of buildings should have the ability to regulate privacy according to the needs of users (Mustafa 2010). At the scale of the cluster, traditional layouts offer better design solutions regarding the location of entrances, as they protect families from outside strangers. In contrast, entrances in most current developments are located opposite to each other with no visual barriers in front of doors.

Inside the house, the main characteristic of modern houses is the open layout, which means that public, semi-public and most of private spaces (e.g. kitchen and living room) are connected with no physical elements (such as screens or walls). This is supported by high integration values for the main entrance, kitchen, guest room and living spaces,

which leads decreasing the privacy of the family (Figure 4.105). On the contrary, private spaces (kitchen, services, and living rooms) and guest rooms in traditional houses have lower integration values than entrances. This means that these spaces have more privacy as they are closed and separated spaces.

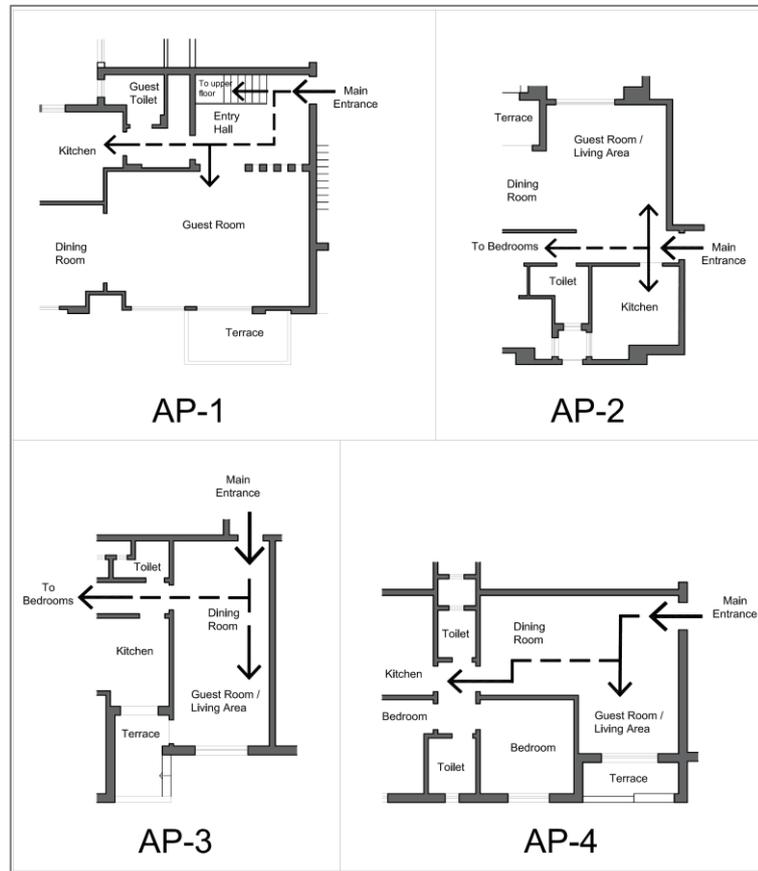


Figure 4.105: Visual connections between public, semi-public, and private spaces in contemporary apartments

Regarding the intimate zone, which includes bedrooms, both contemporary and courtyard houses have the highest depth and the lowest integration values compared to other zones in the house. However, bedrooms in old residential units are more integrated with private/semi-private zones than new houses. This can be observed in RA values for bedrooms, which indicate that the average RA for current developments is 0.35, whereas bedroom in traditional houses has an average RA value = 0.24. Lower values mean that spaces are more integrated and more accessible, and higher numbers indicate that spaces are more segregated, private, and more controlled in movement. Finally, the isovist analysis shows that achieving visual privacy in traditional houses depends on the configuration of spaces and openings rather than furniture. In contrast, protecting the privacy of living areas in new apartments depends on decorations and furniture items (Figure 4.106).

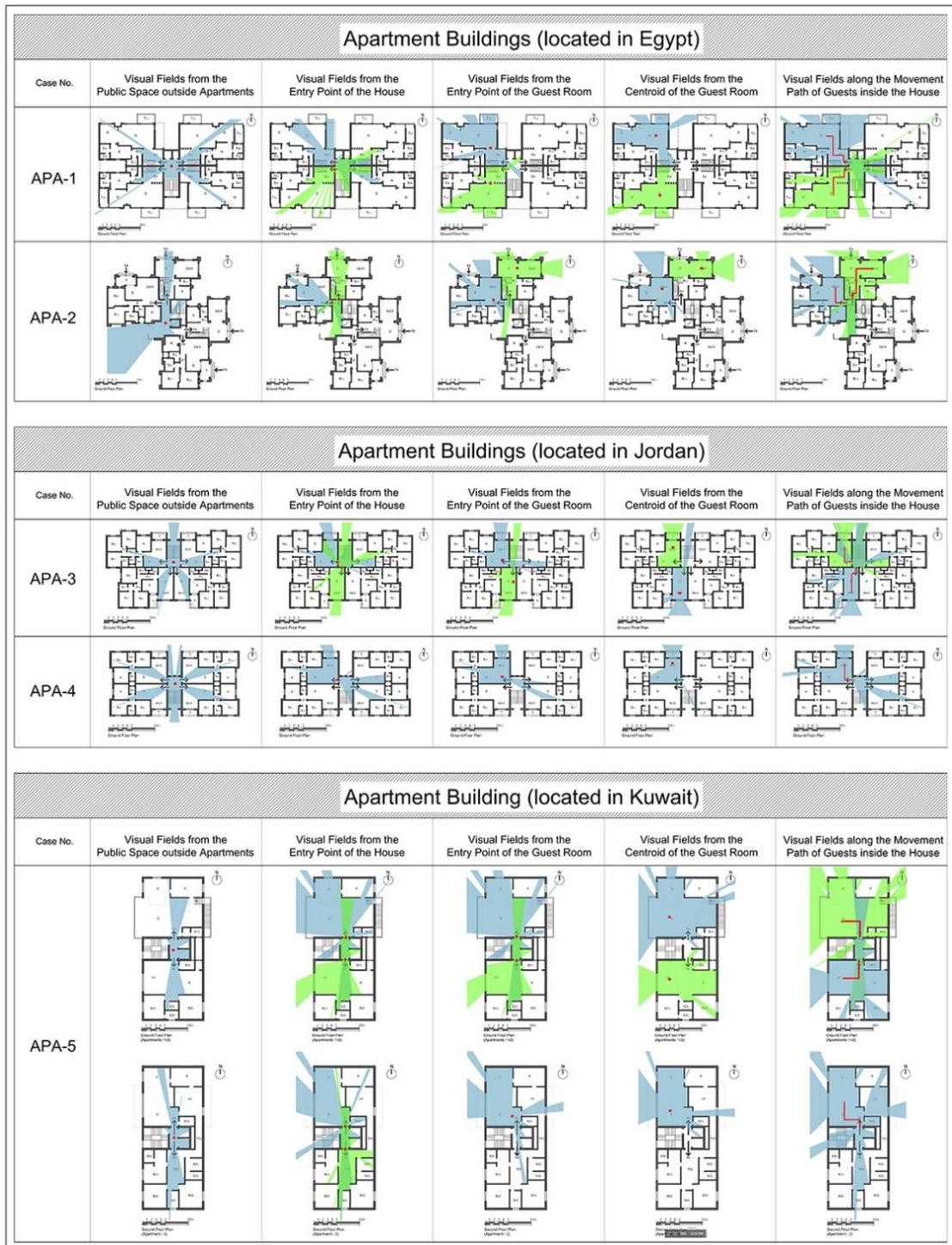


Figure 4.106: *Isovist* analysis for contemporary apartments, produced by 'Syntax2D 1.3.0.7' software

## 4.9. Conclusion

Developing residential buildings that are responsive to the requirements of social sustainability needs a holistic approach to clarify spatial qualities that affect the social life inside the house. Information gained from the analytical reasoning process could help designers in problem interpretation and the projection of gained data into new alternatives. For instance, studying the location of each space, and measuring distances between functions, are useful for analysing accessibility and movement. Moreover, defining the topology of spaces, and describing their geometry and scale, offer information about hierarchy, degree of social interaction that takes place, and the ability to provide comfort to their occupants. Analyzing these factors creates a type-based database that can be used to improve the social qualities of future developments.

Several spatial features that affect the social life of occupants in both traditional houses/neighbourhoods and contemporary apartments were observed. The traditional model consists of different hierarchical zones (public, private, and intimate spaces). The variety of semi-public and semi-private spaces in neighbourhoods is useful for managing social interaction between residents, increasing their sense of community and belonging, and protecting their privacy. The courtyard is the largest space in the house and the most accessible and connected function. Other functions are controlled and accessed through the courtyard and follow its geometric pattern with a symmetrical layout arrangement. Moreover, the deep location of private areas and intimate spaces in relation to courtyards provide a protected and comfortable atmosphere for the family members to move easily. The Isovist analysis and the Visual Graph Analysis (VGA) show that the privacy of the household is protected from public and semi-public spaces (the entry hall and the guest room). Different mechanisms are used for achieving this result, and to strictly limit access to the courtyard by guests. These features include the bent entrance, the use of partitions in front of the main entrance, and size/location of windows for guest rooms. Moreover, the spatial configuration shows that reception rooms are shallow spaces that are situated off the courtyard next to the entry hall. In contrast, findings reveal that intimate spaces (bedrooms), which have a lower integration value, are more integrated with private spaces.

Investigating different contemporary residential units showed that some social and cultural needs, such as privacy and availability of spaces for encouraging social interaction, were missing in these developments.

The proposed automated model of syntactical analysis, embodied in Rhino/Grasshopper, offers an alternative method for extracting spatial topologies and syntactic calculations. This

tool could be easily and efficiently used to analyse floor layouts that have any size or geometry. Moreover, users do not need to know exact procedures of space syntax calculations, or draw the justified graph for the system, as the model provides these automatically. Translating such qualities into rules and parameters leads to the construction of a socio-spatial grammar that is related to the local context.

Typological analysis approach could help designers to save time and effort in generating solutions from scratch. Prototypes extracted from historical precedents form a database of design knowledge that acts as the input for new designs. Based on this social-spatial catalogue for traditional houses and neighbourhoods in MENA region, two types of grammars that express the language of the vernacular model will be constructed in the next chapter. These grammars will be used as a base for the construction of socio-spatial grammar for high-rise buildings.

## Chapter Five

# **A Computational Design Tool for Socially Sustainable High-rise Residential Buildings in MENA Region**

**Part (A): A Parametric Socio-Spatial Grammar for Vernacular Houses and Neighbourhoods**

**Part (B): The Development of a Computational Design Tool for Socially Sustainable High-rise Residential Buildings**

**Part (C): The Generation of New Solutions, Validation of Results, and Usability Evaluation for the Tool**

## Chapter Five:

# **A Computational Design Tool for Socially Sustainable High-rise Residential Buildings in MENA Region**

## **5.1. Introduction**

A design process is a multi-disciplinary work. It needs from designers an overall understanding of the context and preferences of users. Moreover, it requires a proper method to address spatial, formal, and social dimensions of a design (Hillier and Hanson 1984). As illustrated in the previous chapter, 'space syntax' approach was used to explore spatial topologies and social relations implicit in the architectural setting. However, generating new designs using this method is a complicated process, as it requires information about geometric properties (Lee *et al.* 2013; Peponis *et al.* 2003). On the other hand, shape grammar is a formal method that allows designers to describe and analyse existing geometries, and then generate new alternatives based on the original style. Yet, there is no focus on the social and cultural meanings of the architectural composition (Eilouti and Al-Jokhadar 2007b).

Chapter Five includes three parts. The first part (Part A: A Parametric Socio-Spatial Grammar for Vernacular Houses and Neighbourhoods) builds on the benefits of those two approaches to construct a spatial grammar that is specific to the Middle East and North Africa, and at the same time addresses the different indicators of social sustainability. Information gained from the analytical process, presented in Chapter 4, is used to establish a database that identifies vocabularies, parametric rules, geometric expressions, social descriptions, and topological relationships. The grammar, which is a rule-based system, is divided into two categories. The first set deals with generating neighbourhoods, and the second set allows the construction of vernacular houses. The primary target of both types is to generate new solutions that do not exist before, and meanwhile, have the same architectural/urban style, and social/cultural principles. However, creativity and adaptability are also important issues that need to be considered in the design process. Therefore, a parametric design approach is incorporated in the construction of the grammar. This procedure integrates the social aspect of design, with formal and geometric parameters. For instance, changing proportions for spaces, or geometric relationships between two vocabularies could affect certain aspects

of social sustainability. This allows the process to be more flexible and contextual, and serves as a creative instrument that guides the emergence of socially sustainable solutions.

The second part (Part B: The Development of a Computational Design Tool for Socially Sustainable High-rise Residential Buildings) presents the construction of a socio-spatial grammar for high-rise residential buildings based on the two sets of grammars for traditional houses and neighbourhoods. It also shows the translation of the new grammar into a computational design tool that integrates the design brief, preferences of residents, requirements of high-rise buildings, and spatial topologies that have the potential to achieve the different social indicators.

The third part (Part C: The Generation of New Solutions, Validation of Results, and Usability Evaluation for the Tool) examines and evaluates the developed computational tool for the emergence of high-rise residential buildings. The process includes two parts. The first part is to produce different alternatives, and then test the results in terms of spatial and social qualities. The second part includes an experimental study that asked professionals and architecture students to use the tool and produce alternatives for multi-story residential buildings. These solutions were analysed according to the same process of socio-spatial analysis. Finally, a usability evaluation, which assesses the efficiency of the tool in the early stage of design, has been conducted through distributing a questionnaire to the same sample of participants.

## Part (A): A Parametric Socio-Spatial Grammar for Vernacular Houses and Neighbourhoods

### **5.2. A Socio-Spatial Grammar for Traditional Neighbourhoods**

According to topological and scalar analyses for traditional clusters, and the social meanings of these spatial layouts, specific rules that represent such qualities are presented in this section.

#### **5.2.1. Spatial Vocabularies and Social Parameters**

Each cluster of houses within the study area has specific characteristics that define the language of traditional neighbourhoods. Accordingly, the social life of residents at urban scale could be affected positively or negatively. The following is a brief about the main vocabularies of clusters, and the different associated social parameters, which are needed for guiding the emergence of socially sustainable environments.

- Public spaces: a hierarchical system of public spaces were observed. It includes three types: (a) main gathering areas (MPS); (b) semi-private open spaces between residential units (PvS); and (c) pedestrian pathways that connect those two types (Figure 5.1). The total area of these spaces represents 21-38% from the area of the cluster.
- Circulation pattern: a system of movement between houses affects different dimensions of social sustainability in neighbourhoods. For instance, perpendicular alleys have a negative impact on accessibility and human comfort. However, the visual privacy of the family increases.
- The configuration of residential units: arrangement of houses, and determining their heights and thickness of shared surfaces, affect the privacy of each family, and thermal comfort outside/inside the house.
- The arrangement of entrances for houses, which includes specifying their locations, angles between opposite doors, and any spatial element in front of the entrance. These aspects affect mainly the visual privacy and the security for the family.

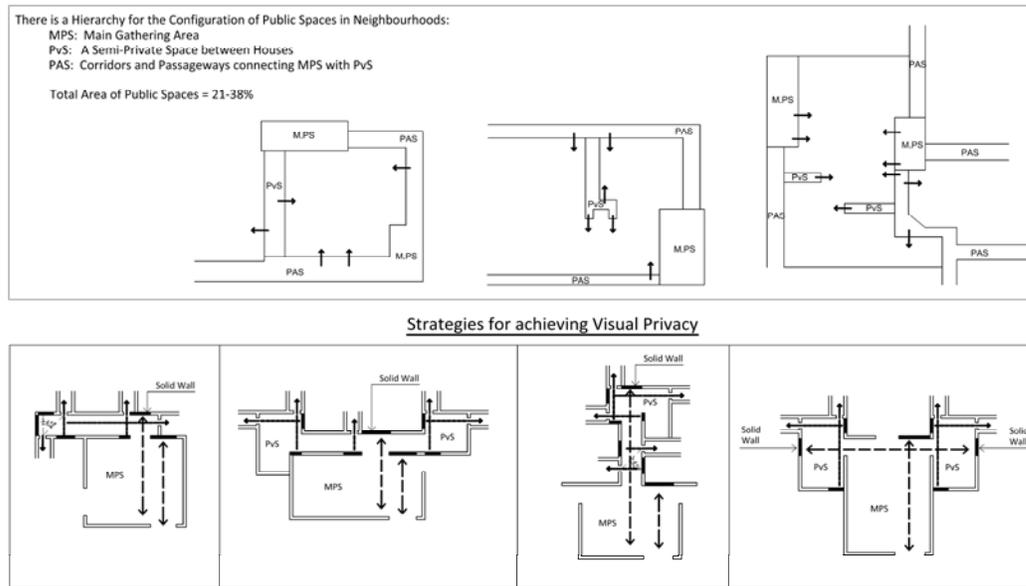


Figure 5.1: Prototypes of public spaces and arrangement of entrances in traditional neighbourhoods

The study determined correlations between social indicators and the main elements of clusters based on the following spatial parameters (Figure 5.2):

- Hierarchy of public spaces.
- Geometric configuration of public spaces and surrounding buildings.
- The percent of public spaces relative to the total area of the cluster.
- Width of public spaces.
- Orientation of public spaces.
- Patterns of openings.
- Spatial elements (such as partitions, walls, steps, or high windows) that are needed for achieving certain social qualities.

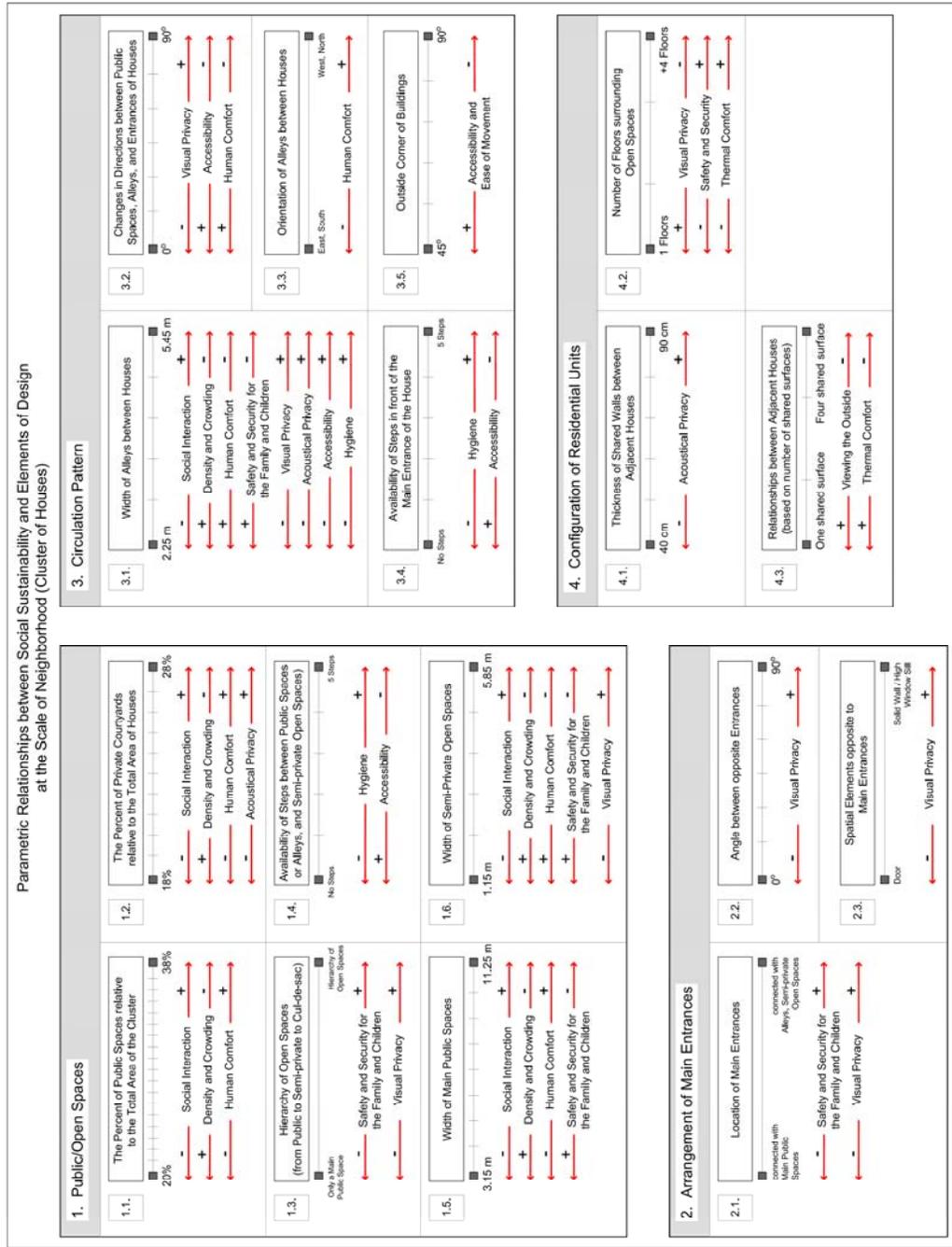


Figure 5.2: Parametric relationships between aspects of social sustainability and elements of design at the scale of neighbourhoods

### 5.2.2. Sets of Parametric Rules

A total number of 73 parametric rules, are categorised into seven groups, and defined the language of traditional neighbourhoods in MENA region (Table 5.1). Mathematical expressions, which address geometric aspects such as area, width, and orientation, are attached to these rules. During the implementation of rules, designers need to consider the following issues:

- Rules that generate public spaces and semi-private areas between residential units could be repeated according to the needs of the design.
- Rules for the configuration of passageways that connect the different public spaces with residential units could be applied according to the number of houses and the overall layout of the cluster.
- Rules for allocating entrances for houses and public spaces are guidance that needs to be applied to all doors/openings.
- Area and geometry of residential units could be divided into houses according to the design brief.
- Labels are associated with shapes to define its corners, centres, and orientation.

Table 5.1: Sets of parametric rules that define the language of traditional neighbourhoods in MENA region

| Sets of Rules  | Number of Parametric Rules |
|--|----------------------------|
| Set # 1: Rules for the configuration of main public spaces (MPS)         | 3                          |
| Set # 2: Rules for the configuration of semi-private open spaces (PVS)   | 3                          |
| Set # 3: Rules for the configuration of passageways between houses (PAS) | 3                          |
| Set # 4: Rules for achieving visual privacy between houses               |                            |
| 1.1. Rules for allocating openings between public spaces                 | 3                          |
| 1.2. Rules for allocating main entrances (EA) for houses                 | 3                          |
| Set # 5: Rules for achieving acoustical privacy between houses           | 2                          |
| Set # 6: Rules for achieving hygiene between public spaces and houses    | 1                          |
| Set # 7: Rules showing relationships between adjacent houses             |                            |
| 1.1. Houses that are attached from three sides                           | 11                         |
| 1.2. Houses that are attached from two sides                             | 24                         |
| 1.3. Houses that are attached from one side                              | 20                         |
| <b>Total number of parametric rules</b>                                  | <b>73</b>                  |

The first rule in the grammar (RN1-1) starts on the left-hand side with a labelled point that represents the centre of the cluster. When this rule is applied, the point label (0,0,0) is replaced on the right-hand side with a parameterised polygon with vertices (s1, s2, s3, s4) that represent the corners of the main public space. Angles of that shape and dimensions

could be changed according to the specifications attached to the rule. Rules (RN1-2 and RN1-3) are used to rotate and move the shape based on the context and the requirements of the design (Figure 5.3). This set of rules could be applied according to the required number of public spaces in the neighbourhood.

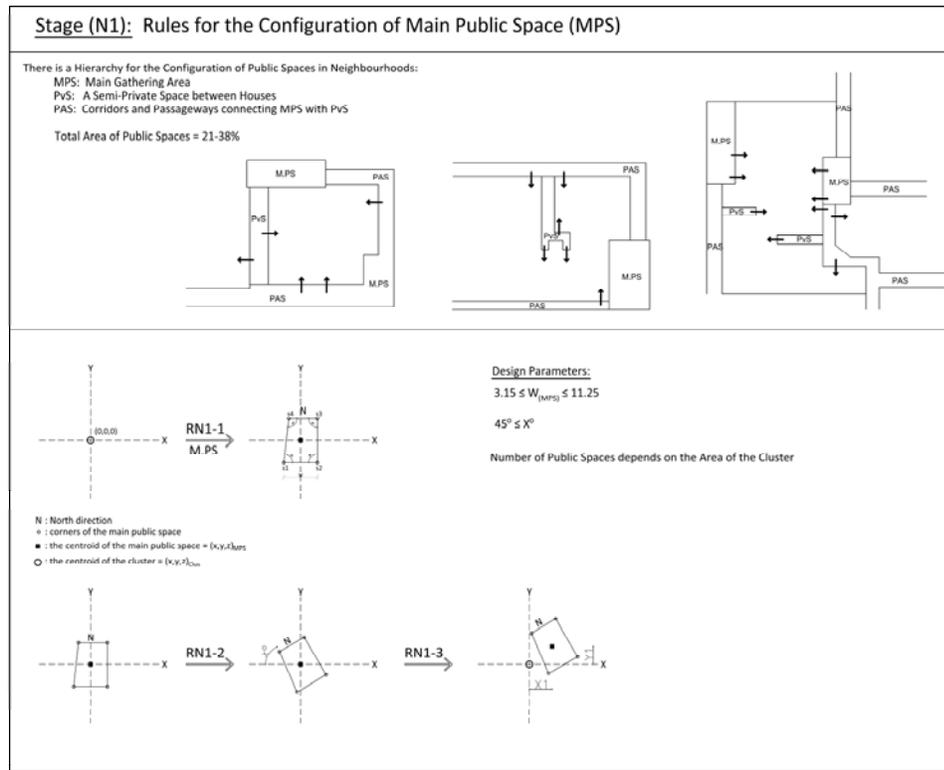


Figure 5.3: Parametric rules for the configuration of main public spaces in a neighbourhoods

The same process is used for the configuration of semi-private open spaces between residential units. These rules are illustrated in (Figure 5.4).

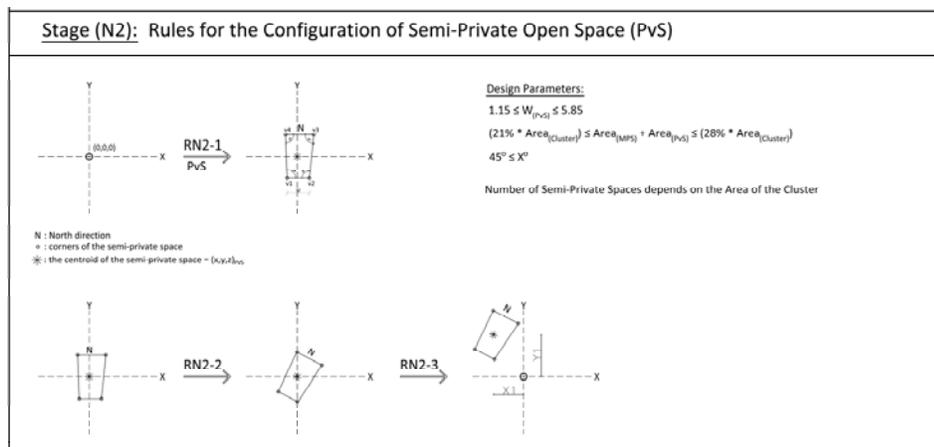


Figure 5.4: Parametric rules for the configuration of semi-private open spaces between residential units

Stage (3) from the grammar defines rules for generating patterns of movement and connections between public and semi-private spaces, which then leads to the different houses in the cluster. However, location of passageways is varied according to the overall layout of the cluster. This means that rules could be applied based on the distribution of open spaces and houses. Passageways could have a linear shape (Rule RN3-2), or an angular layout (RN3-1). Width of these connections is ranged between 2.25 and 5.45 meters. Also, designers can determine the percentage of covered alleys according to rule (RN3-3). Shelters or rooms from houses could be cantilevered up to 75 cm on one of both sides (Figure 5.5).

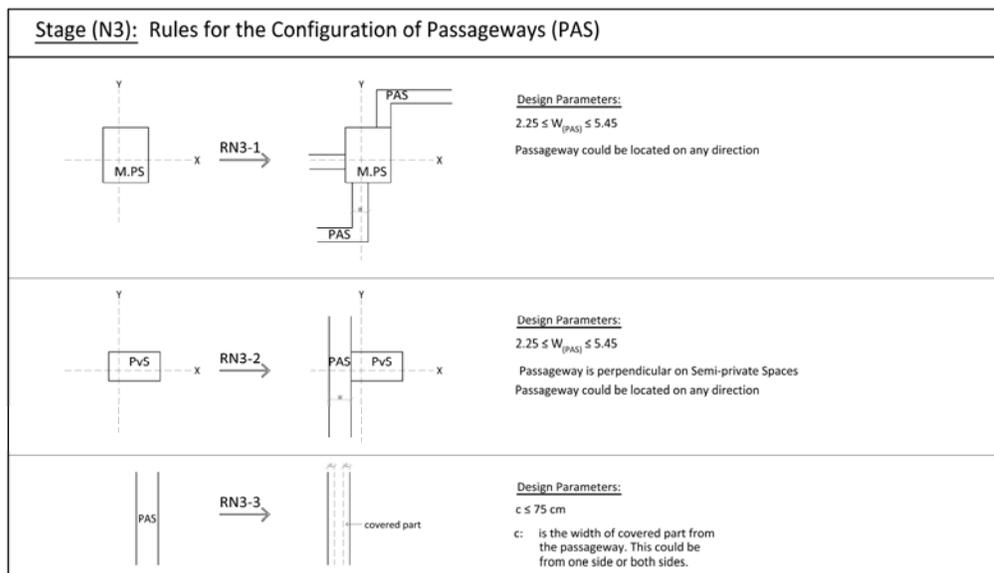


Figure 5.5: Parametric rules for the configuration of passageways in neighbourhoods

The next three stages of the grammar define spatial features that are needed to achieve certain social qualities. Stage (4) represents a set of six parametric rules for allocating openings and doors (Figure 5.6). These rules give an overall guidance for designers about relationships between adjacent openings. For instance, the gate for the main public space should face a solid wall in front of it instead of the gate of the passageway. This formula is represented as the following:

$$\text{If } (X)_{D1.1} \leq \frac{W(MPS)}{2}, \text{ then } (X)_{D2.1} > (X)_{D1.2}$$

$$\text{If } (X)_{D1.1} > \frac{W(MPS)}{2}, \text{ then } (X)_{D2.2} < (X)_{D1.1}$$

Where:

D1: is the main entrance for the cluster

D2: is the opening between the passageway and the main public space

D3: is the opening between the passageway and the semi-private open space

D1.1: is the left-side corner for D1

D1.2: is the right-side corner for D1

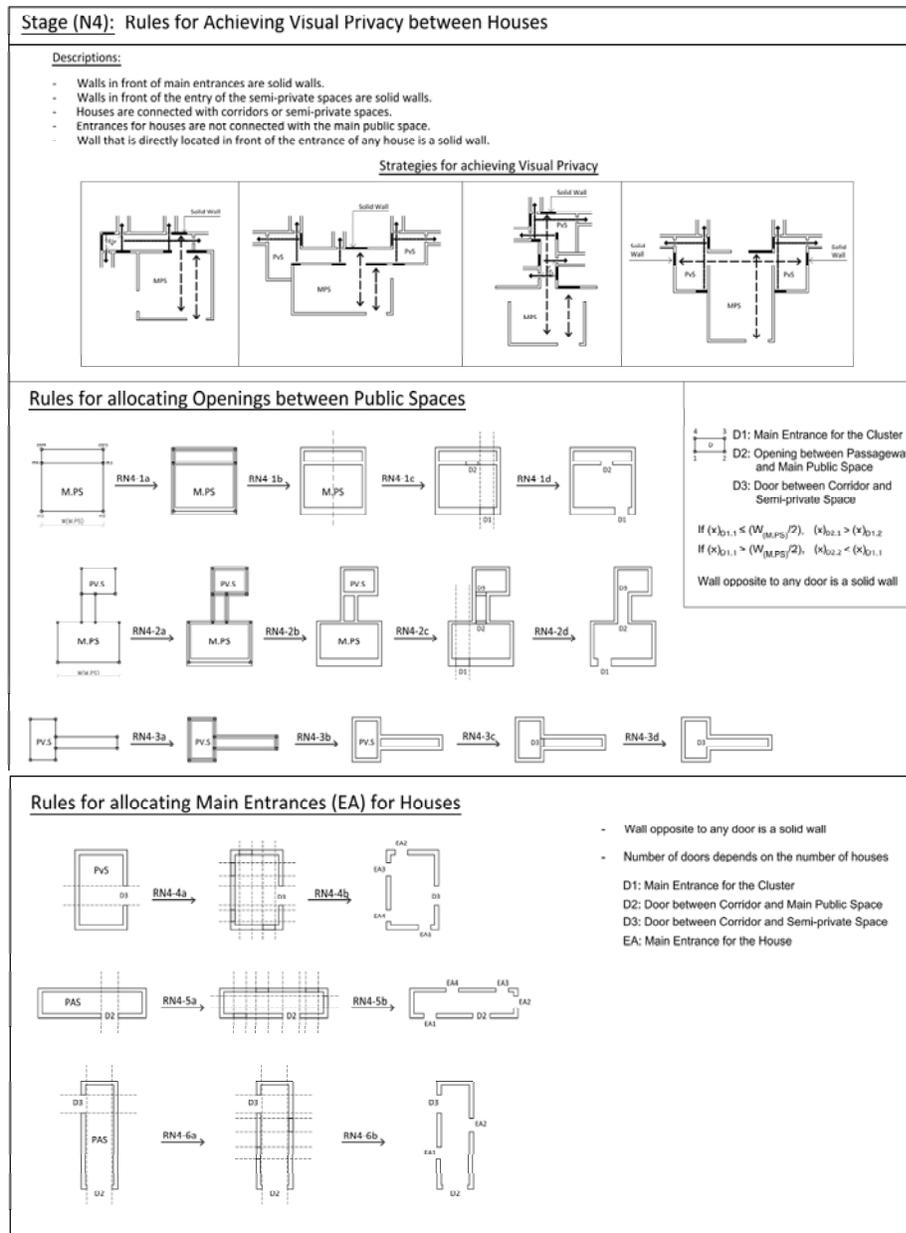


Figure 5.6: Parametric rules for achieving visual privacy between houses

Stage (5) shows rules for achieving acoustical privacy between adjacent houses, through determining thickness of shared walls. Set (6) defines rules for achieving hygiene through adding steps between open spaces and in front of entrances (Figure 5.7).

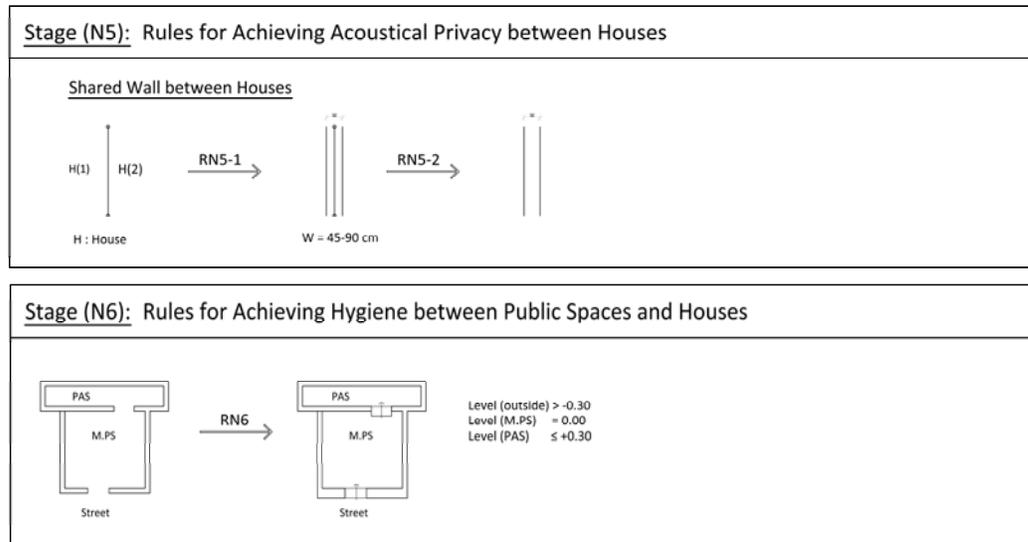


Figure 5.7: Sets of parametric rules for achieving acoustical privacy and hygiene in traditional neighbourhoods

The final stage of the grammar shows how the different houses could be arranged in the cluster according to the location of private courtyards. Three sets of rules are illustrated in (Figures 5.8 and 5.9), which represent alternatives based on number of shared surfaces. Houses could be shared with adjacent neighbours from one side, two sides, or three sides. As a result, social/environmental qualities, such as thermal comfort and potentials for viewing the outside context, could be affected.

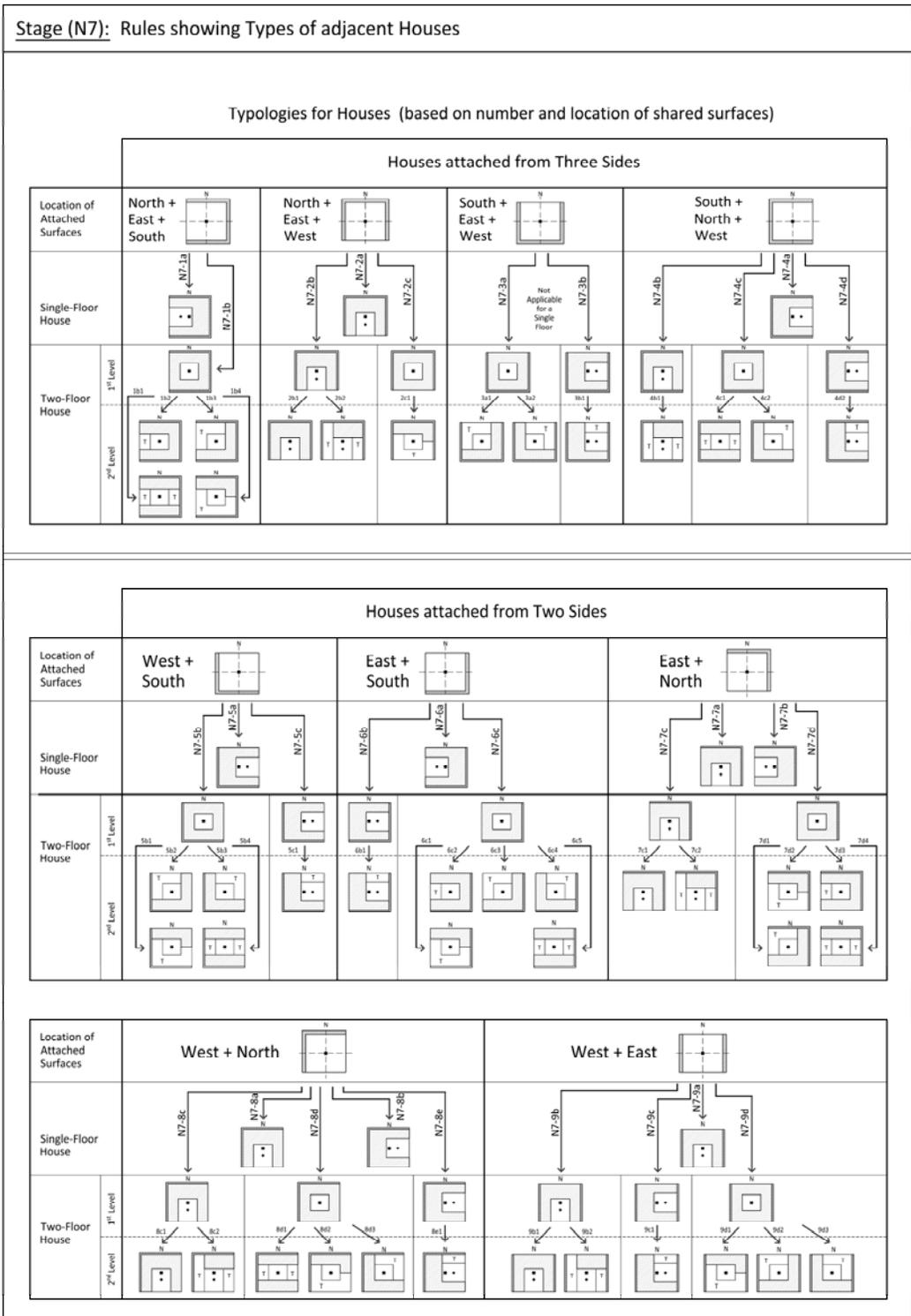


Figure 5.8: Sets of parametric rules for the configuration of adjacent houses in traditional neighbourhoods (part 1)

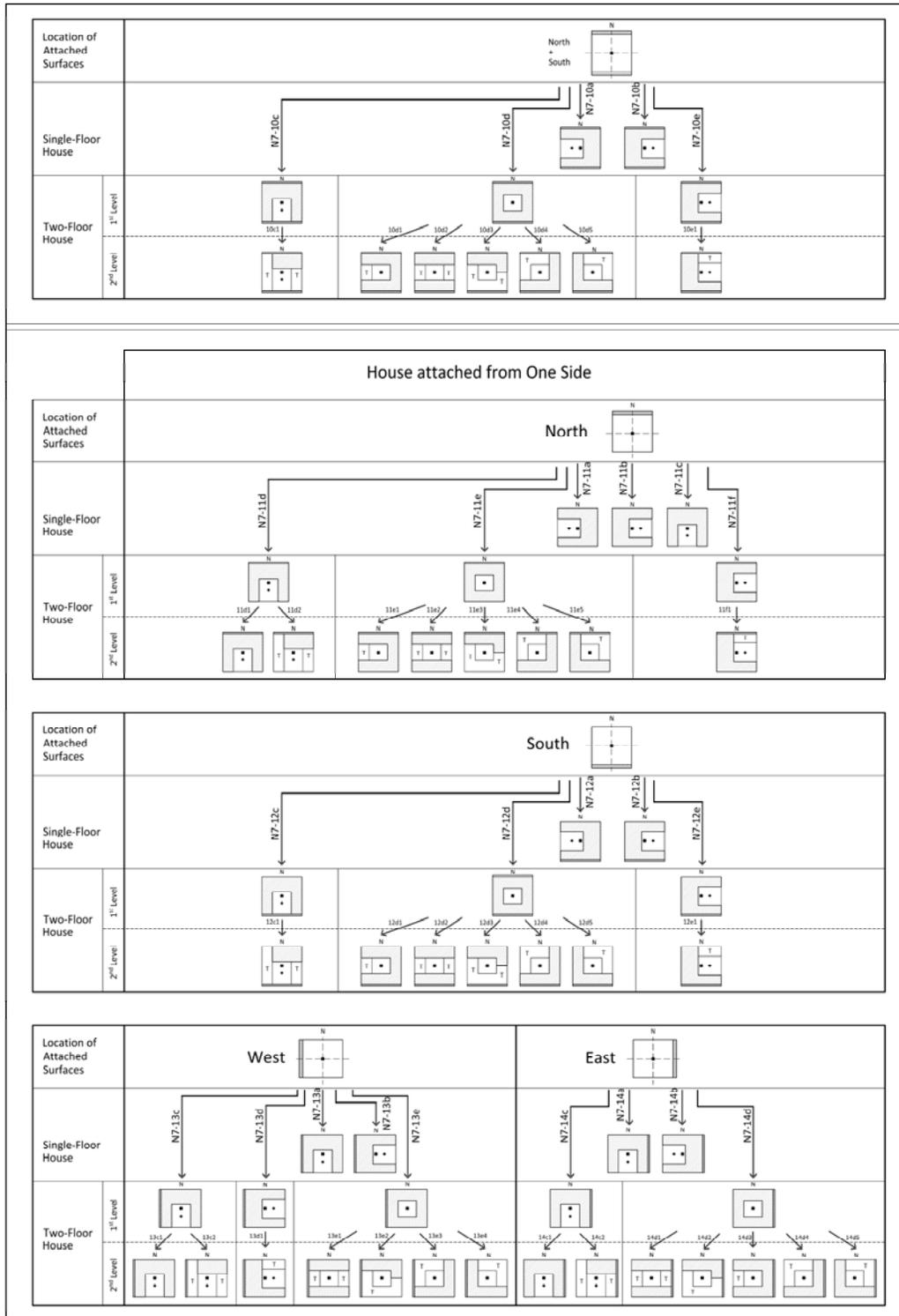


Figure 5.9: Sets of parametric rules for the configuration of adjacent houses in traditional neighbourhoods (part 2)

### 5.3. A Socio-Spatial Parametric Grammar for Vernacular Houses in MENA Region

Based on spatial, formal, and syntactical analyses carried out for the different cases distributed on the study area, the language and the social logic of residential units are presented in this section.

#### 5.3.1. Spatial Vocabularies and Social Parameters

The language of design is characterised by defining the following spatial features:

- a. Initial shape: it represents the centre of the courtyard, as it has the highest integration and control values.
- b. Vocabularies and elements of design. Each stage of the grammar is specific for generating a vocabulary element, which is considered equivalent to a function of space in the house. The dominant spatial and functional components of traditional houses in MENA region are classified according to their hierarchy (from public to private and intimate spaces), and type of enclosure (open, semi-open and closed spaces). These vocabularies are:
  - The main courtyard (MC), which is a semi-private open space. However, the courtyard could be replaced with a main covered hall that has the same function of the courtyard.
  - *Iwan* (IW), which is a semi-open and semi-private living space connected directly with the main courtyard.
  - Gallery (GL), which is a semi-open and semi-private space connected directly with the main courtyard.
  - The main entry hall (EA), which is a public space connected with the outside, and used by guests and/or family members.
  - Guest room (G), which is a semi-public space, used dominantly by male visitors.
  - Living space (LV), which is a private space.
  - Bedroom (B), which is an intimate space.
  - Paths and corridors (P), which are private transitional spaces.
  - Vertical circulation (Cir), which are private stairs leading to upper floors and used by family members.
  - Service entrance (EB), which is a semi-private space connected with the outside.
  - Services (S), which are private/intimate spaces, including kitchen, storage areas, toilets, and bathrooms.
  - Terraces (T): which are semi-private spaces.

- c. Geometric properties for each space, which are associated with mathematical expressions that describe width (W), length (L), and area (Table 5.2).
- d. Spatial topologies that describe the location (through defining the Cartesian coordinates of the space (x,y)), orientation (West (W), East (E), North (N), South (S)), and spatial relationships between adjacent spaces. A label for each corner of the shape is defined. As each zone of the study area (the Middle East, North Africa, and the Gulf Area) has its contextual constraints, genotypes of houses were extracted and divided into groups. Each set includes different patterns for the location of main elements in relation to other zones in the composition (Table 5.3, Figures 5.10 and 5.11):

Table 5.2: Mathematical expressions and design parameters for each design element in vernacular houses

| Vocabularies and Elements of Design      | Mathematical Expressions and Design Parameters   |
|--|--|
| The main courtyard or the main hall (MC) | $1.0 \leq \frac{W(MC)}{L(MC)} \leq 1.66$ $(6.4\% \times \text{Area}_{(\text{House})}) \leq \text{Area}(\text{MC}) \leq (29.8\% \times \text{Area}_{(\text{House})})$   |
| <i>Iwan</i> (IW)                         | <p><u>ONE Iwan (IW-N) is located on the Northern side of the courtyard</u></p> $1.18 \leq \frac{W(IW.N)}{L(IW.N)} \leq 1.97$ $0.44 \leq \frac{W(IW.N)}{W(MC)} \leq 0.80$ <p><math>L(IW.N) = L(R.N)</math>, where (R.N) are rooms located on the Northern side of the courtyard</p> <p><u>ONE Iwan (IW-S) is located on the Southern side of the courtyard</u></p> $1.00 \leq \frac{W(IW.S)}{L(IW.S)} \leq 1.51$ $0.21 \leq \frac{W(IW.S)}{W(MC)} \leq 0.65$ <p><u>ONE Iwan (IW-E) is located on the Eastern side of the courtyard</u></p> $1.18 \leq \frac{W(IW.E)}{L(IW.E)} \leq 1.60$ $0.42 \leq \frac{W(IW.E)}{W(MC)} \leq 0.66$ <p><math>L(IW.E) = W(R.E)</math>, where (R.E) are rooms located on the Eastern side of the courtyard</p> <p><u>ONE Iwan (IW-W) is located on the Western side of the courtyard</u></p> $1.33 \leq \frac{W(IW.W)}{L(IW.W)} \leq 1.80$ $0.44 \leq \frac{W(IW.W)}{W(MC)} \leq 0.48$ |

TWO Iwans (IW.N, IW.S) are located on the Northern & Southern sides of the courtyard

$$1.52 \leq \frac{W(IW.N)}{L(IW.N)} \leq 2.14$$

$$1.04 \leq \frac{W(IW.S)}{L(IW.S)} \leq 1.42$$

$$0.18 \leq \frac{W(IW.N)}{W(MC)} \leq 0.63$$

$$0.30 \leq \frac{W(IW.S)}{W(MC)} \leq 0.65$$

$L(IW.N) = L(R.N)$ , where (R.N) are rooms located on the Northern side of the courtyard

Gallery (GL)

Gallery (GL.W) is located on the Western side of the courtyard

$$L(GL.W) = L(MC)$$

$$1.10 \leq W(GL.W) \leq 4.80 \text{ m}$$

$$(0.15 \times W(MC)) \leq W(GL.W) \leq (0.43 \times W(MC))$$

Gallery (GL.E) is located on the Eastern side of the courtyard

$$L(GL.E) = L(MC)$$

$$1.40 \leq W(GL.E) \leq 3.10 \text{ m}$$

$$(0.10 \times W(MC)) \leq W(GL.W) \leq (0.47 \times W(MC))$$

Gallery (GL.N) is located on the Northern side of the courtyard

$$L(GL.N) = W(MC)$$

$$1.15 \leq W(GL.N) \leq 3.65 \text{ m}$$

$$(0.13 \times L(MC)) \leq W(GL.N) \leq (0.53 \times L(MC))$$

Gallery (GL.S) is located on the Southern side of the courtyard

$$L(GL.S) = W(MC)$$

$$1.50 \leq W(GL.S) \leq 3.60 \text{ m}$$

$$(0.17 \times L(MC)) \leq W(GL.S) \leq (0.47 \times L(MC))$$

The main entry hall (EA)

EA (Type 1): Entry Hall as a Room

$$(2.2\% \times \text{Area}_{(\text{House})}) \leq (W(EA) \times L(EA)) \leq (5.3\% \times \text{Area}_{(\text{House})})$$

$$2.25 \leq W(EA) \leq 3.60 \text{ m}$$

$L(EA)$  = length of adjacent room

EA (Type 2): Entry Hall as a Corridor

$$(1.4\% \times \text{Area}_{(\text{House})}) \leq (W(EA) \times L(EA)) \leq (3.8\% \times \text{Area}_{(\text{House})})$$

$$1.35 \leq W(EA) \leq 1.90 \text{ m}$$

$L(EA)$  = length of adjacent room

|                       |   |
|-----------------------|---|
|                       | <p><u>EA (Type 3): Entry Hall as L-shape</u></p> <p><math>(W(EA) \times L(EA)) \leq (3.5\% \times \text{Area}_{(\text{House})})</math></p> <p><math>1.35 \leq W(a) \leq 1.90</math> m, where (a) is the width of the corridor</p> <p><math>L(EA), W(EA)</math> = width &amp; length of adjacent rooms</p> <p><u>EA (Type 4): Entry Hall as Z-shape</u></p> <p><math>(W(EA) \times L(EA)) \leq (5.3\% \times \text{Area}_{(\text{House})})</math></p> <p><math>1.35 \leq W(a) \leq 1.90</math> m, where (a) is the width of the corridor</p> <p><math>L(EA), W(EA)</math> = width and length of adjacent rooms</p> |
| Guest room (G)        | <p><math>(4.5\% \times \text{Area}_{(\text{House})}) \leq (W(G) \times L(G)) \leq (13.1\% \times \text{Area}_{(\text{House})})</math></p> <p><math>1.17 \leq \frac{W(G)}{L(G)} \leq 3.86</math></p>   |
| Living space (LV)     | <p><math>(4\% \times \text{Area}_{(\text{House})}) \leq (W(LV) \times L(LV)) \leq (12\% \times \text{Area}_{(\text{House})})</math></p> <p><math>(7\% \times \text{Area}_{(\text{House})}) \leq \sum \text{Area}_{(\text{All Living Rooms})} \leq (21\% \times \text{Area}_{(\text{House})})</math></p> <p><math>1.17 \leq \frac{W(LV)}{L(LV)} \leq 3.25</math></p>   |
| Bedroom (B)           | <p><math>(4\% \times \text{Area}_{(\text{House})}) \leq (W(B) \times L(B)) \leq (7\% \times \text{Area}_{(\text{House})})</math></p> <p><math>(12\% \times \text{Area}_{(\text{House})}) \leq \sum \text{Area}_{(\text{All Bedrooms})} \leq (28\% \times \text{Area}_{(\text{House})})</math></p> <p><math>1.00 \leq \frac{W(B)}{L(B)} \leq 2.00</math></p>   |
| Service entrance (EB) | <p><u>EB (Type 1): Service Entrance as a Hall</u></p> <p><math>2.25 \leq W(EB) \leq 3.60</math> m</p> <p><math>L(EB)</math> = length of adjacent room</p> <p><u>EB (Type 2): Service Entrance as a Corridor</u></p> <p><math>1.35 \leq W(EB) \leq 1.90</math> m</p> <p><math>L(EB)</math> = length of adjacent room</p>   |
| Services (S)          | <p><math>(11\% \times \text{Area}_{(\text{House})}) \leq \sum \text{Area}_{(\text{Services})} \leq (20\% \times \text{Area}_{(\text{House})})</math></p> <p>The width of services depends on the width of rooms surrounding the main courtyard.</p>   |
| Terraces (T)          | <p><math>(11\% \times \text{Area}_{(\text{House})}) \leq \sum \text{Area}_{(\text{Terraces})} \leq (16\% \times \text{Area}_{(\text{House})})</math></p>  |

Table 5.3: Patterns for the location of main elements of vernacular houses in relation to other zones in the composition

| Main elements of vernacular houses       | Patterns for the location of main elements in relation to other zones in the composition  |
|--|---|
| The main courtyard or the main hall (MC) | <p><u>The main courtyard (MC) could be located:</u></p> <ul style="list-style-type: none"> <li>- At the centre of the layout (Type MC-C).</li> <li>- On the Southern side of the layout (Type MC-S).</li> <li>- On the Eastern side of the layout (Type MC-E).</li> <li>- On the Western side of the layout (Type MC-W).</li> </ul>   |
| <i>Iwan</i> (IW)                         | <ul style="list-style-type: none"> <li>- <u>Options for the Location of (IW.N), which is located on the Northern side of the courtyard:</u> <math display="block">(X,Y)_{IW.N} = (X,Y)_{MC} + \left(\frac{L(MC)}{2}\right) + \left(\frac{L(IW.N)}{2}\right)</math> <math display="block">(X,Y)_{IW1} = (X,Y)_{C4},</math> <p>where (IW1) and (C4) are corners of <i>iwan</i> and courtyard</p> </li> <li>- <u>Options for the Location of (IW.S), which is located on the Southern side of the courtyard:</u> <math display="block">(X,Y)_{IW.S} = (X,Y)_{MC} - \left(\frac{L(MC)}{2}\right) + \left(\frac{L(IW.S)}{2}\right)</math> <math display="block">(X,Y)_{IW4} = (X,Y)_{C1},</math> <p>where (IW4) and (C1) are corners of <i>iwan</i> and courtyard</p> <math display="block">(X,Y)_{IW.S} = (X,Y)_{MC} + \left(\frac{W(MC)}{2}\right) + \left(\frac{W(IW.S)}{2}\right) + d,</math> <p>where: <math>0 \leq d \leq \left(\frac{L(MC)}{2} - \frac{L(IW.S)}{2}\right)</math></p> </li> <li>- <u>Options for the Location of (IW.E), which is located on the Eastern side of the courtyard:</u> <math display="block">(X,Y)_{IW.E} = (X,Y)_{MC} + \left(\frac{W(MC)}{2}\right) + \left(\frac{W(IW.E)}{2}\right)</math> <math display="block">(X,Y)_{IW4} = (X,Y)_{C3},</math> <p>where (IW4) and (C3) are corners of <i>iwan</i> and courtyard</p> <math display="block">(X,Y)_{IW.E} = (X,Y)_{MC} + \left(\frac{W(MC)}{2}\right) + \left(\frac{W(IW.E)}{2}\right) + d,</math> <p>where: <math>0 \leq d \leq \left(\frac{L(MC)}{2} - \frac{L(IW.E)}{2}\right)</math></p> </li> <li>- <u>Options for the Location of IW.W:</u> <math display="block">(X,Y)_{IW.W} = (X,Y)_{MC} - \left(\frac{W(MC)}{2}\right) + \left(\frac{W(IW.W)}{2}\right)</math> <math display="block">(X,Y)_{IW3} = (X,Y)_{C4},</math> <p>where (IW3) and (C4) are corners of <i>iwan</i> and courtyard</p> </li> </ul> |
| Gallery (GL)                             | <ul style="list-style-type: none"> <li>- Gallery is attached to the courtyard</li> <li>- <u>Gallery (GL.W) on the Western side of the courtyard</u> <math display="block">(X,Y)_{GL3} = (X,Y)_{C4}</math> <math display="block">(X,Y)_{GL2} = (X,Y)_{C1}</math> <p>where (GL3), (GL2), (C4), and (C1) are corners of the <i>gallery</i> and the courtyard</p> </li> </ul>   |

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|--|---|
| <p>- <u>Gallery (GL.E) is located on the Eastern side of the courtyard</u><br/> <math>(X,Y)_{GL1} = (X,Y)_{C2}</math><br/> <math>(X,Y)_{GL4} = (X,Y)_{C3}</math><br/>         where (GL1), (GL4), (C2), and (C3) are corners of the <i>gallery</i> and the courtyard</p> <p>- <u>Gallery (GL.N) is located on the Northern side of the courtyard</u><br/> <math>(X,Y)_{GL1} = (X,Y)_{C4}</math><br/> <math>(X,Y)_{GL2} = (X,Y)_{C3}</math><br/>         where (GL1), (GL2), (C4), and (C3) are corners of the <i>gallery</i> and the courtyard</p> <p>- <u>Gallery (GL.S) is located on the Southern side of the courtyard</u><br/> <math>(X,Y)_{GL4} = (X,Y)_{C1}</math><br/> <math>(X,Y)_{GL3} = (X,Y)_{C2}</math><br/>         where (GL4), (GL3), (C1), and (C2) are corners of the <i>gallery</i> and the courtyard</p> |   |
| <hr/> <p>The main entry hall (EA)</p>  | <p>- EA is attached directly to the main courtyard.<br/>         - EA is attached to a gallery in front of the main courtyard.<br/>         - EA is attached to a corridor that leads to the gallery in front of the main courtyard.</p>  |
| <hr/> <p>Guest room (G)</p>  | <p>- The guest room is attached to the main entry hall.</p>   |
| <hr/> <p>Living space (LV)</p>   | <p>- Location of a living room depends on the location of semi-private spaces (IW, GL, and MC).<br/>         - The living room is located opposite to bedrooms (for achieving acoustical privacy).<br/>         - In most cases, the guest room and the main entry hall are located adjacent to the living room, as it is used by female visitors.<br/>         - In some cases, there are two living rooms: one is for female visitors (adjacent to the guest room), and the other is for the family (adjacent to bedrooms).</p>   |
| <hr/> <p>Bedroom (B)</p>   | <p>- Location of bedrooms depends on the location of guest room and living room.</p>  |
| <hr/> <p>Vertical circulation (Cir)</p>  | <p>- On the ground floor, stairs could be attached to the main entry hall (EA), the courtyard (MC), or a gallery (GL).<br/>         - On upper floor(s), stairs are attached to the gallery (GL), terraces (T), or paths/transitional spaces (P).<br/>         - There are three prototypes for the location of stairs in relation to courtyards (MC), galleries (GL), and main entry hall (EA):</p> <ul style="list-style-type: none"> <li>o Type (1): accessed directly from the entry hall (EA).</li> <li>o Type (2a): adjacent to the courtyard, and located at the opposite corner of the entry hall (diagonal relationships).</li> <li>o Type (2b): adjacent to the courtyard, and located at the opposite corner of the entry hall (linear relationships).</li> <li>o Type (3): adjacent to the courtyard/gallery, and accessed from the gallery.</li> </ul> |

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|-----------------------|---|
| Service entrance (EB) | <ul style="list-style-type: none"><li>- EB is connected with services and/or courtyard/gallery, and it has to open to the outside context.</li><li>- Service entrance could be located opposite to, or adjacent to the main entrance (EA).</li></ul>  |
| Services (S)          | <ul style="list-style-type: none"><li>- Location of services depends on the overall layout of the house, and the location of the courtyard and other rooms.</li><li>- Kitchen, storage areas, and toilets are adjacent to living room and/or service entrance.</li><li>- Bathrooms are adjacent to bedrooms.</li><li>- Toilets are adjacent to the guestroom.</li></ul>   |
| Terraces (T)          | <ul style="list-style-type: none"><li>- Options for the location of terraces in relation to the layout of the ground floor: South-West, West, North-West, North, South-East.</li><li>- Location of terraces in relation to the layout of the first floor: (N+W sides), (N+E sides), (S+W+E sides), (N side), (W side), (E+W sides).</li><li>- Terraces could be connected with bedrooms or living spaces.</li></ul> |

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Information gained from spatial and syntactical analyses - at both urban and residential unit scales - is used to establish a database that identifies relationships between spatial elements of designs and aspects of social sustainability. Based on these records and specifications, designers can generate contextual design solutions that are responsive to social and cultural needs.

At the scale of residential units, parametric relationships between aspects of social sustainability and main vocabularies of houses are identified based on the following parameters (Figures 5.12, 5.13, and 5.14):

- The percent of areas relative to the total area of the cluster.
- Width of spaces.
- Proportion of spaces.
- Location in relation to other spaces.
- Geometric configuration of spaces.
- Orientation
- Pattern, number, size, and location of openings.
- Movement patterns.
- Thickness of walls.
- Spatial elements (such as partitions, screens, steps, sunken areas, or high windows) that are needed for achieving certain social qualities.

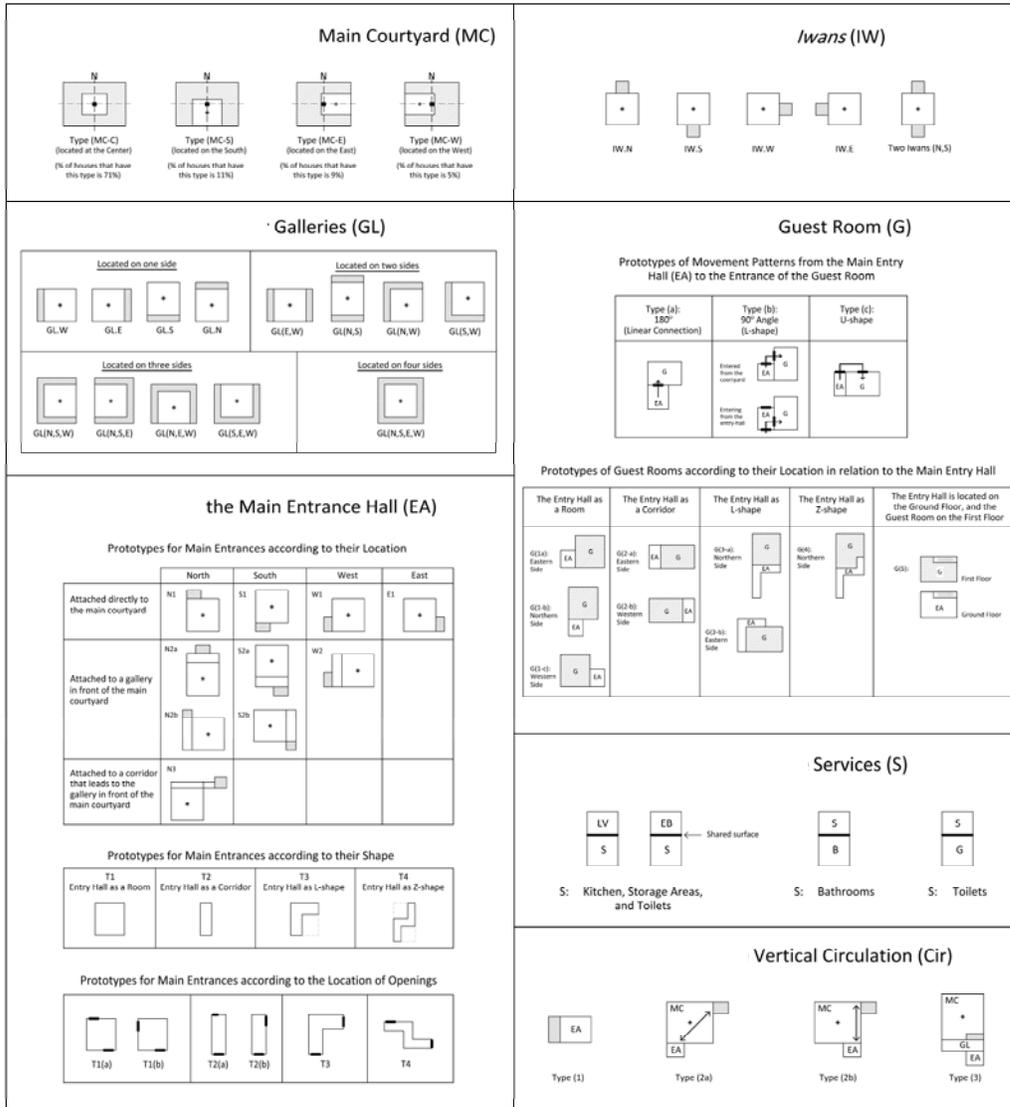


Figure 5.10: Diagrams showing design variations for the different elements in vernacular houses (part 1)

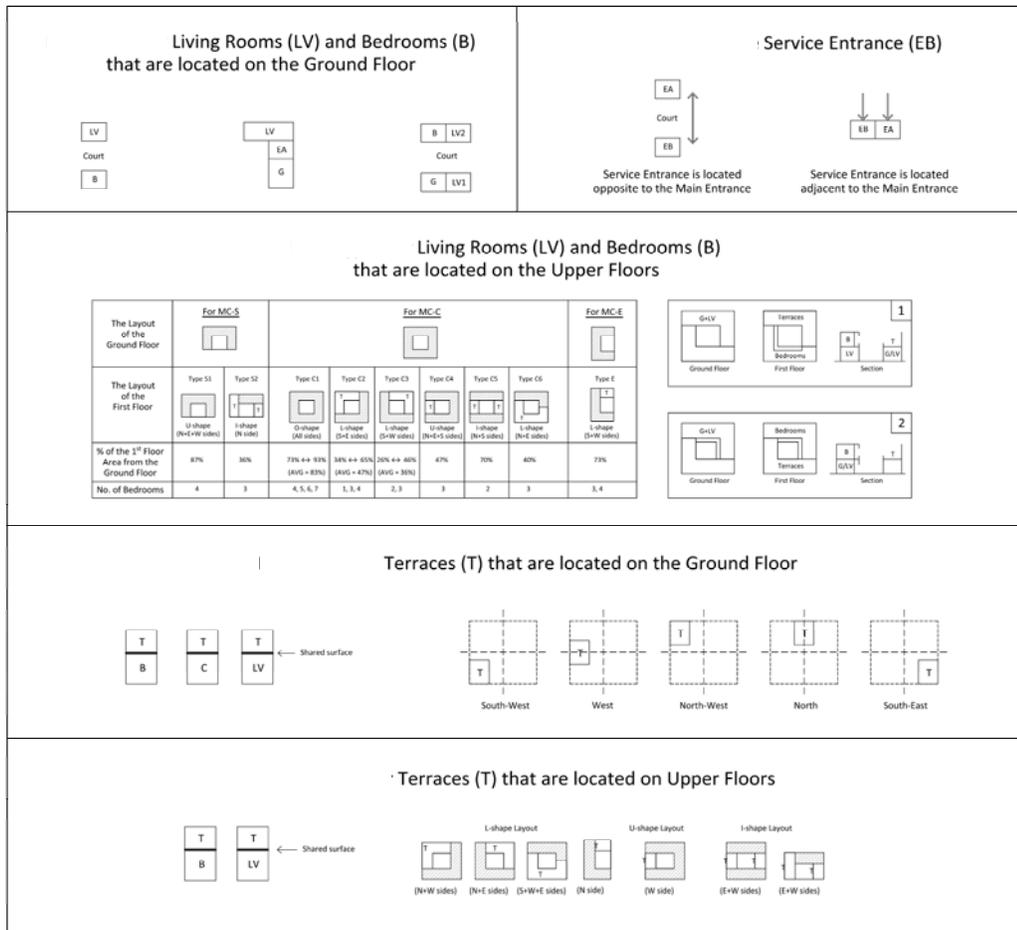


Figure 5.11: Diagrams showing design variations for the different elements in vernacular houses (part 2)

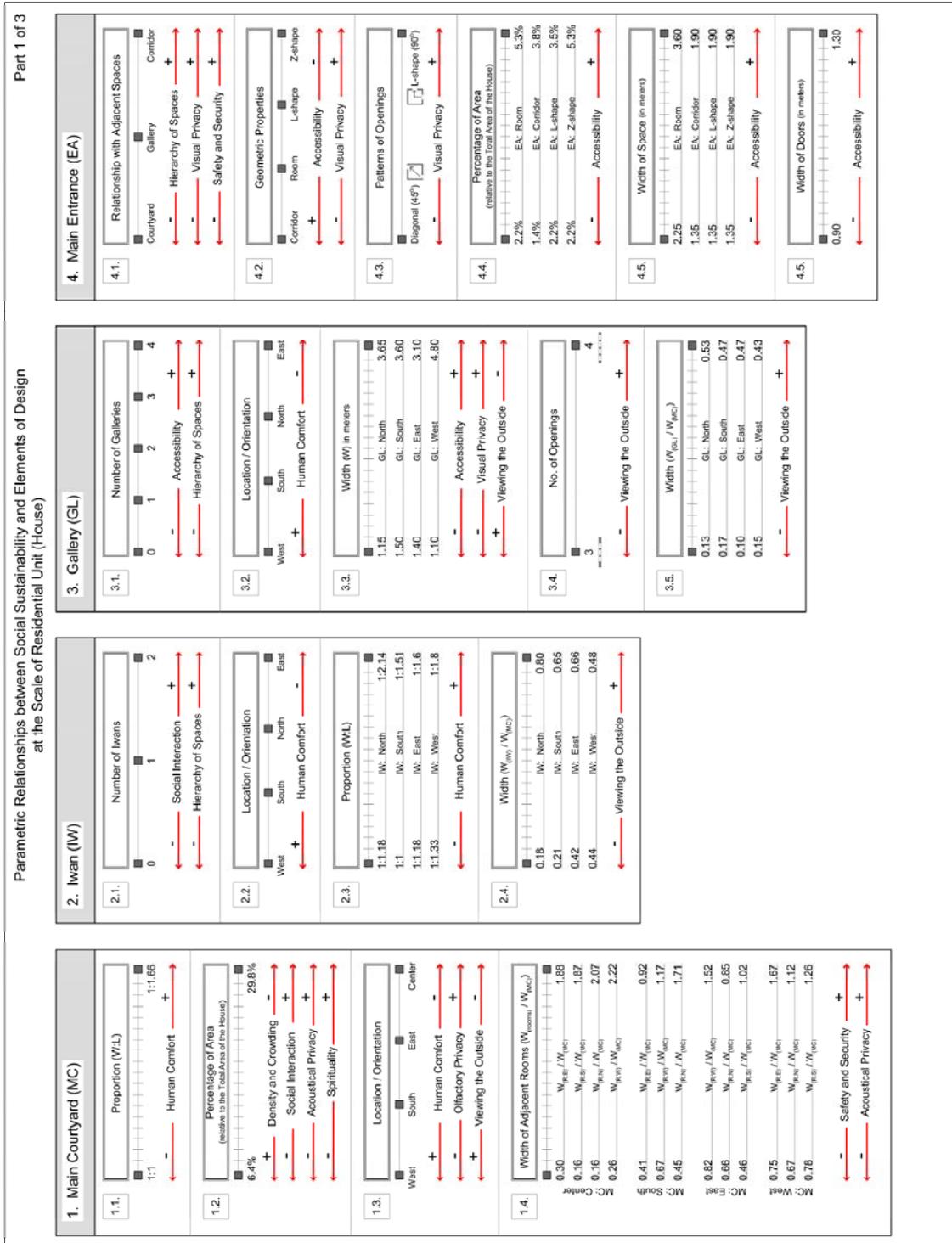


Figure 5.12: Parametric relationships between social sustainability and elements of design at the scale of residential units (part 1)

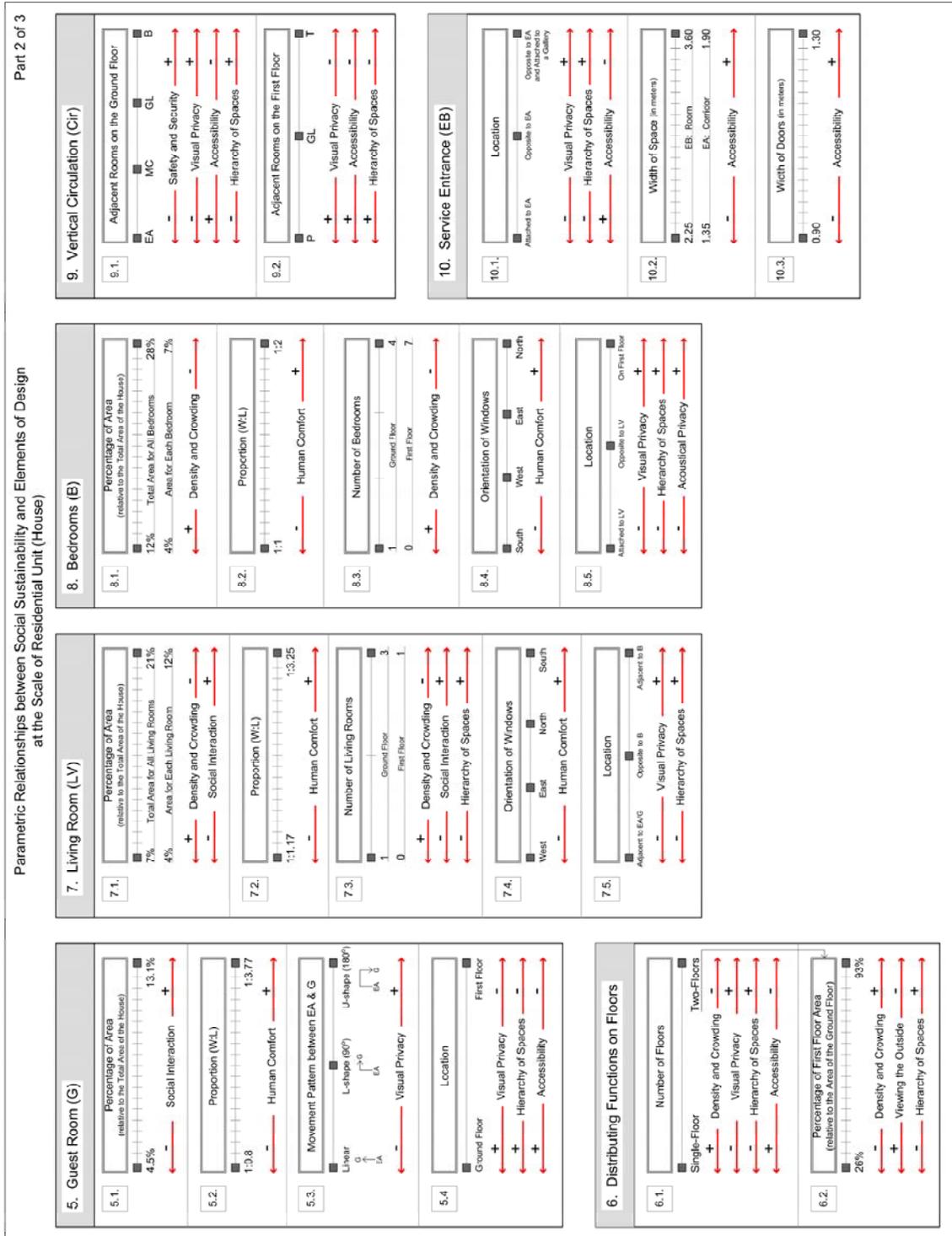


Figure 5.13: Parametric relationships between social sustainability and elements of design at the scale of residential units (part 2)

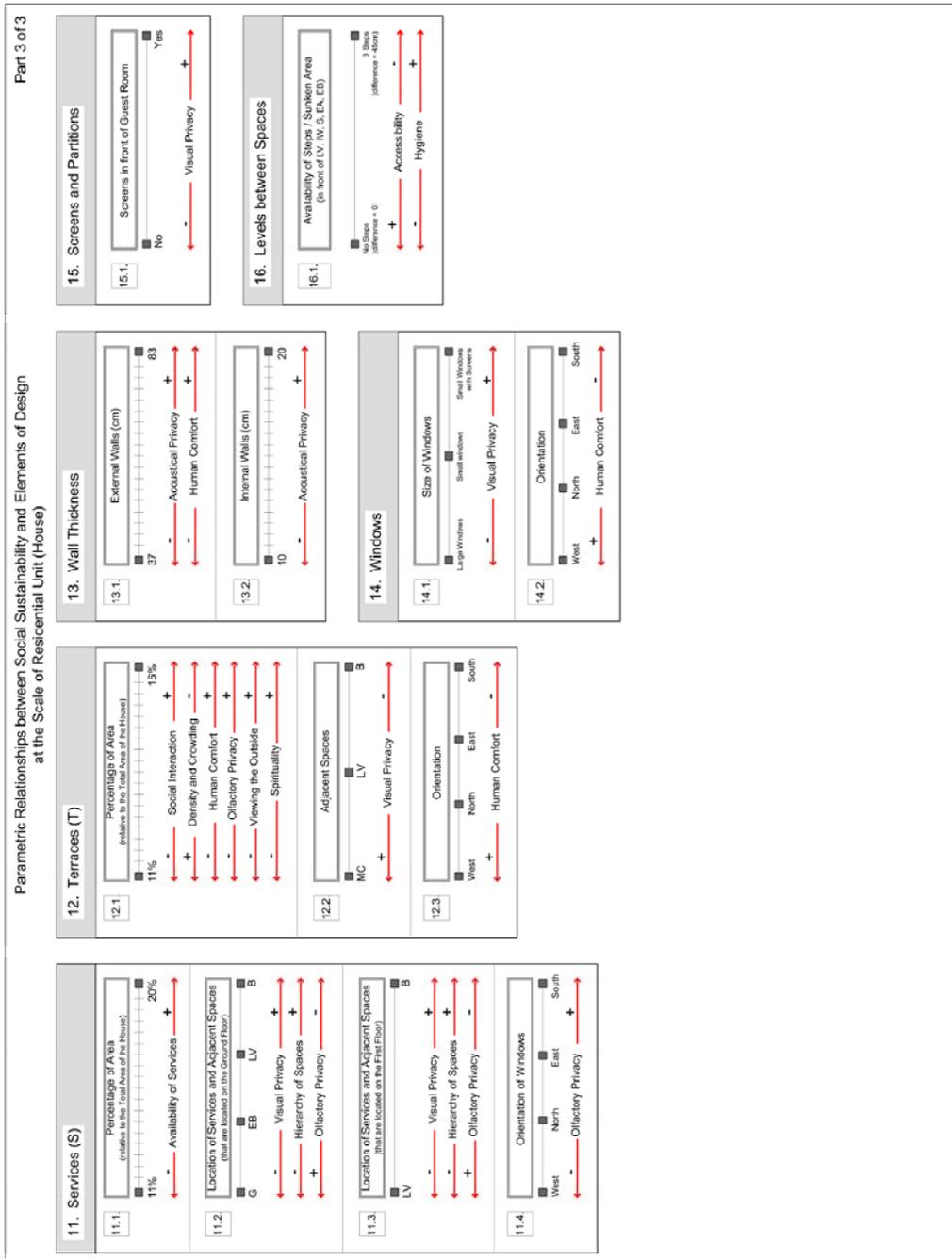


Figure 5.14: Parametric relationships between social sustainability and elements of design at the scale of residential units (part 3)

### 5.3.2. Sets of Parametric Rules

Shape rules are derived from spatial relations and social constraints. Seventeen groups of rule-sets, with a total number of 185 parametric rules, are defined for constructing the grammar for courtyard houses in the Middle East and North Africa (Figure 5.15). Each set addresses the spatial configuration of a specific vocabulary/function that captures the social logic of the form. Rules in one set are geometric transformations that are based on specific meanings and social needs. Descriptions are associated with rules to specify social/spatial attributes for each space. For instance, hierarchy of spaces, orientation, type of enclosure, shared surfaces, location of entry points, and the dominant users for each space are samples of these descriptions. Moreover, dimensions for each space, its location in relation to other spaces in the composition, and percentages of areas relative to the total area of the house, are specified as parameters linked with rules. Labels are used to guide the plan generation process.

During the construction of the parametric discursive grammar, different issues have been considered:

- All vocabularies were represented by polygons, and abstracted into squares and rectangles instead of their geometric complexity.
- Any rule could be applied if the left side of the rule matches topological relationships between that element and other spaces, regardless the geometric properties of the space.
- A rule applies if there is a similarity transformation that will bring the shape on the left side into coincidence with a sub-shape in progress.
- Labels that describe the function of each space, or its corners, or its centre are associated with shapes and points. These labels are used to control shapes and application of rules.
- Proportion and geometric properties for each space are assigned to each rule.

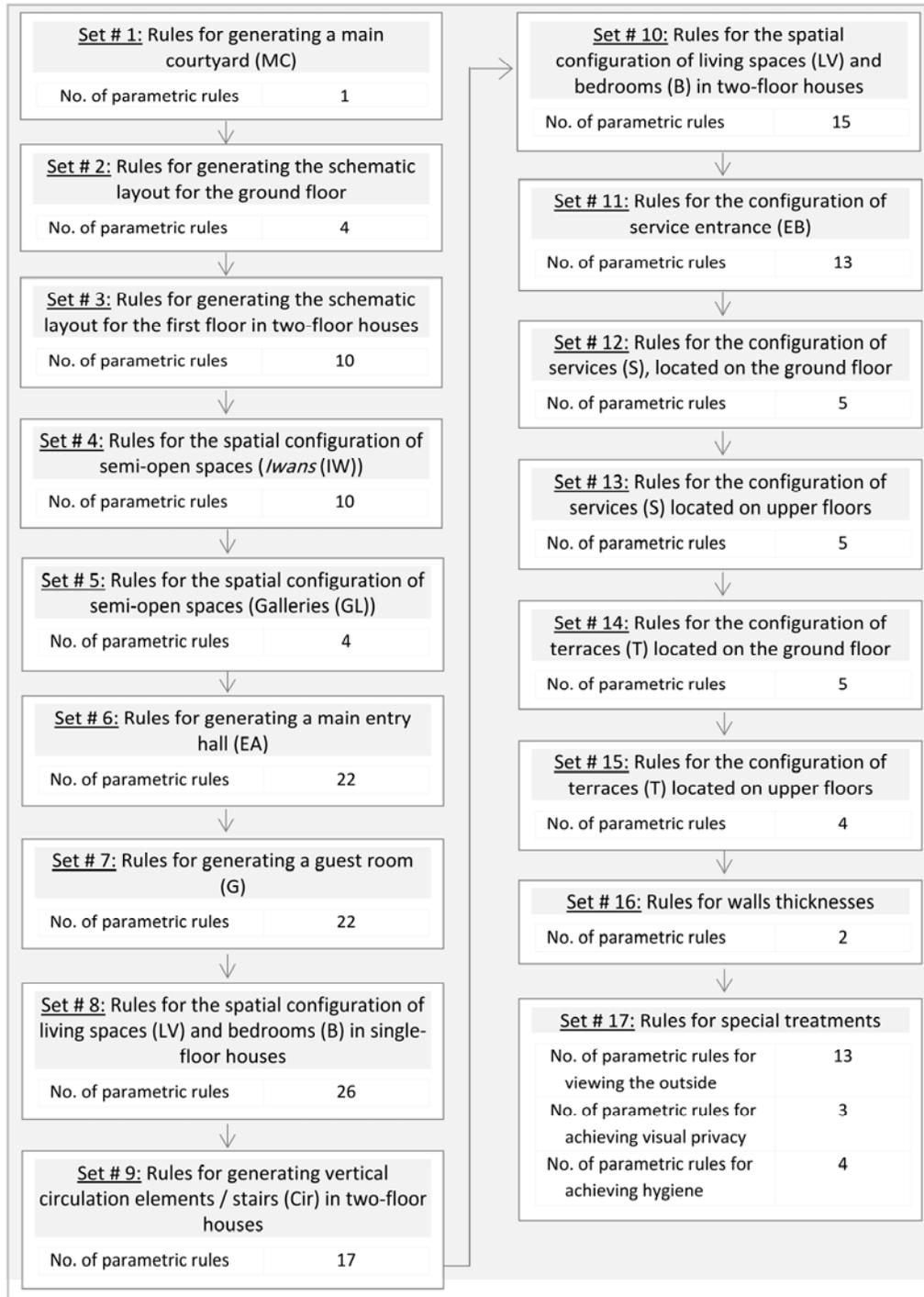


Figure 5.15: Sets of parametric rules for the construction of socio-spatial grammar for vernacular houses in MENA region

According to the syntactic analysis, the main courtyard or the main hall, the *iwan*, and the gallery were found to have the highest integration value. Therefore, the generation process that identifies topological relations between different functions depends on these three elements. The first rule in the grammar (R1-01) starts on the left-hand side with a labelled point that represents the centre of the main courtyard/hall. When this rule is applied, the point label (0,0,0) is replaced on the right-hand side with a parameterised polygon with vertices (c1, c2, c3, and c4) that represent the corners of the main courtyard. The designer needs to specify the dimensions and the area of this geometry according to the specifications associated with this rule (Figure 5.16).

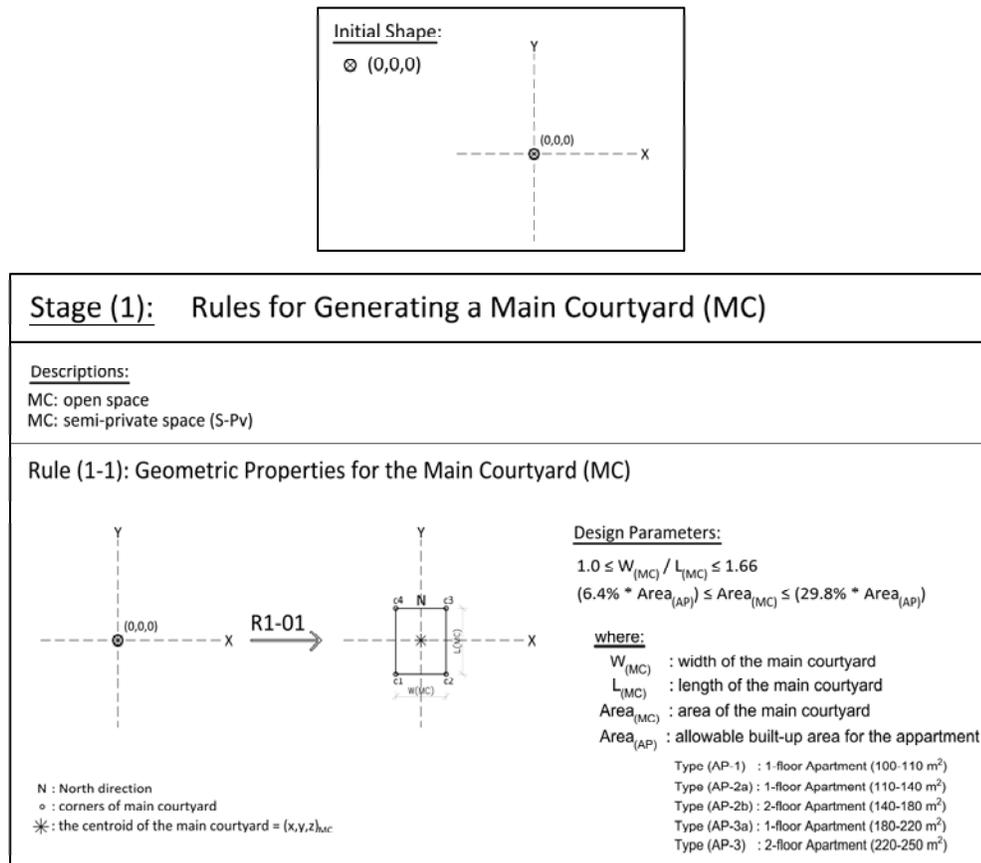


Figure 5.16: The initial shape, and the parametric rule (R1-01) for generating a main courtyard/hall in a traditional house in MENA region

The second and the third sets show rules that are used for generating the schematic layout of the ground floor in single-floor houses, and the ground/first floors in two-floor houses. Designers need to decide which rule is applicable according to the different prototypes for the location of the courtyard (Figures 5.17 to 5.20).

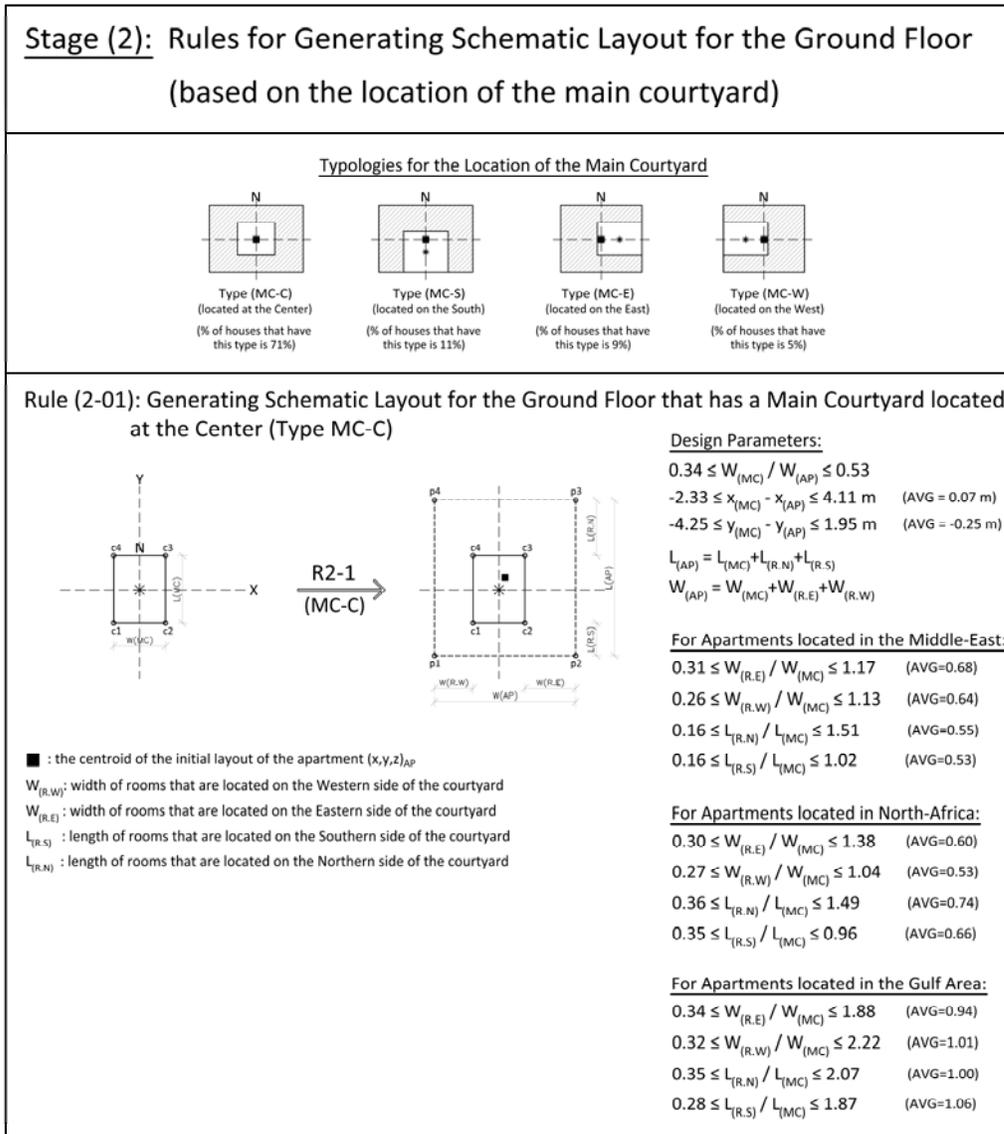


Figure 5.17: Sets of parametric rules for generating the schematic layout of the ground floor in single-floor houses (part 1)

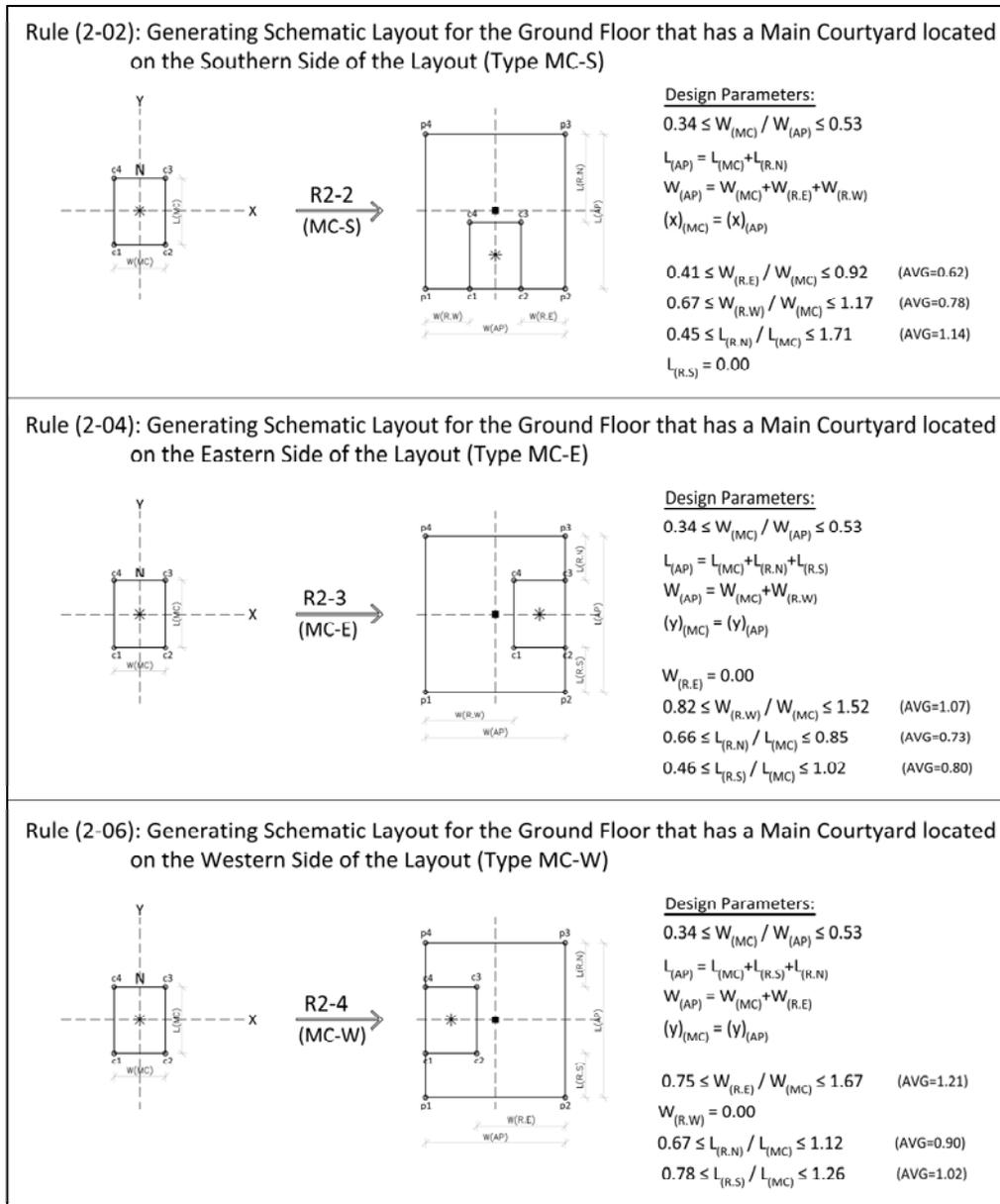


Figure 5.18: Sets of parametric rules for generating the schematic layout of the ground floor in single-floor houses (part 2)

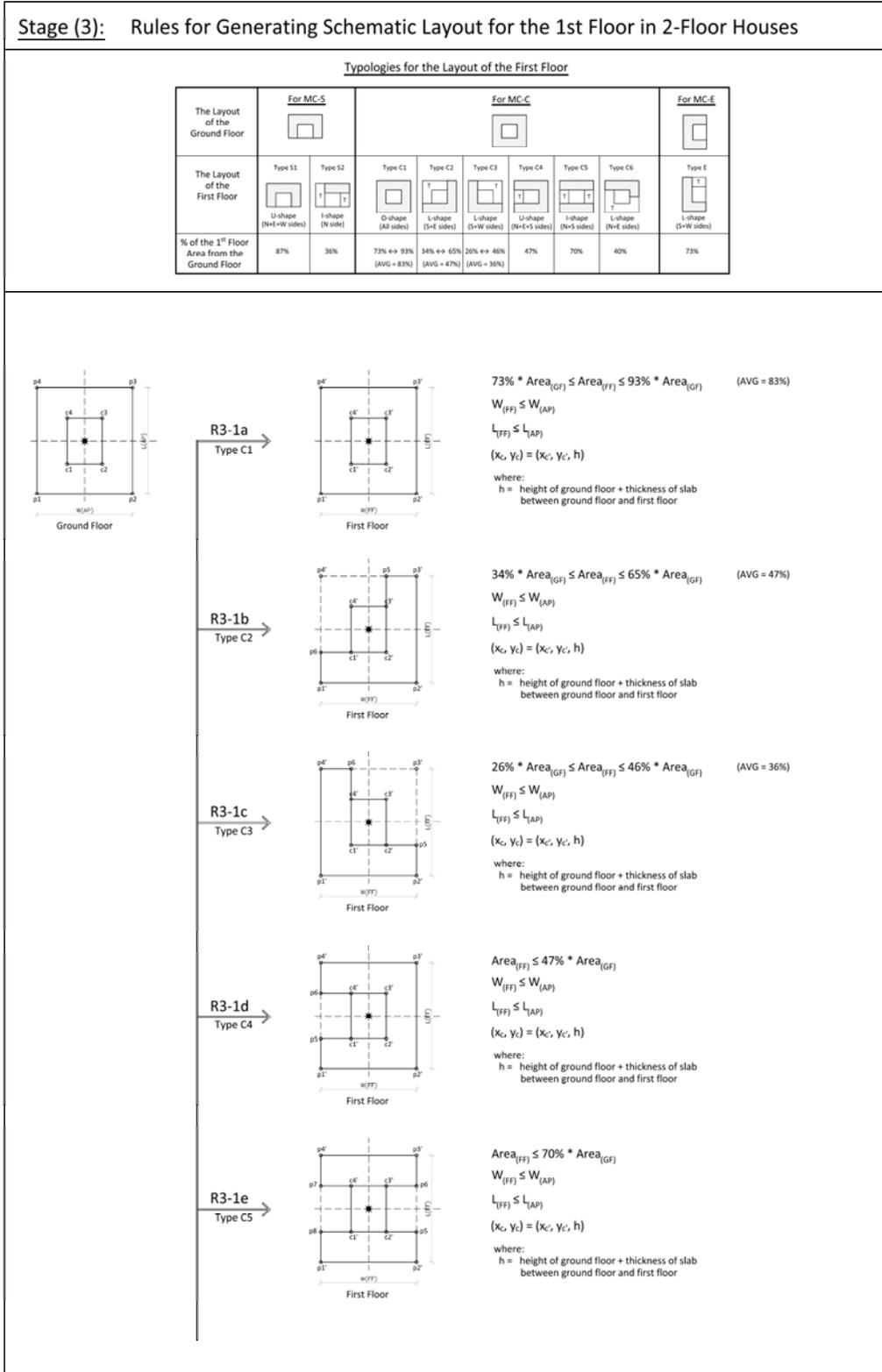


Figure 5.19: Sets of parametric rules for generating the schematic layout of the ground/first floors in two-floor houses (part 1)

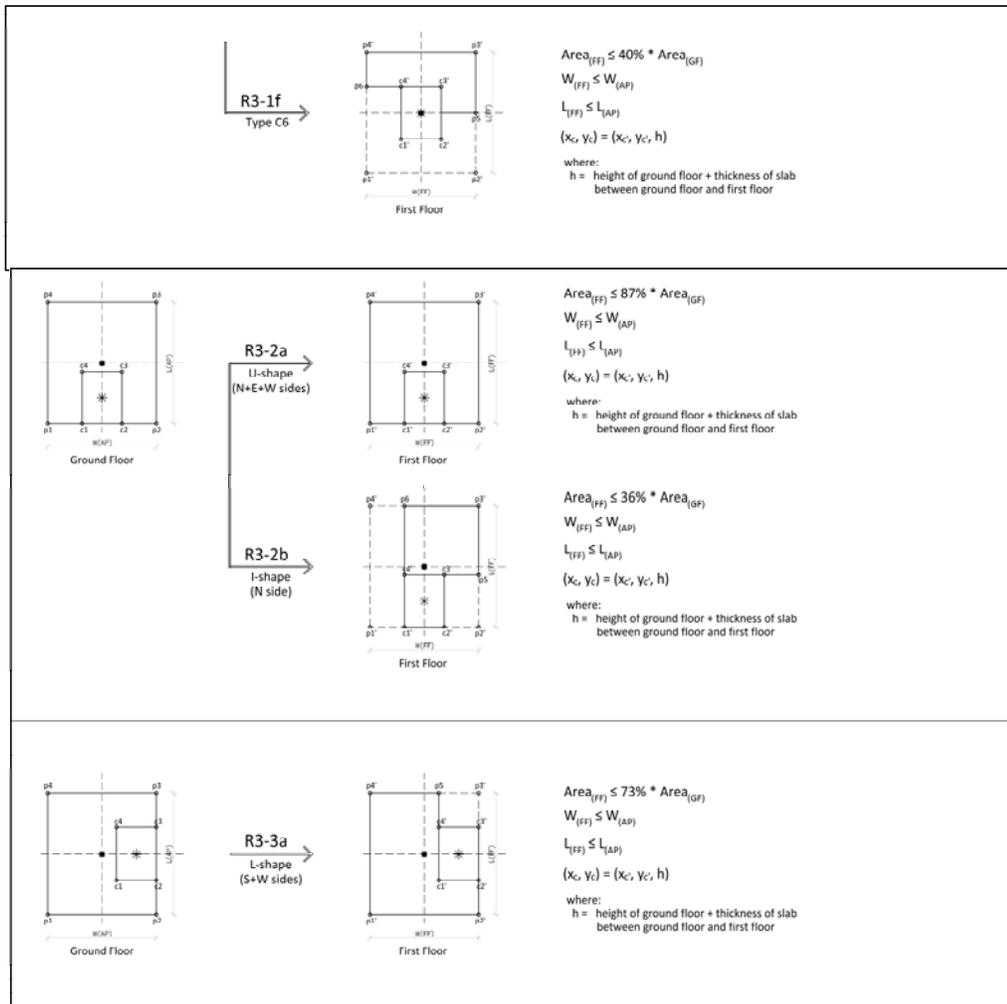


Figure 5.20: Sets of parametric rules for generating the schematic layout of the ground/first floors in two-floor houses (part 2)

The next sets of rules generate semi-open spaces (galleries and *iwans*), the main entry hall, and guest rooms (Figures 5.21 to 5.26).

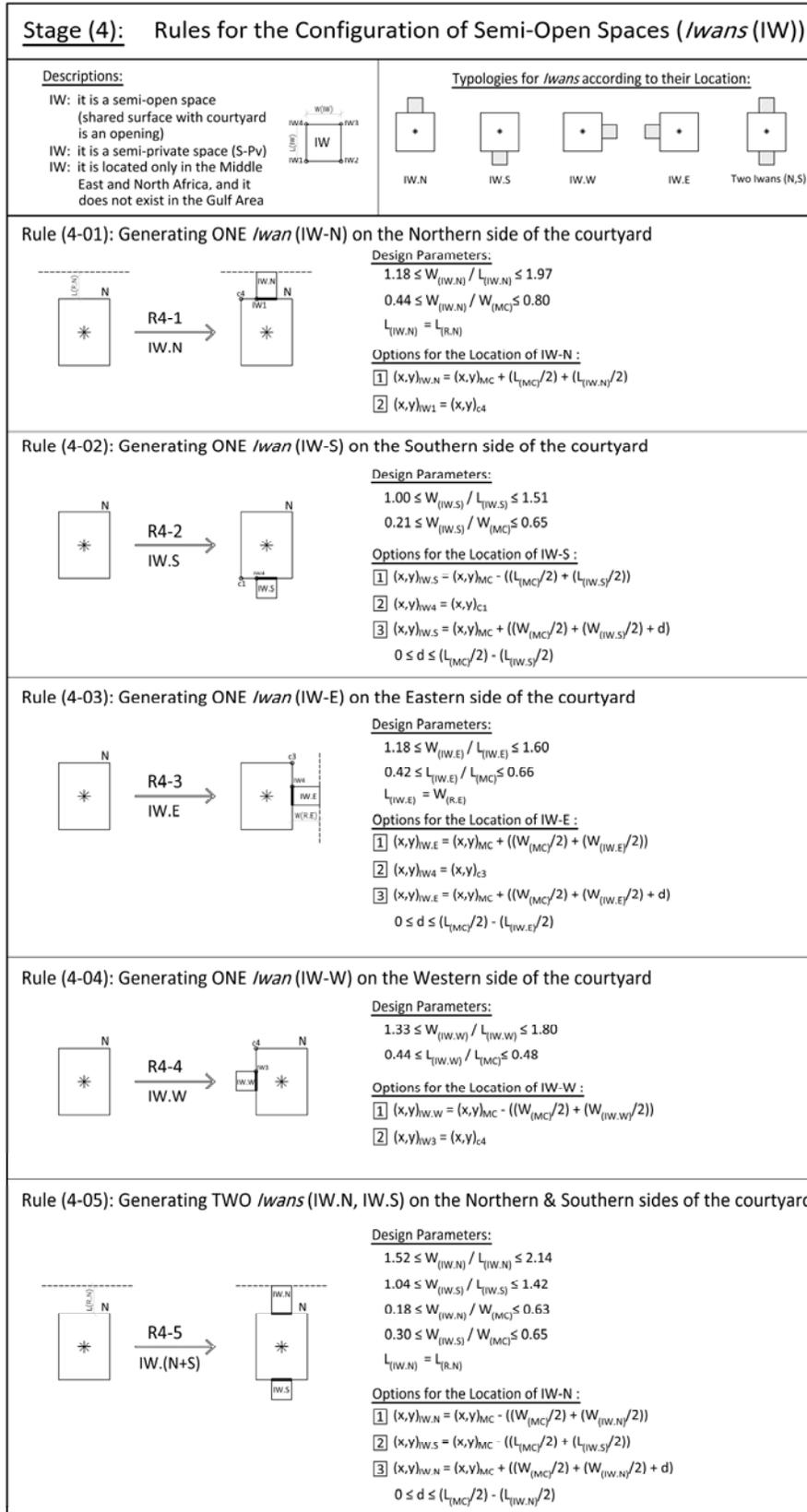


Figure 5.21: Sets of parametric rules for generating semi-open spaces (*iwans*)

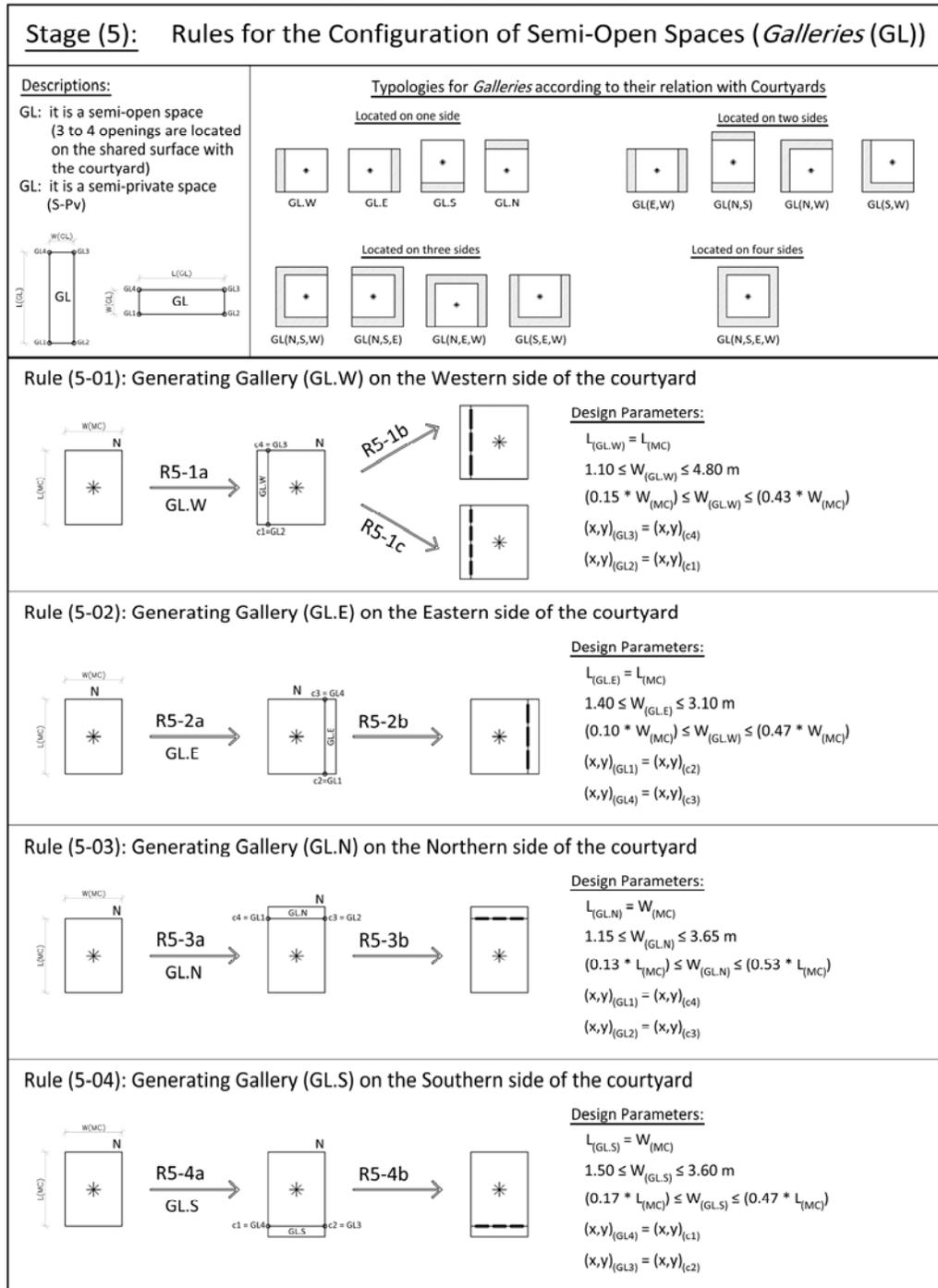


Figure 5.22: Sets of parametric rules for generating semi-open spaces (galleries)

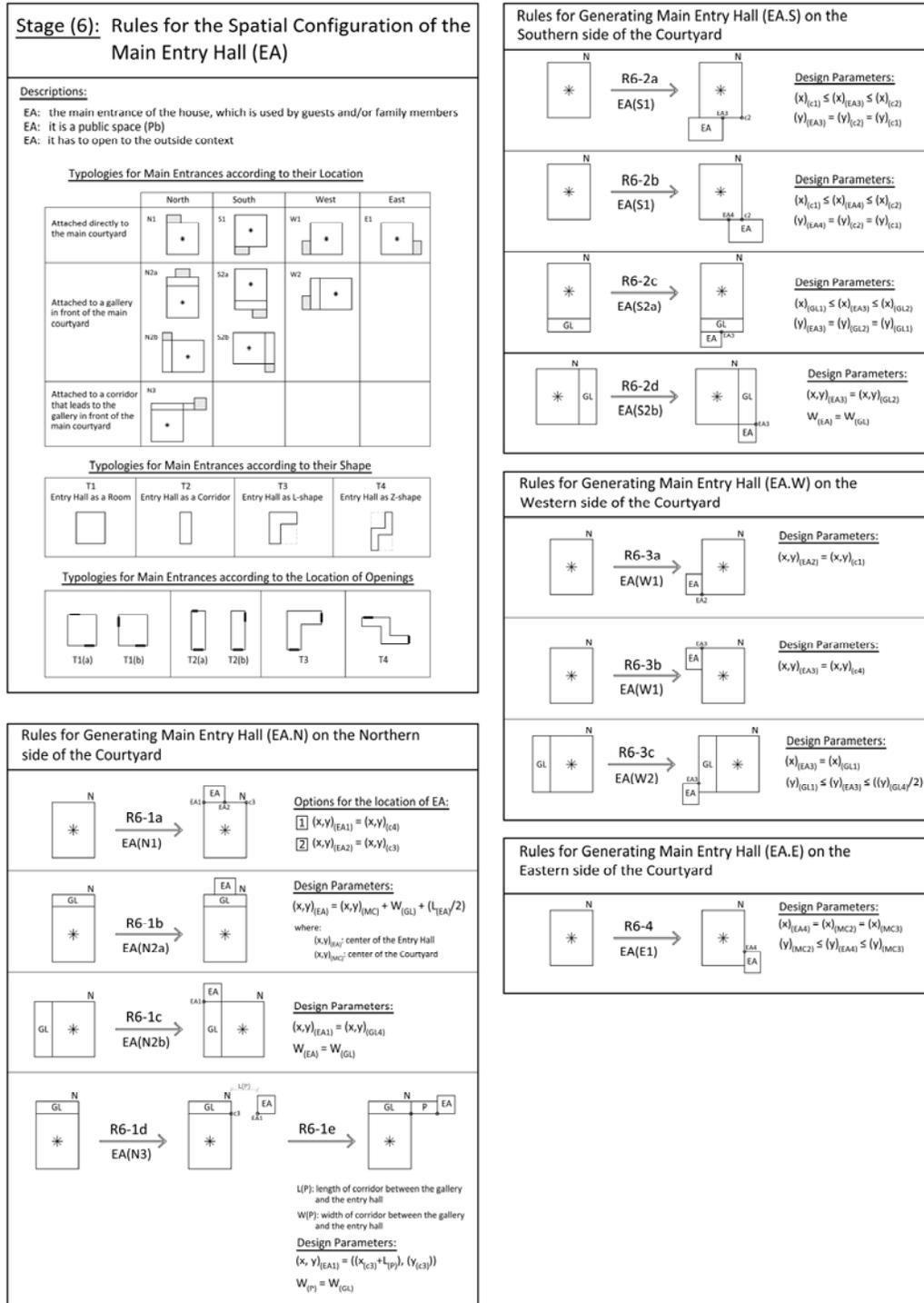


Figure 5.23: Sets of parametric rules for generating the main entry space for vernacular houses in MENA region (part 1)

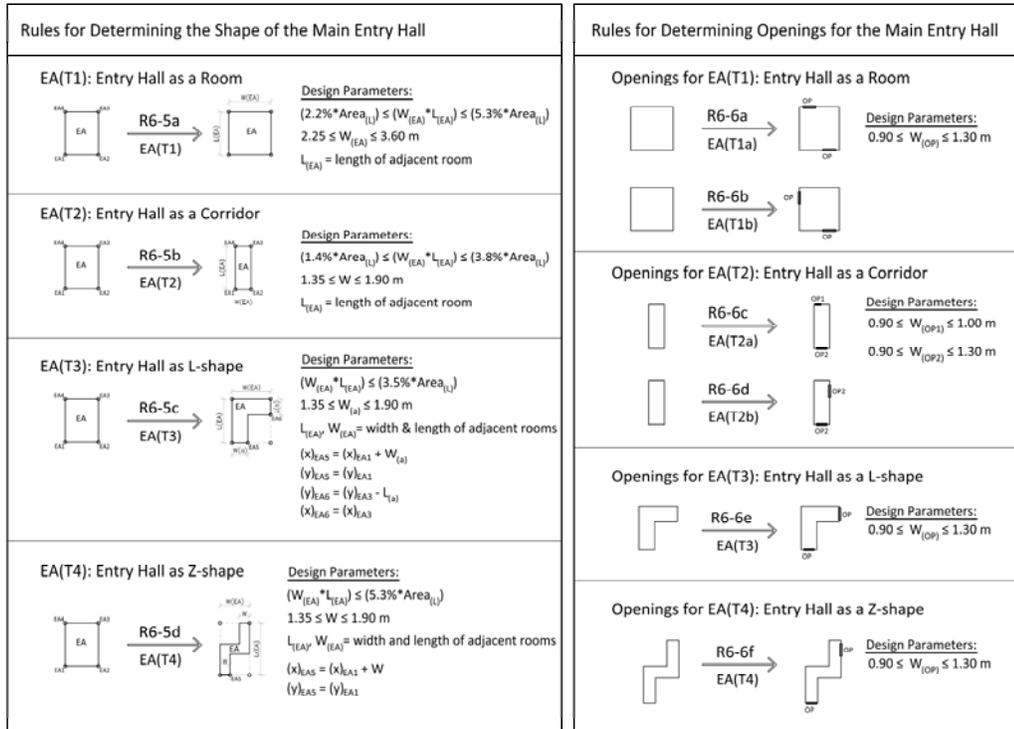


Figure 5.24: Sets of parametric rules for generating the main entry space for vernacular houses in MENA region (part 2)

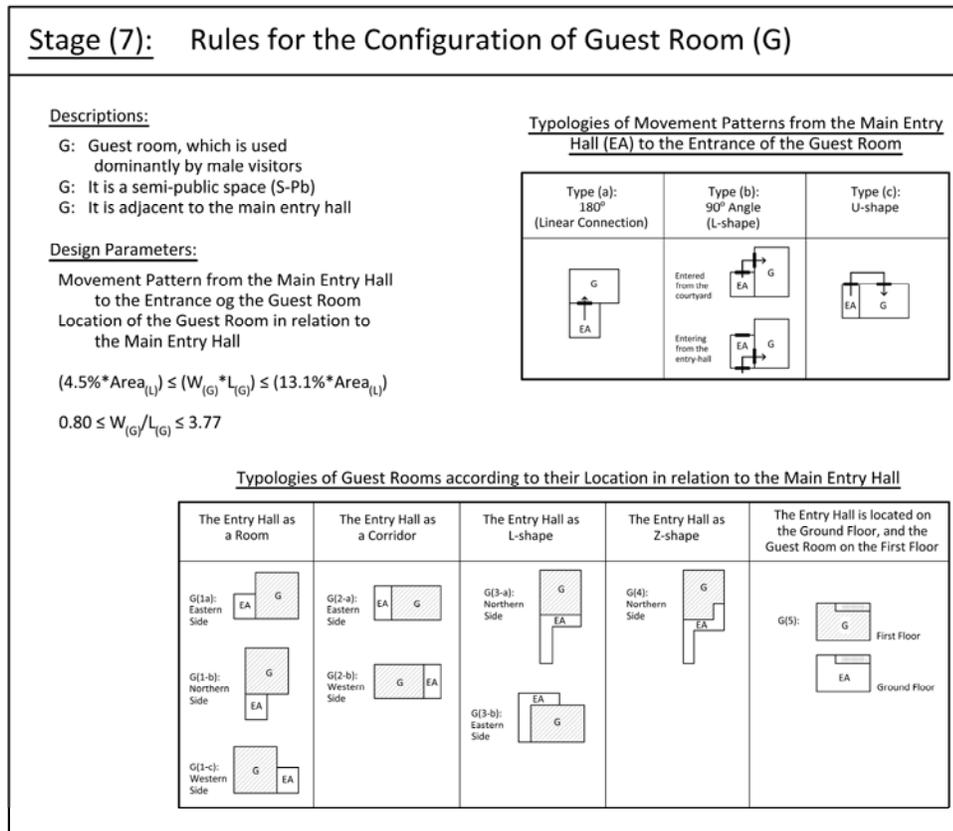


Figure 5.25: Sets of parametric rules for the configuration of a guest room (part 1)

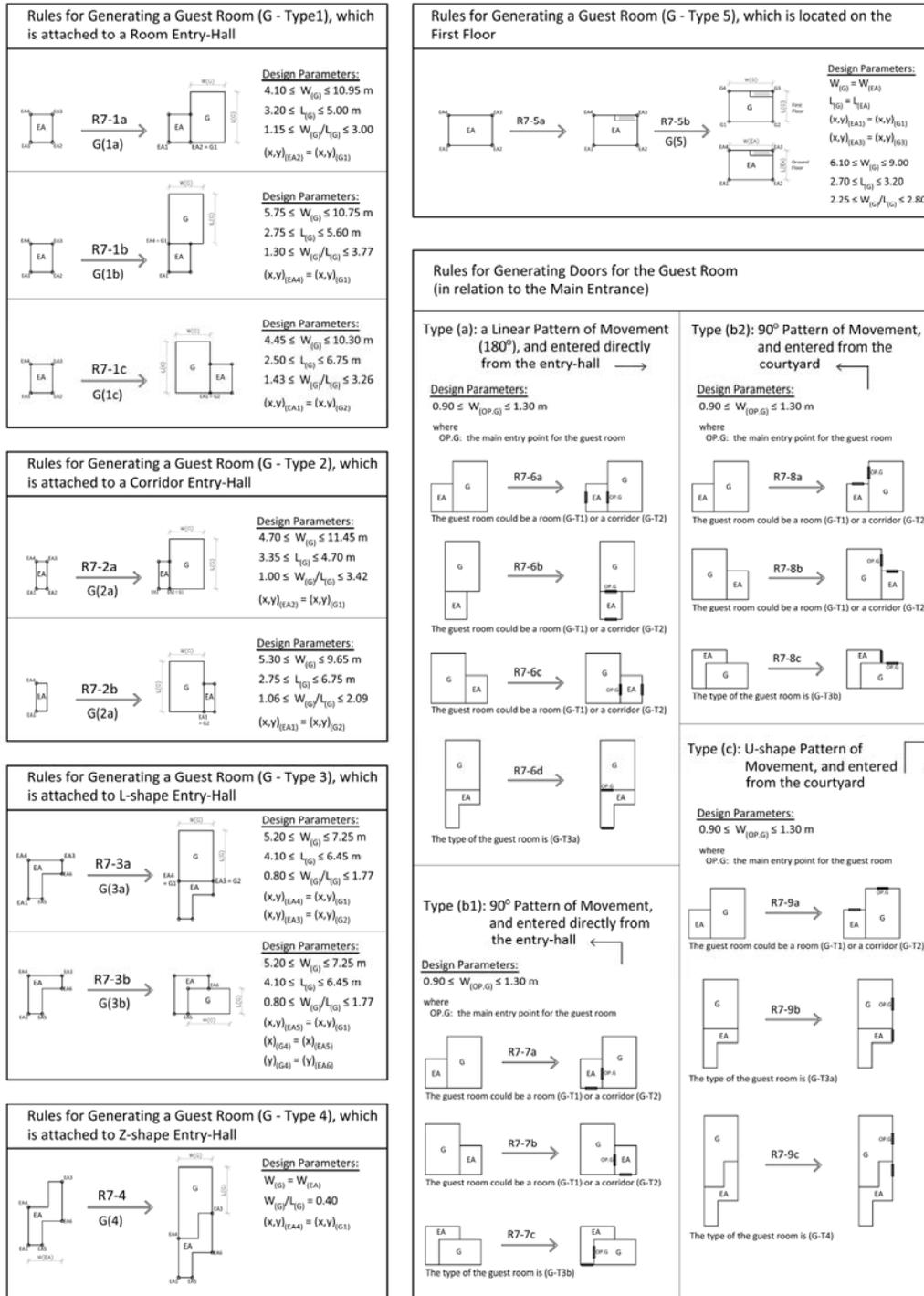


Figure 5.26: Sets of parametric rules for the configuration of a guest room (part 2)

Set 9 illustrates parametric rules that are used for generating living spaces and bedrooms in single-floor houses. Designers need firstly to decide number of living rooms and bedrooms according to the design brief, and then select the applicable rule based on the availability and the location of *iwans* and galleries in relation to the main courtyard (Figures 5.27 to 5.30).

In two-floor houses, the configuration of spaces could be started after the generation of vertical circulation elements. The location of the stair is based on its spatial relationship with the main entry hall (EA). In all cases, stairs are attached with main courtyards or entry halls. However, this relationship has four possibilities: (1) accessed from the main entry hall; (2) adjacent to the courtyard, and located at the opposite corner of the entry hall; (3) adjacent to the courtyard, with a linear relationship with the main entrance; and (4) attached to the courtyard, and accessed from the entry hall through a gallery (Figure 5.31 and 5.32).

The following stage includes the configuration of living spaces and bedrooms in two-floor houses. The schematic layout of the first floor depends on the location of the main courtyard. Four main categories for the shape of upper floors were determined from spatial and geometric analyses of cases: L-shape, O-shape, I-shape, and U-shape. As there is a strong relationship between public/semi-public zones, living spaces, and bedrooms for achieving visual privacy, the configuration of private/intimate spaces is based on the location of the guest room. However, living areas and bedrooms could be located on the ground and/or first floors. To implement these rules, designers need to determine two issues: (1) the location of the guest room, and (2) number of living rooms and bedrooms (Figures 5.33 to 5.36).

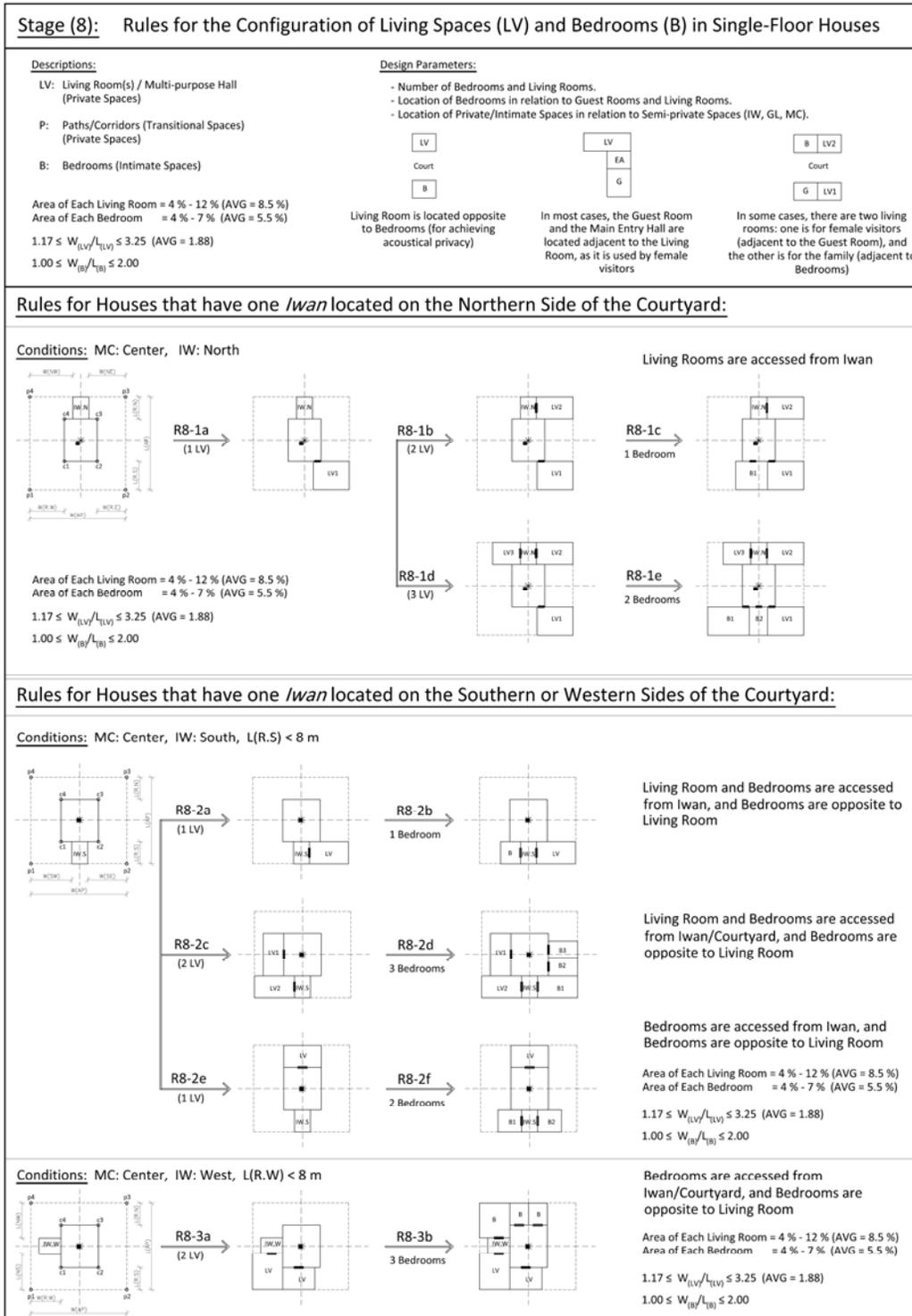


Figure 5.27: Sets of parametric rules for the configuration of living spaces and bedrooms in single-floor houses (part 1)

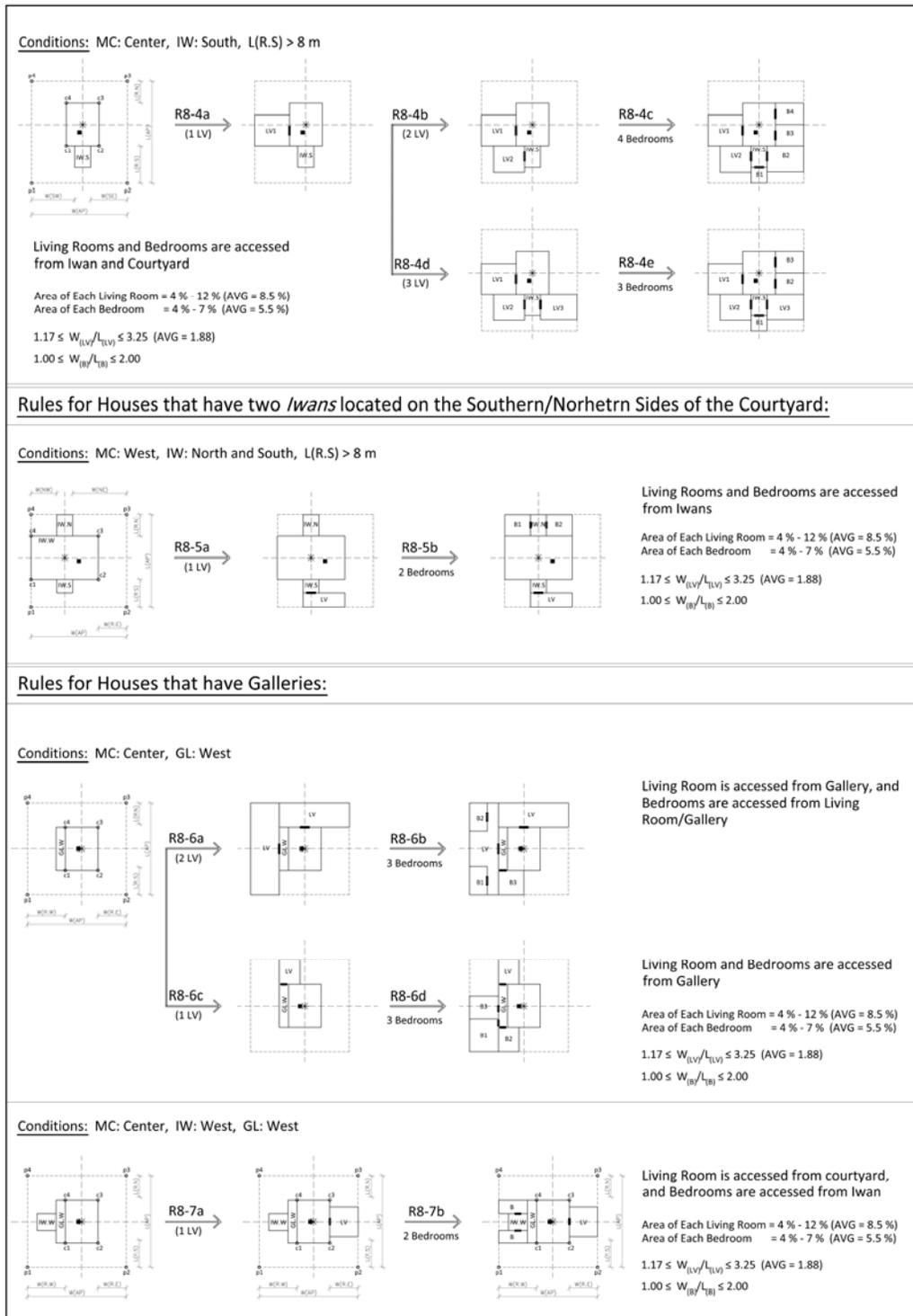


Figure 5.28: Sets of parametric rules for the configuration of living spaces and bedrooms in single-floor houses (part 2)

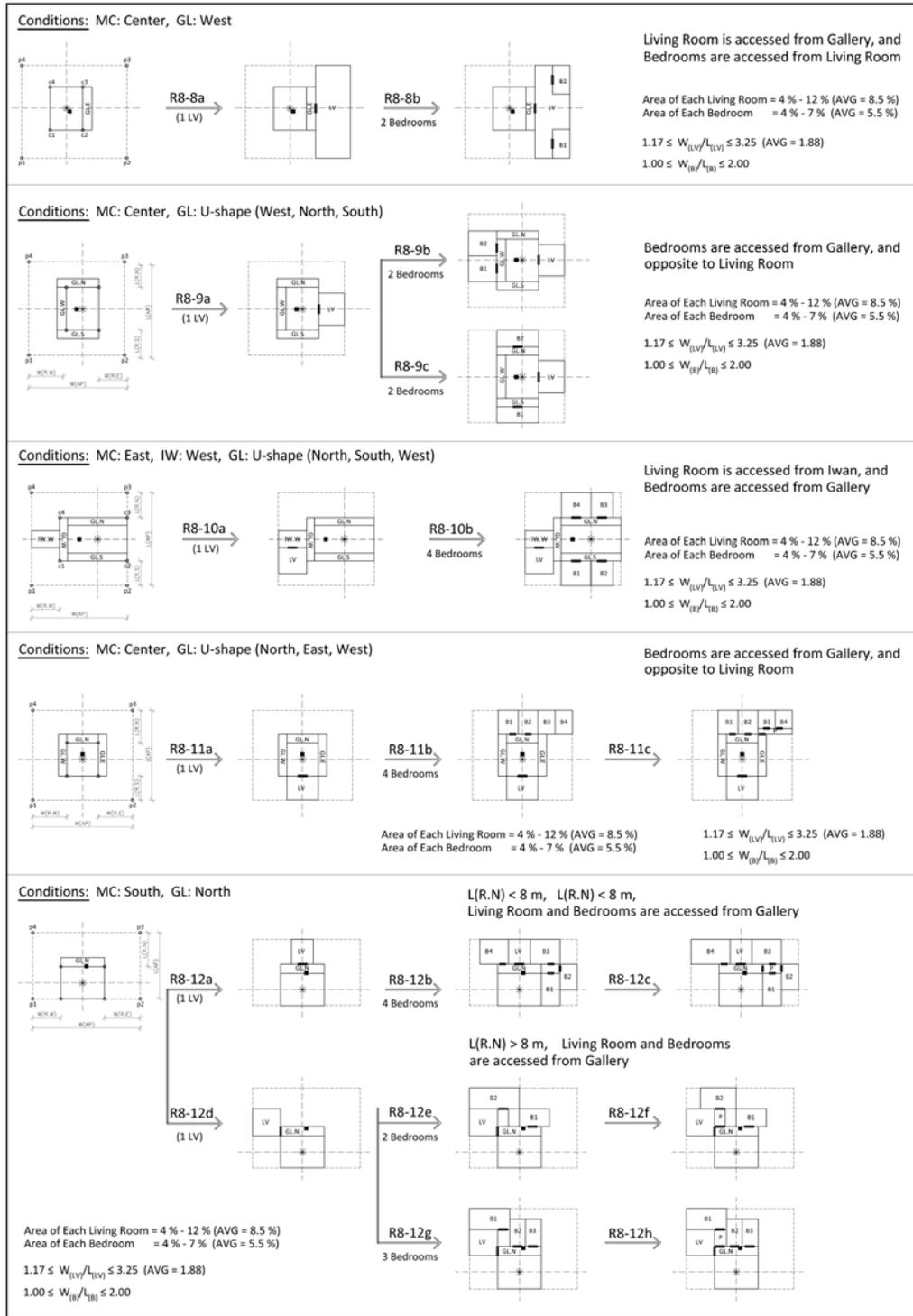


Figure 5.29: Sets of parametric rules for the configuration of living spaces and bedrooms in single-floor houses (part 3)

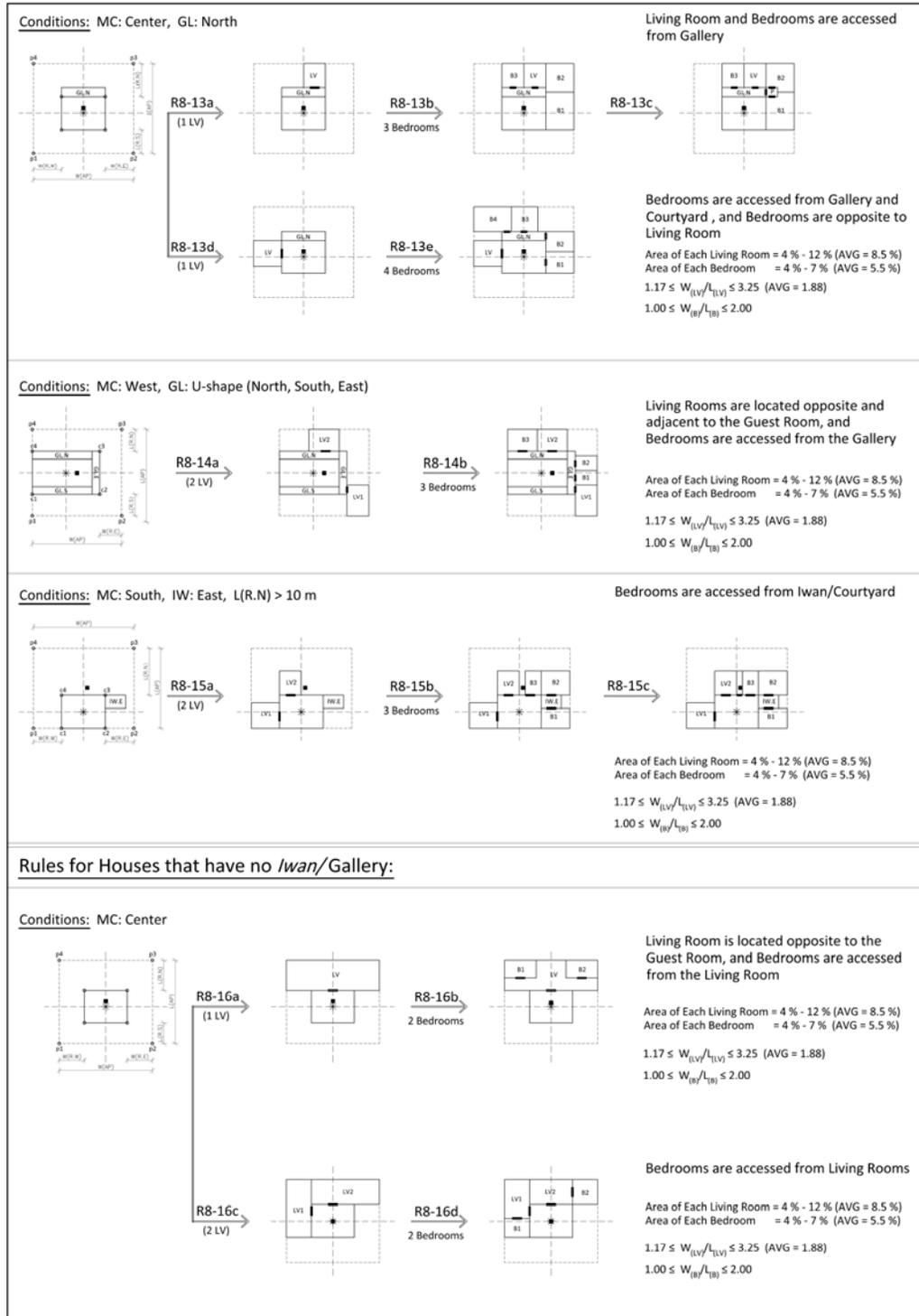


Figure 5.30: Sets of parametric rules for the configuration of living spaces and bedrooms in single-floor houses (part 4)

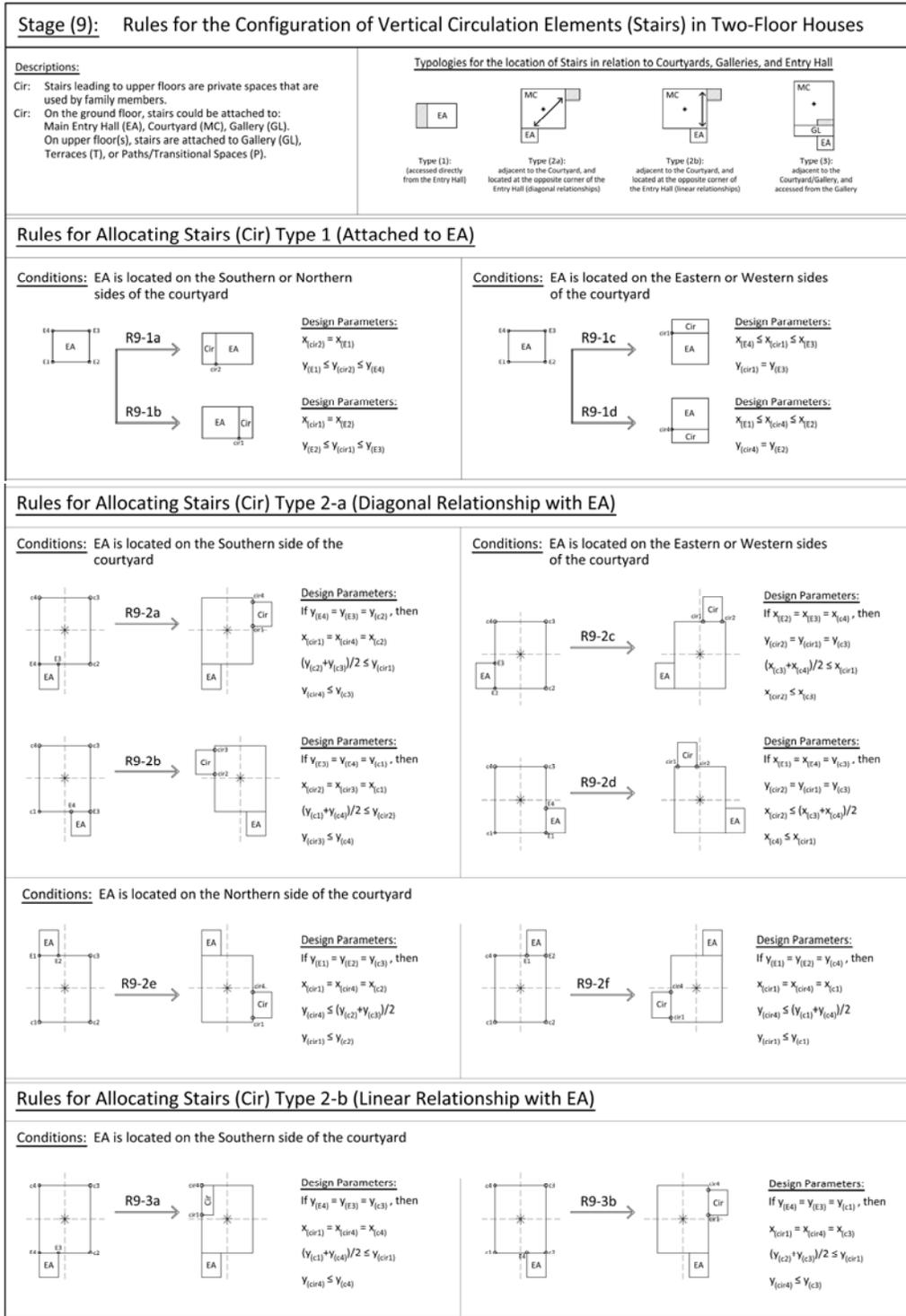


Figure 5.31: Sets of parametric rules for the configuration of vertical circulation elements in two-floor houses (part 1)

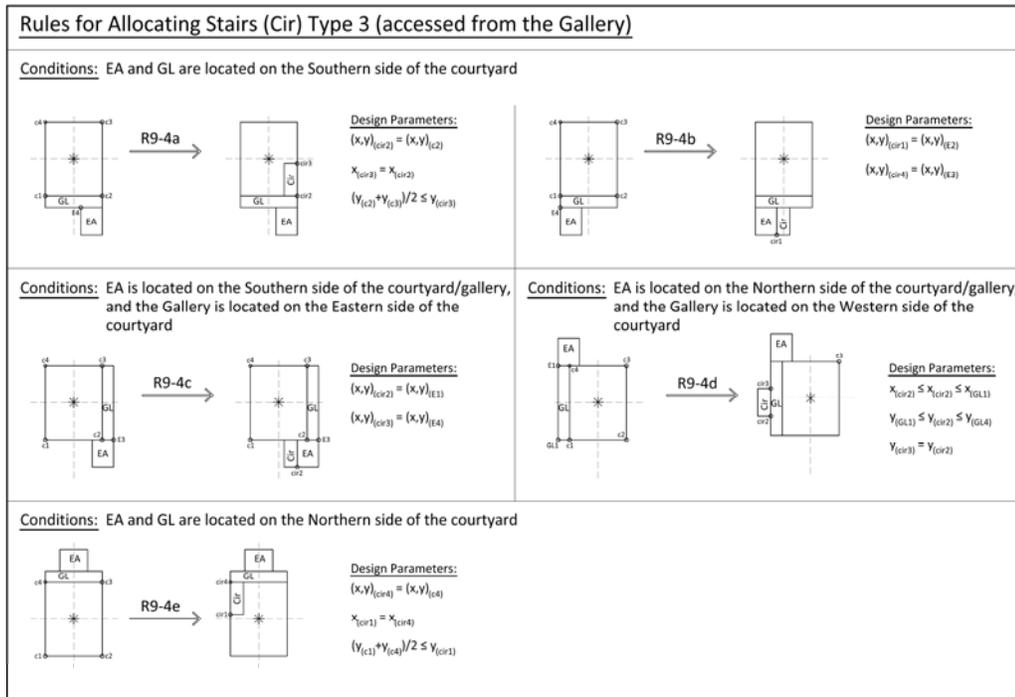


Figure 5.32: Sets of parametric rules for the configuration of vertical circulation elements in two-floor houses (part 2)

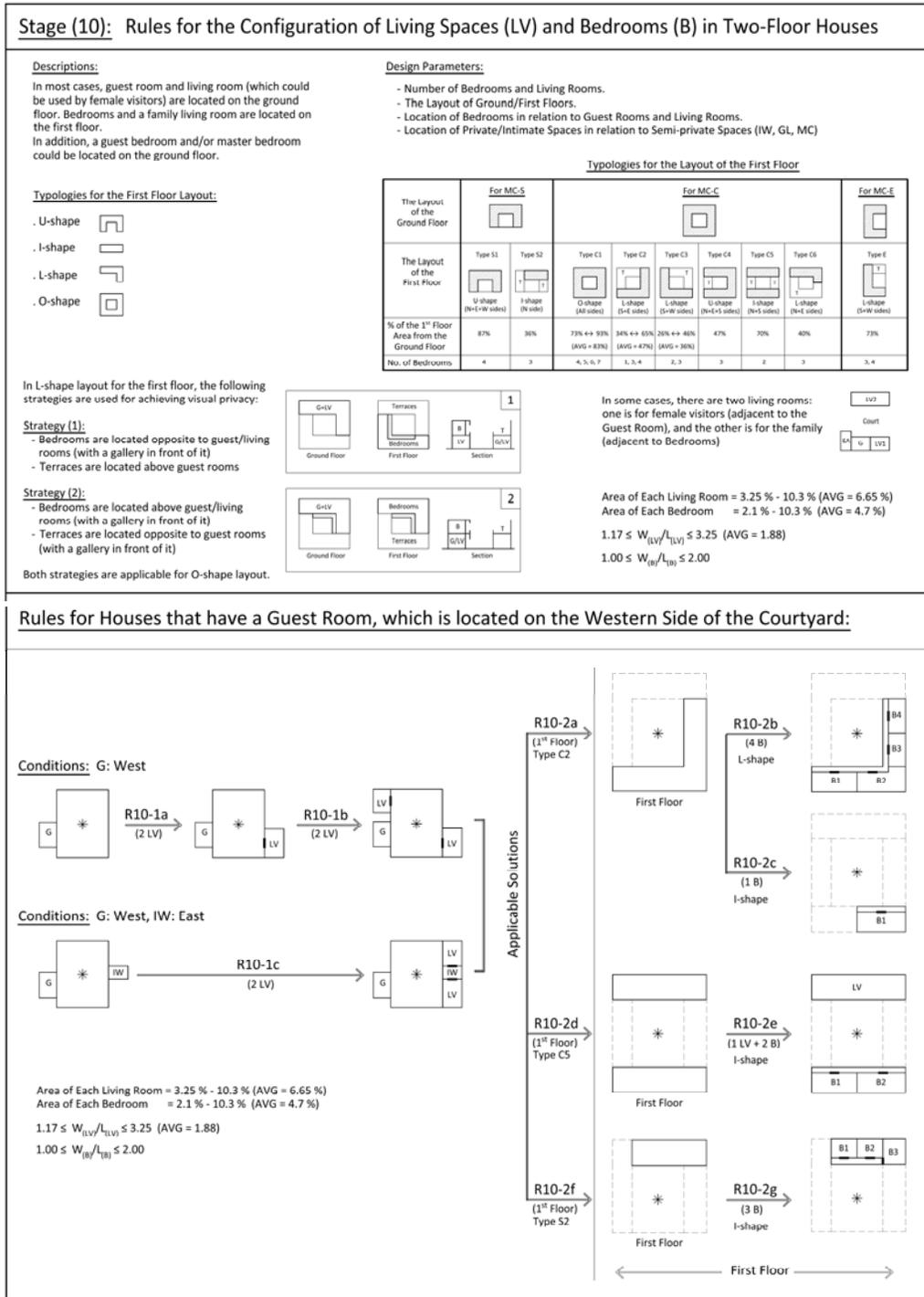


Figure 5.33: Sets of parametric rules for the configuration of living spaces and bedrooms in two-floor houses (part 1)

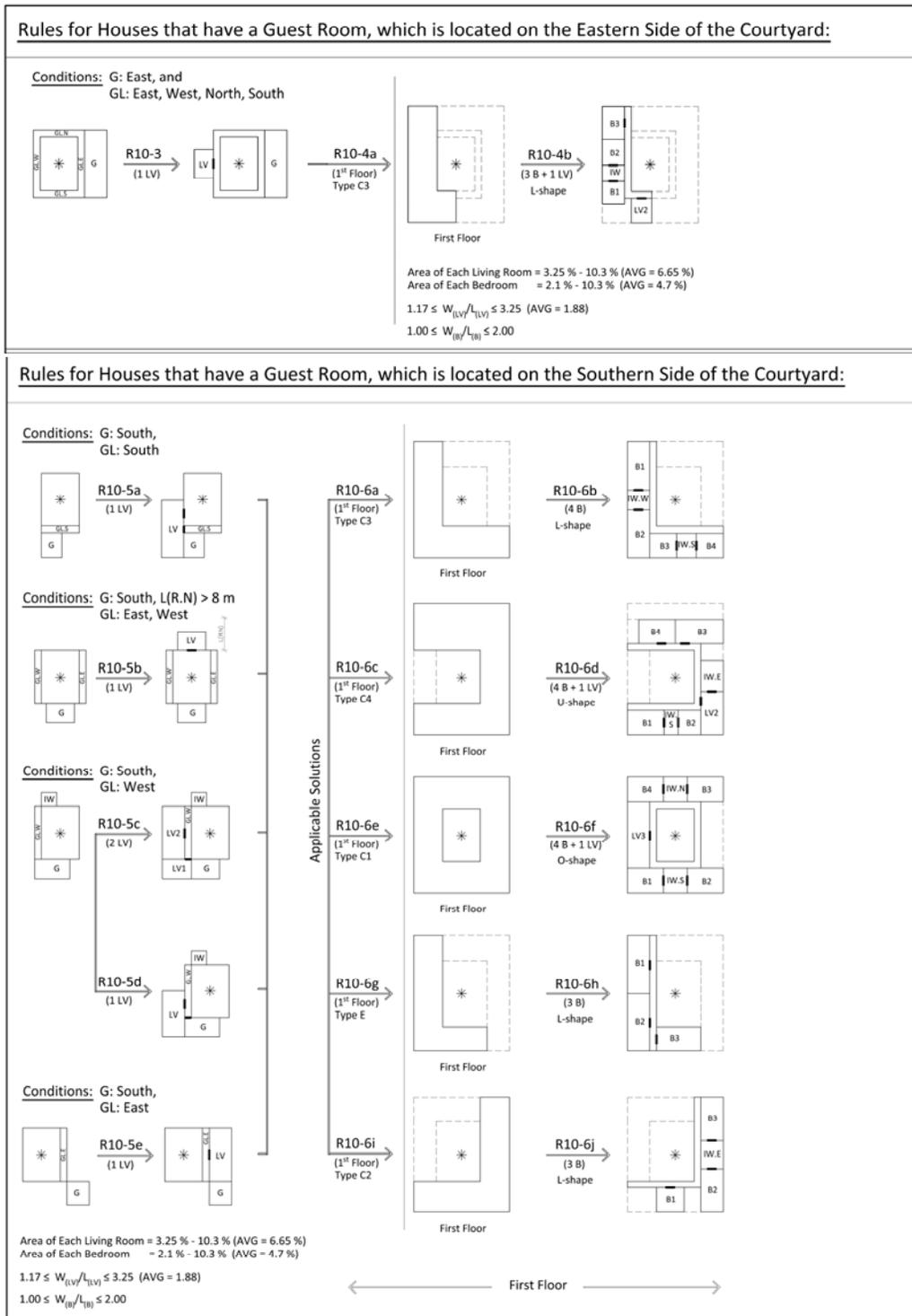


Figure 5.34: Sets of parametric rules for the configuration of living spaces and bedrooms in two-floor houses (part 2)

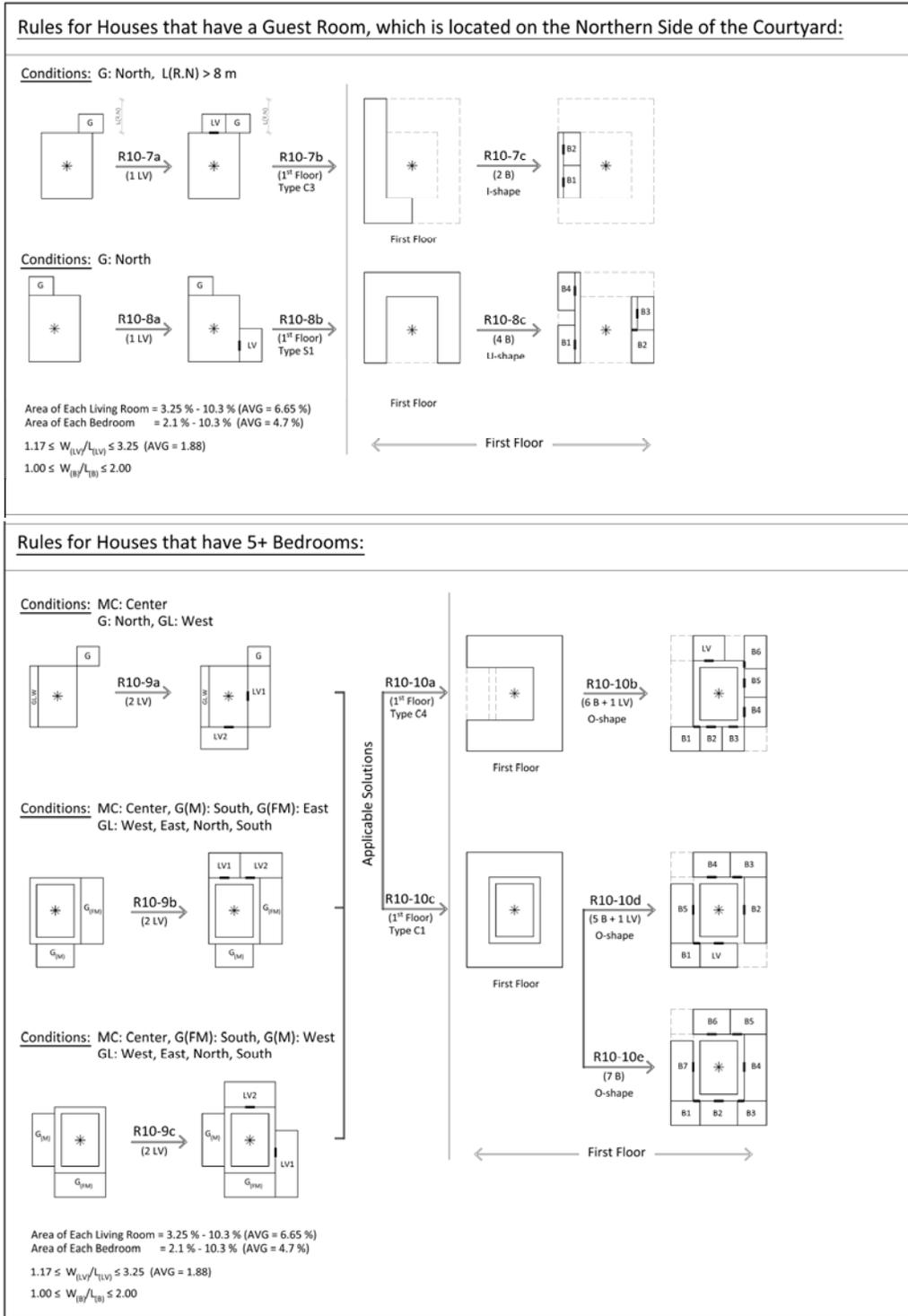


Figure 5.35: Sets of parametric rules for the configuration of living spaces and bedrooms in two-floor houses (part 3)

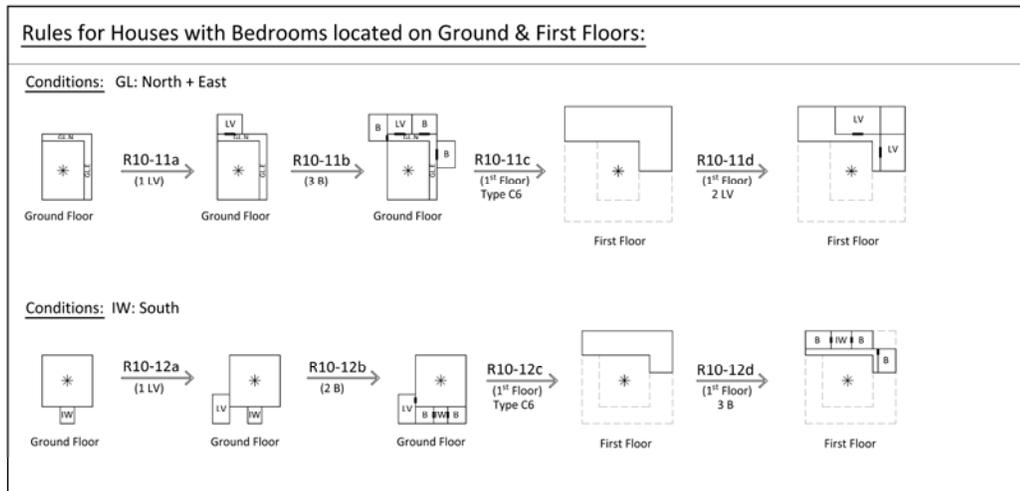


Figure 5.36: Sets of parametric rules for the configuration of living spaces and bedrooms in two-floor houses (part 4)

Stages (11, 12, and 13) represent rules for the configuration of service entrance and services, including kitchen, toilets, bathrooms, and storage areas. The service entrance could be connected directly with a service zone, courtyard, or gallery. Regarding the relationship with the main entry hall, the service entrance could be located opposite or adjacent to the main entrance. Figure (5.37) illustrates these topological relations. After allocating the coordinates for this space, rules (11-10, and 11-11) define geometric properties, in addition to the width, length, and dimensions of openings.

Rules 12-1, 12-2, and 12-3 determine the location and the overall layout of the service zone that is located on the ground and first floors. However, subdivisions for this zone are not included in this grammar, as they depend on the needs of each design. The location of the service zone could be defined in relation to the position of the courtyard. Kitchen, storage spaces and toilets are located adjacent to the living room and/or the guest room, while bathrooms are adjacent to bedrooms (Figures 5.38 to 5.42).

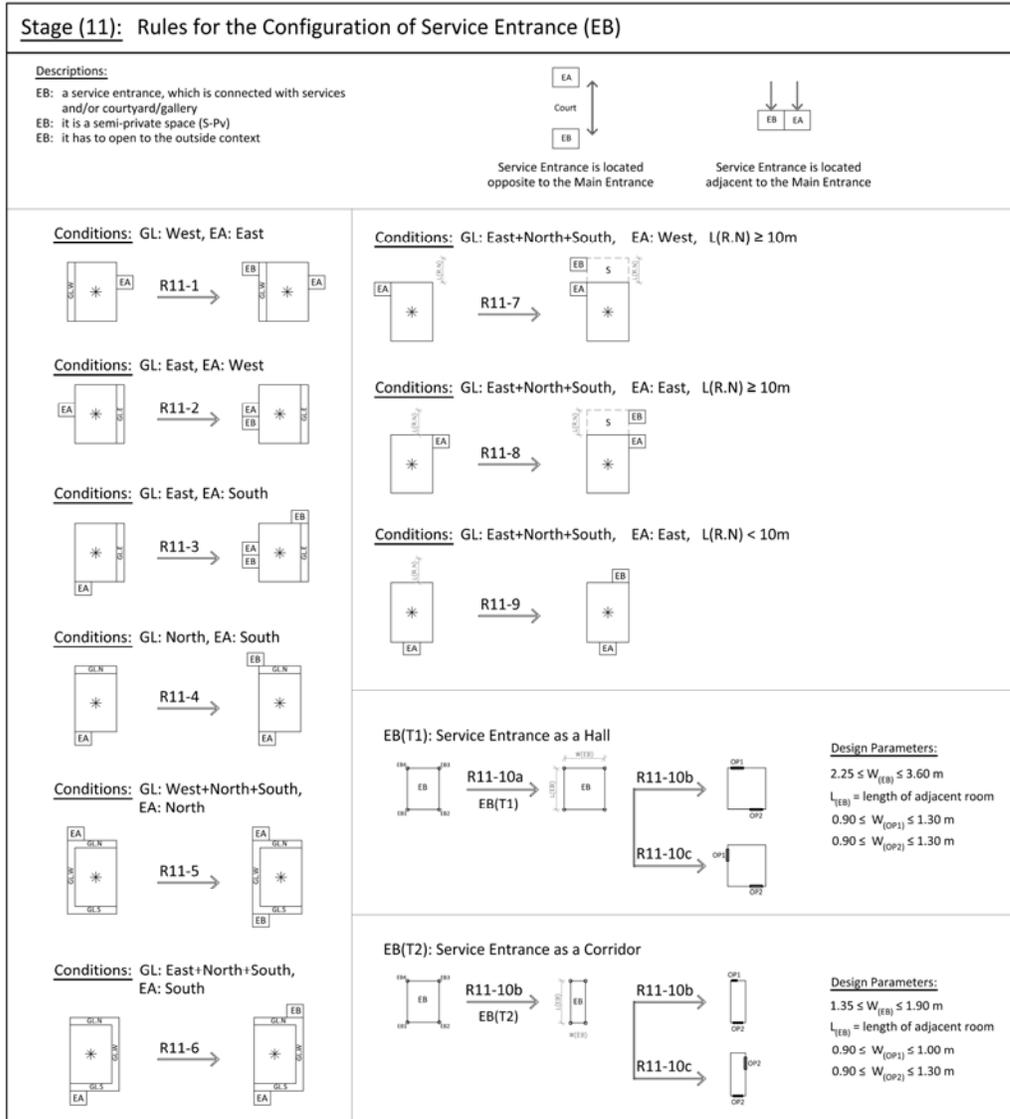


Figure 5.37: Sets of parametric rules for the configuration of service entrance

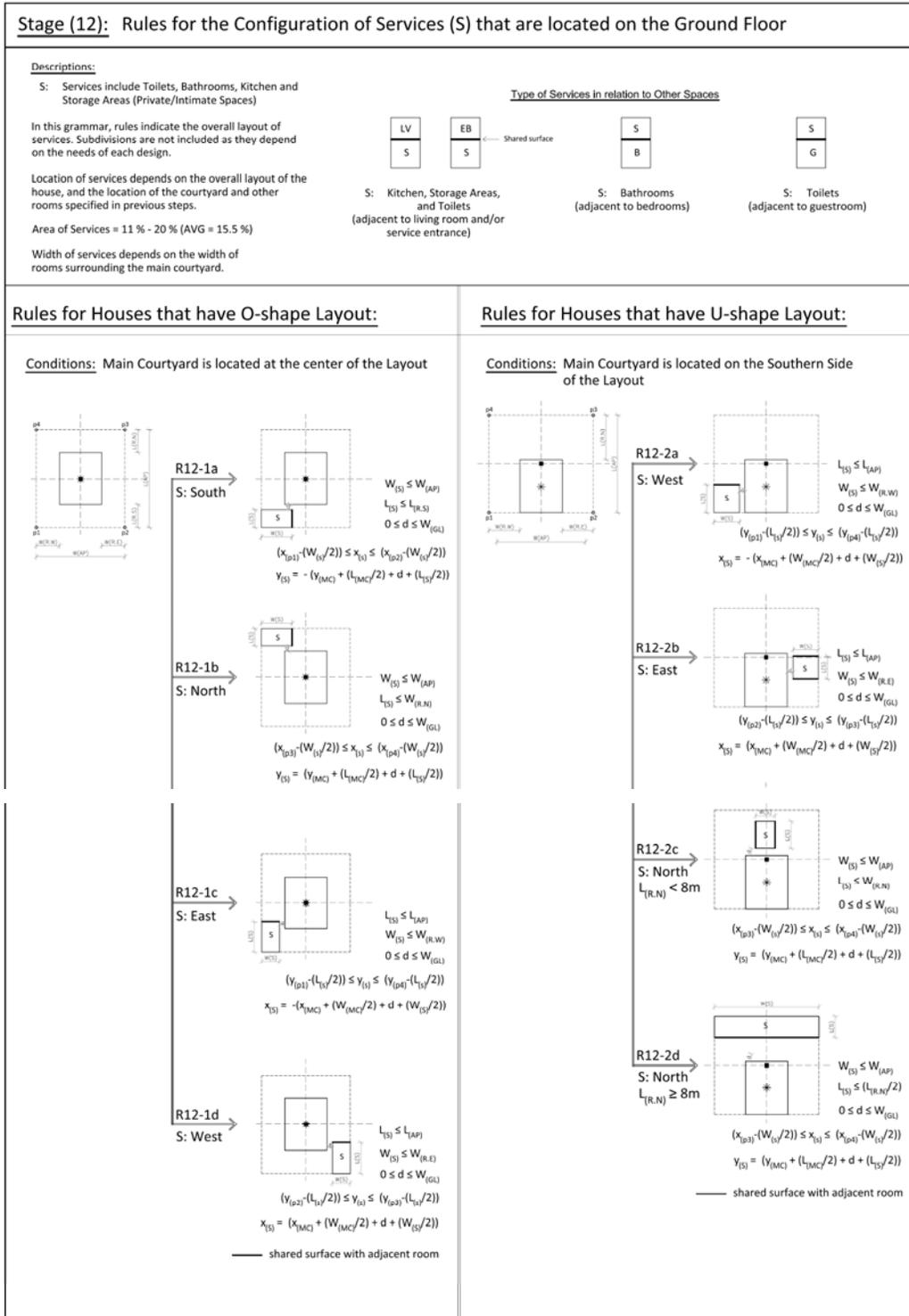


Figure 5.38: Sets of parametric rules for the configuration of services that are located on the ground floor (part 1)

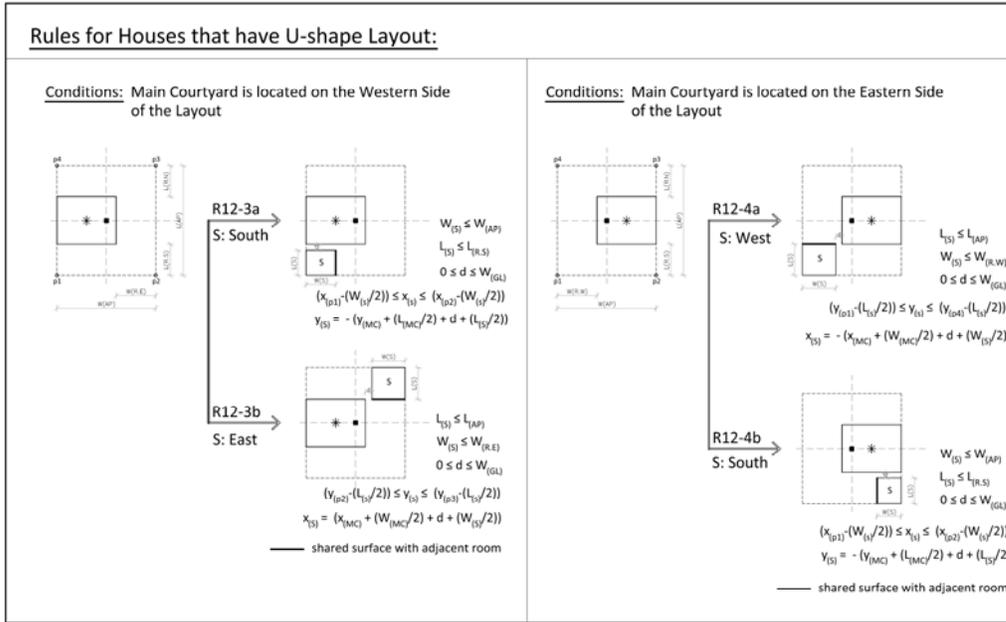


Figure 5.39: Sets of parametric rules for the configuration of services that are located on the ground floor (part 2)

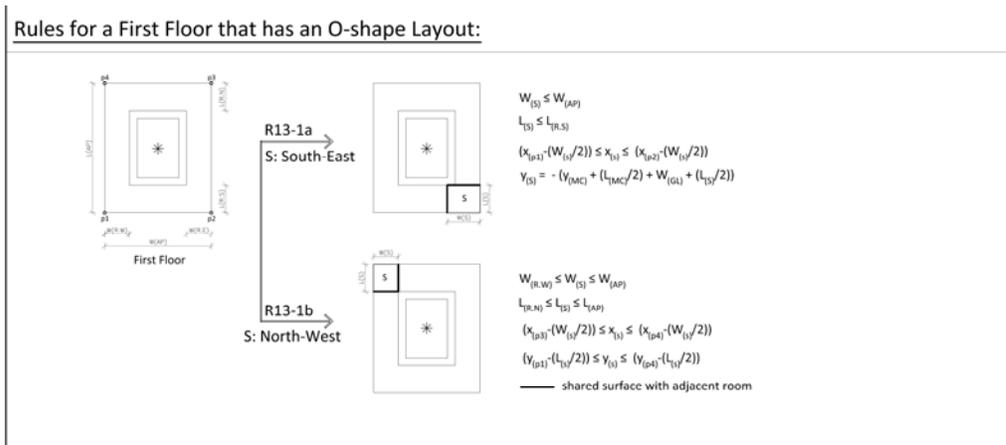
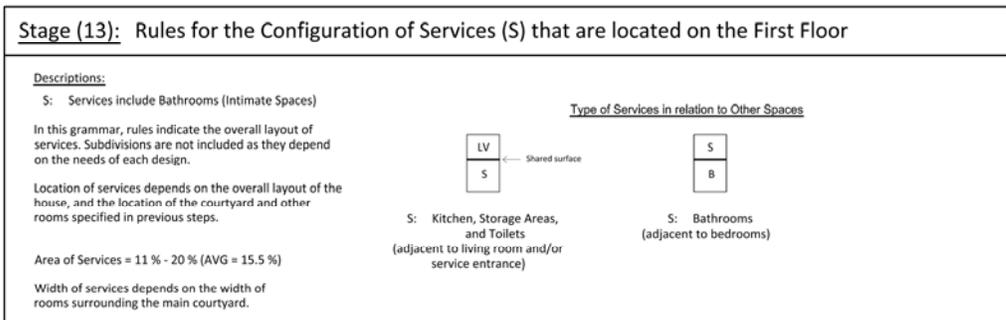


Figure 5.40: Sets of parametric rules for the configuration of services that are located on the first floor (part 1)

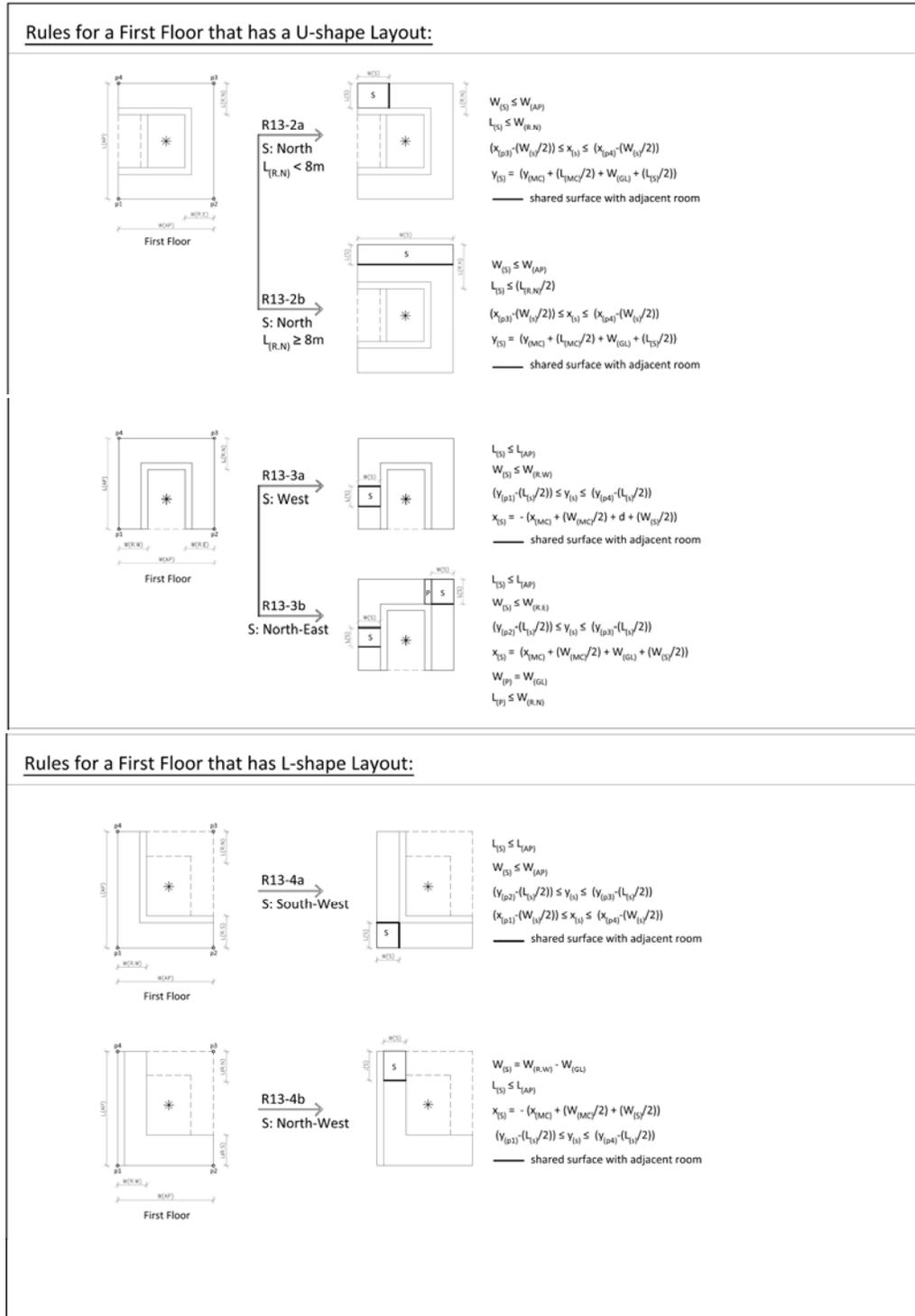


Figure 5.41: Sets of parametric rules for the configuration of services that are located on the first floor (part 2)

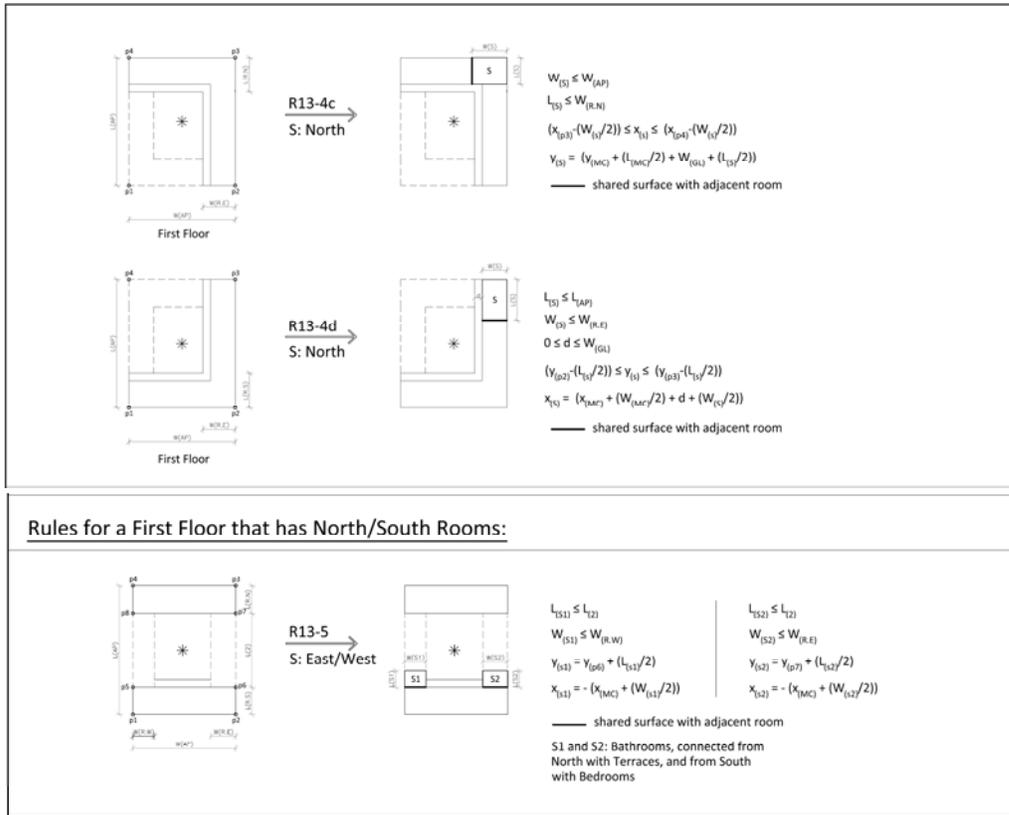


Figure 5.42: Sets of parametric rules for the configuration of services that are located on the first floor (part 3)

The next step from this grammar is to allocate terraces and balconies, which are semi-private spaces used by the family members. These open areas of the house could be connected with bedrooms, living spaces, or courtyard. Terraces could be located on any side of the layout except the south direction. However, when rooms occupy the northern side of the first floor, the other area of the roof is used as a terrace (as illustrated in rule R15-1c) (Figures 5.43 and 5.44).

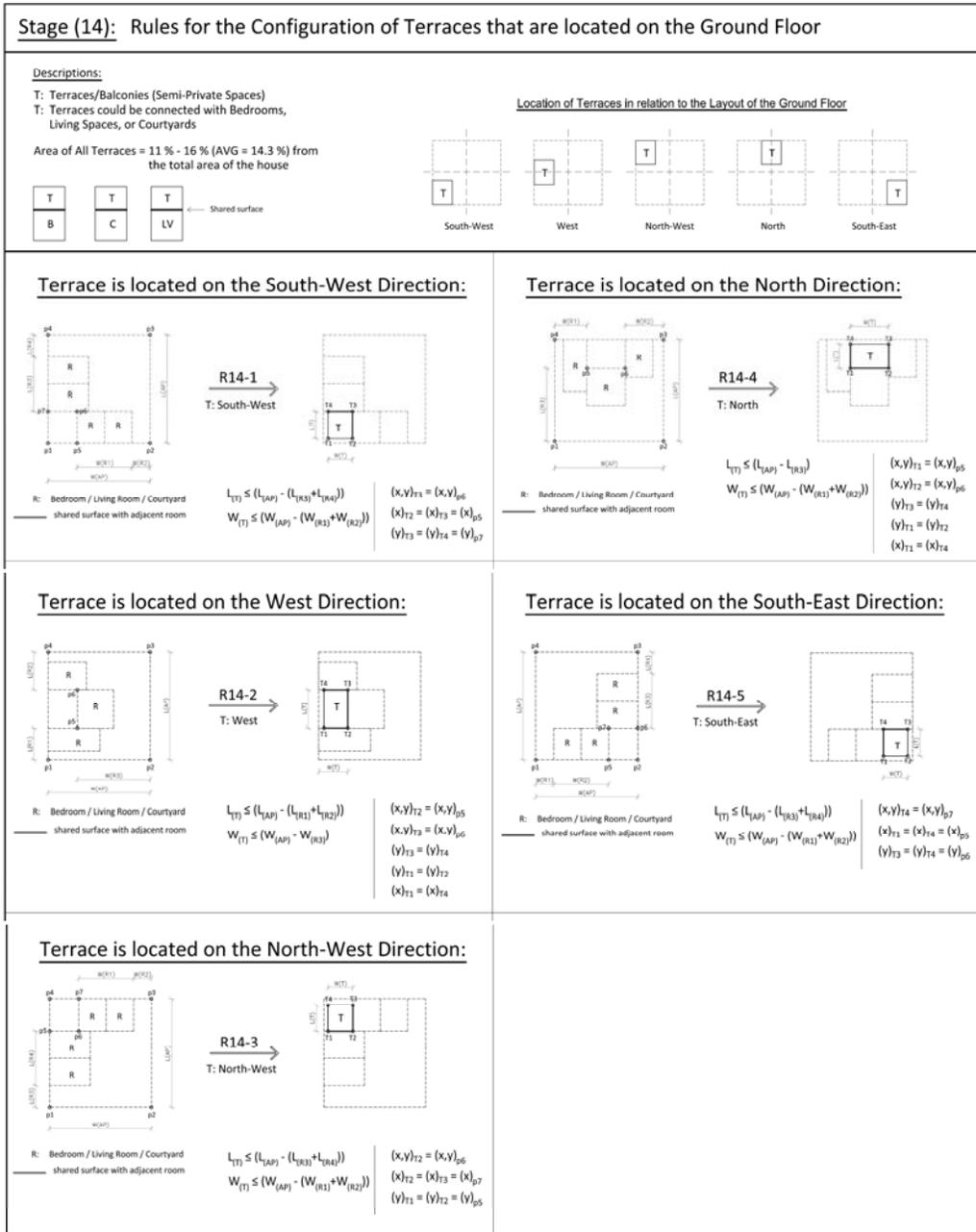


Figure 5.43: Sets of parametric rules for the configuration of terraces and balconies on the ground floor

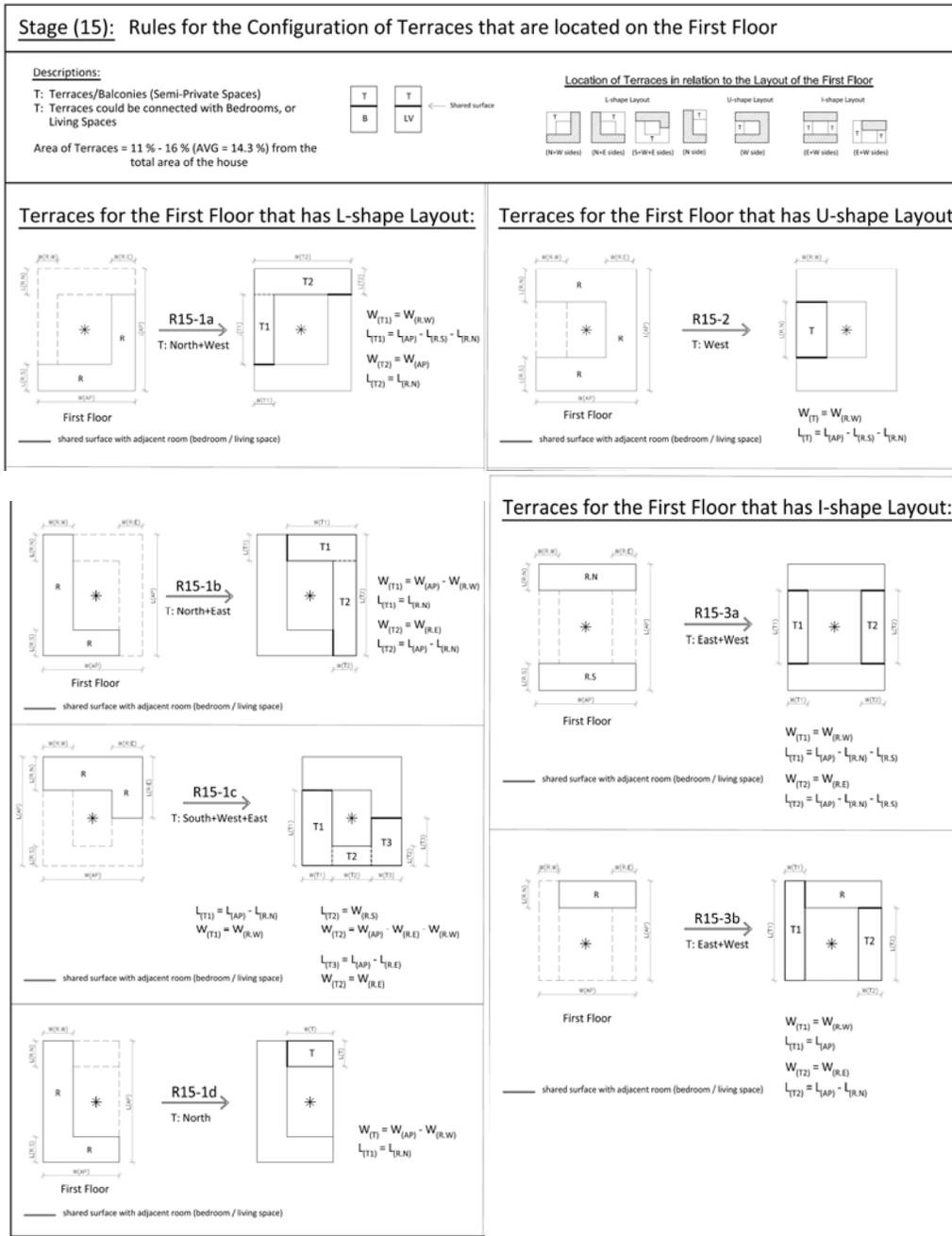


Figure 5.44: Sets of parametric rules for the configuration of terraces on the first floor

After the configuration of main spaces, stages 16 and 17 represent rules for determining thicknesses of internal/external walls, and special treatments for achieving certain social qualities, such as viewing the outside, visual privacy, and hygiene (Figure 5.45).

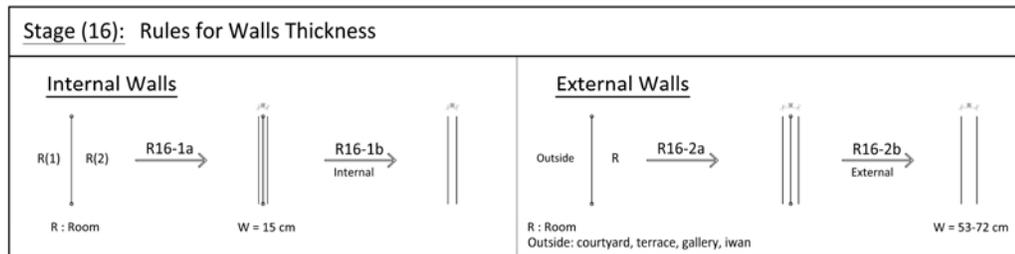


Figure 5.45: Parametric rules for determining internal/external wall thickness

Applying rule (17-1) will add a large window for the living room that is located on the southern side of the courtyard. Rule (17-2) adds windows to spaces according to orientation, function, and the dominant users for each room. Achieving visual privacy in houses, especially between public and private spaces needs additional features that preserve such a need for the family. Rule (17-3) is used to solve the direct connection between the guest room and the courtyard through adding a partition in front of the main door of the guest room. At the scale of facades, it is important to allocate windows for the ground floor at a height that allows the sun and the wind entering spaces without a direct visual axis from the outside. Rule (17-4) specifies such measurements. Keeping living areas and other interior spaces clean needs a rule that changes floor levels between inside and the outside. Different parameters that specify such solutions are indicated in rule (17-5) (Figure 5.46).

Finally, termination rules are specified in (Figure 5.47). These rules provide instructions for erasing the construction lines and labels that were used to guide the plan generation process. When termination rules (R18-1, R18-2, and R18-3) are applied, the final plan is produced clearly.

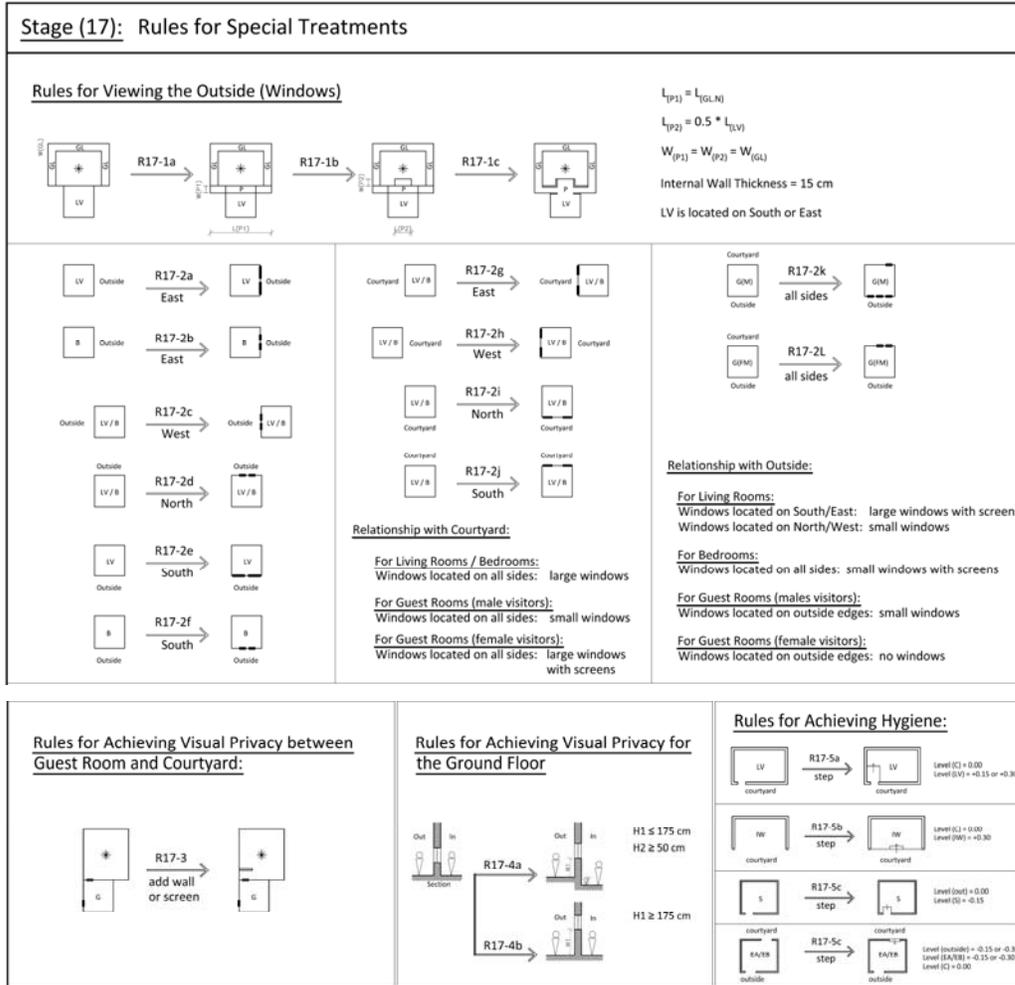


Figure 5.46: Parametric rules for attaining certain social qualities: viewing the outside, achieving visual privacy, and hygiene

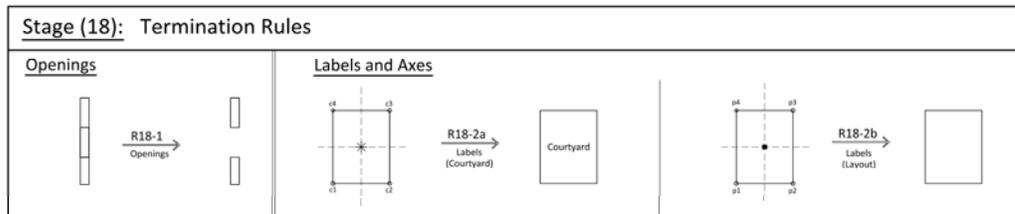


Figure 5.47: Termination rules

## 5.4. Validation of the Two Grammars

An example for the implementation of parametric rules for generating new solutions for courtyard houses is illustrated in Figure (5.48). The target is to generate layouts that are in the same language. A specific design brief is first determined by the following: a 220-m<sup>2</sup> single-floor house, which consists of a guest room, a courtyard, two living rooms, three bedrooms, and services. By changing only two parameters: the location of the courtyard, and its dimensions within certain limits, new layouts have been generated. These emergent solutions have been evaluated, using *Depthmap* and *Syntax2D* software, to test if they are valid and achieve the principles of social sustainability. The assessment process includes: (1) the visual privacy between public/semi-public zones and private/intimate spaces (Figure 5.49); and (2) hierarchy of spaces, through conducting a visibility graph analysis that calculates integration and connectivity values (Figure 5.50).

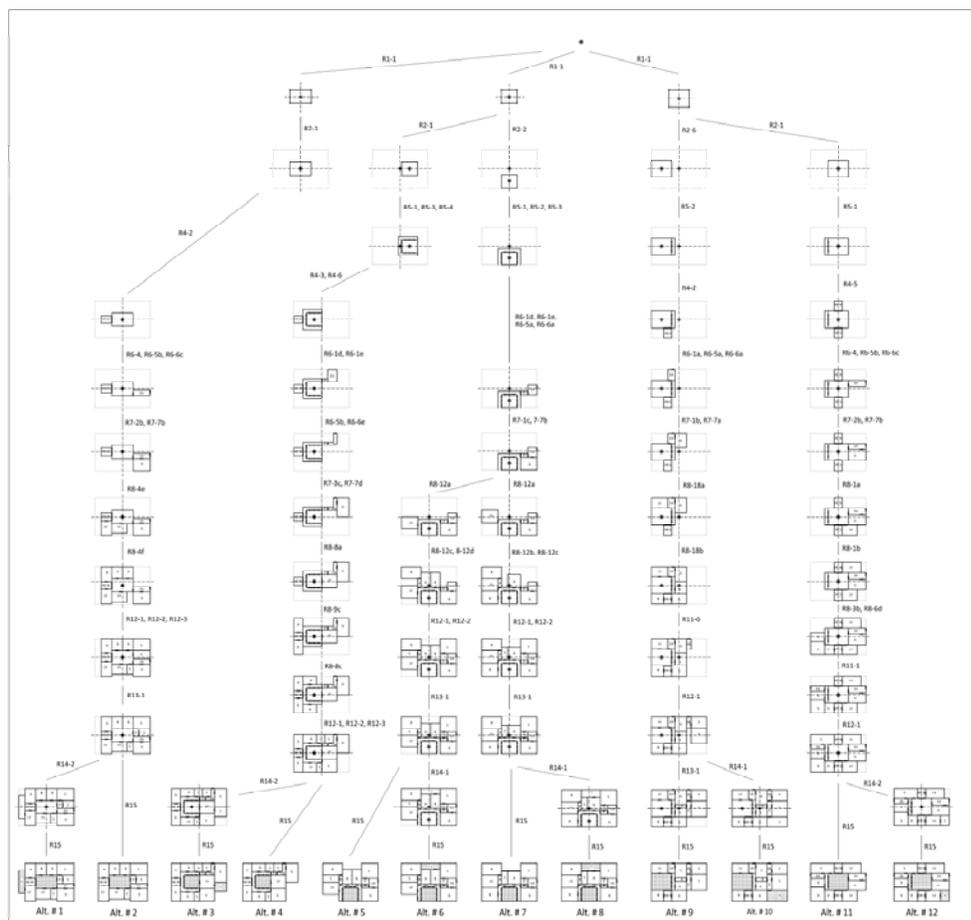


Figure 5.48: The generation process of 12 new solutions for courtyard houses



Figure 5.49: Evaluating the visual privacy between public and private zones for the new alternatives  
(Produced by the Researcher, using Syntax2D software)

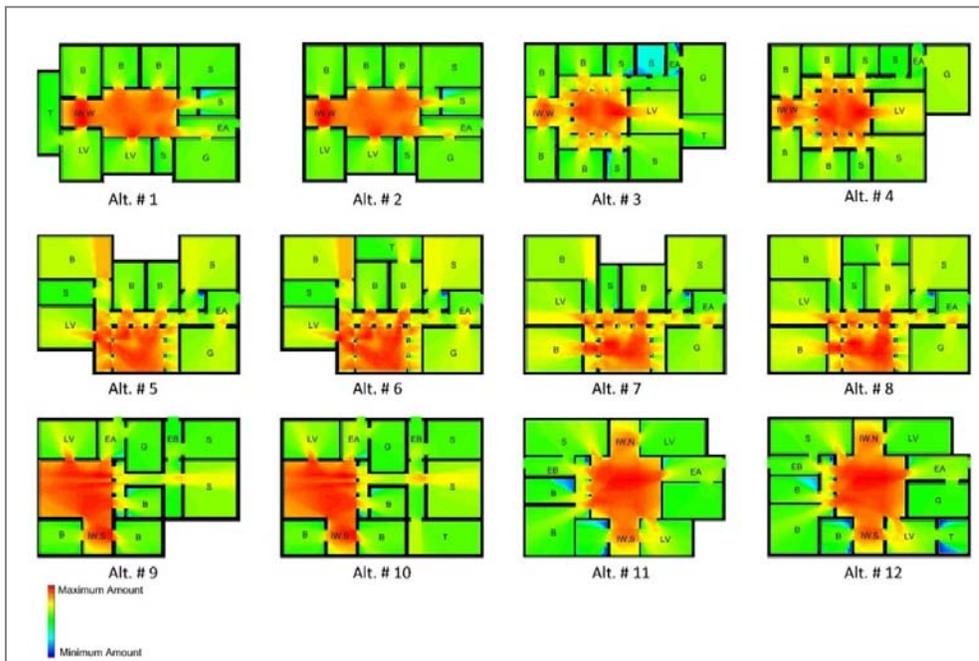


Figure 5.50: Visibility graph analysis for the new solutions showing the connectivity value for each space  
(Produced by the Researcher, using DepthmapX software)

The *Isovist* analysis showed that the privacy of the household is protected from public and semi-public spaces (the entry hall and the guest room). Moreover, results of the VGA analysis showed that the courtyard is the most integrated space, which achieves its primary function as a transitional area. Reception rooms in all cases are shallow spaces as they are situated off the courtyard and next to the entry hall. In contrast, findings revealed that intimate spaces (bedrooms), which have a lower integration value, are more integrated with private spaces.

The second step of validation is the generation of new solutions for clusters of houses based on the grammar of traditional neighbourhoods (Figure 5.51). The process started with determining an overall layout to accommodate four houses. By changing only two parameters: location of the main public space, and its orientation, seven new layouts have been generated (Figure 5.52). Based on the syntactic analysis, results showed that a hierarchical system of movement from public to private zones had been achieved. Moreover, there are no direct visual connections between common areas and inside houses. Therefore, the privacy of the family could be maintained (Figures 5.53, 5.54).

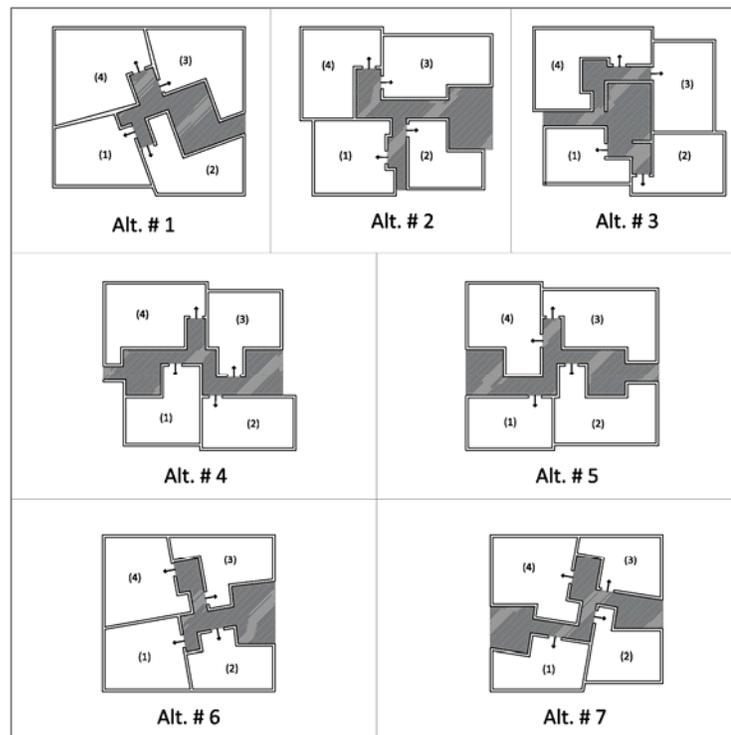


Figure 5.51: New solutions for clusters of houses generated by the constructed grammar

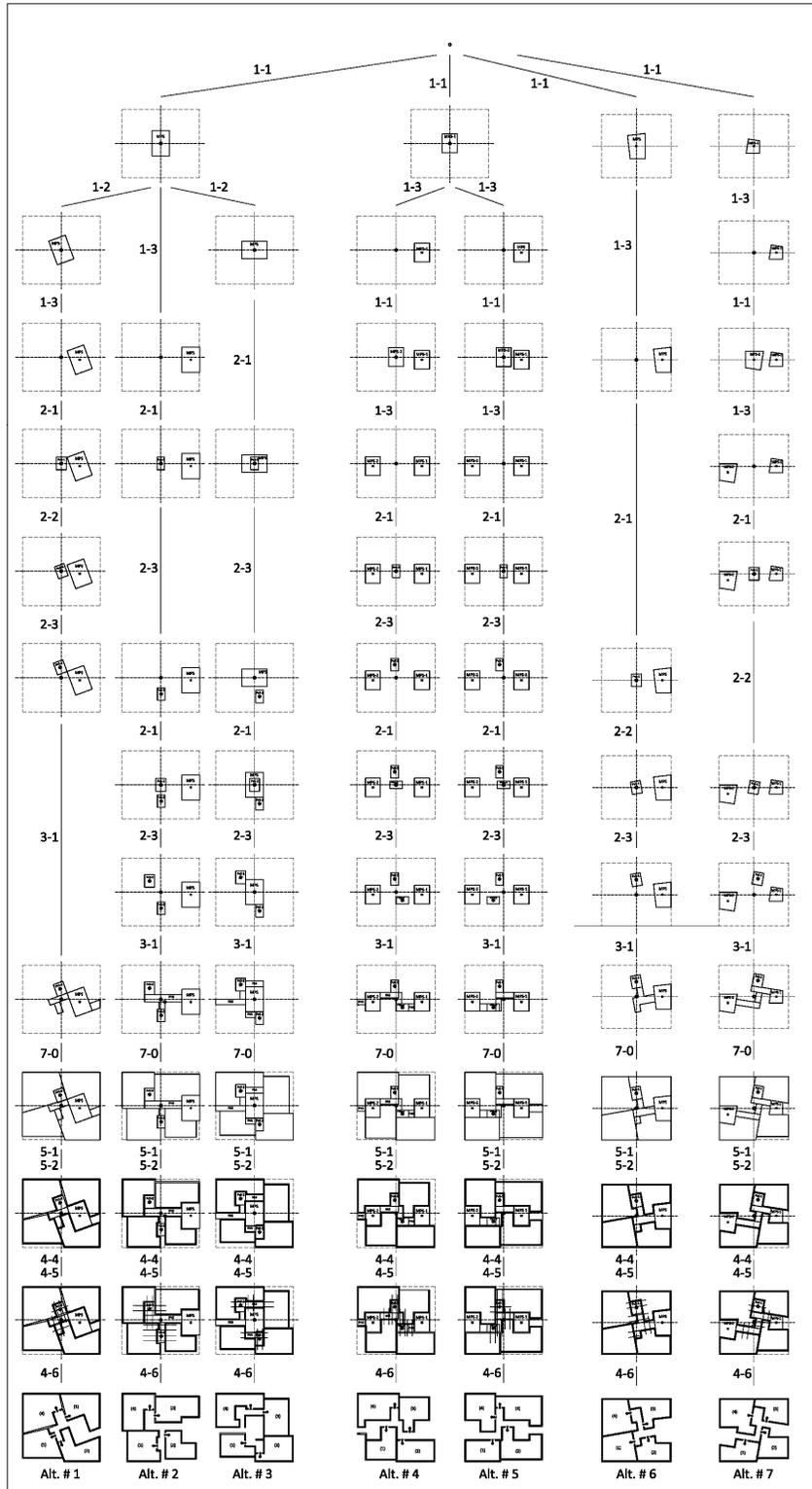


Figure 5.52: The generation process of seven new solutions for clusters of houses

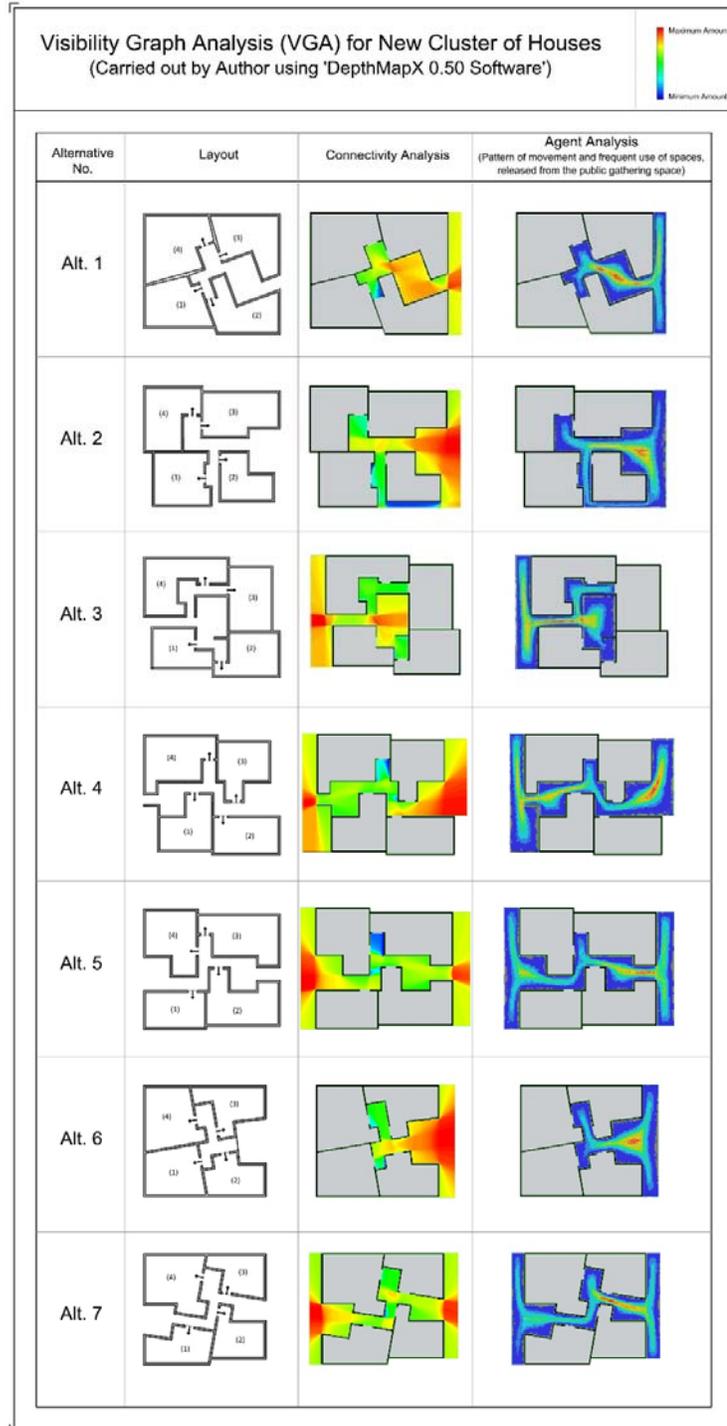


Figure 5.53: Visibility graph analysis for the new solutions showing connectivity values for common spaces (Produced by the Researcher, using DepthmapX software)

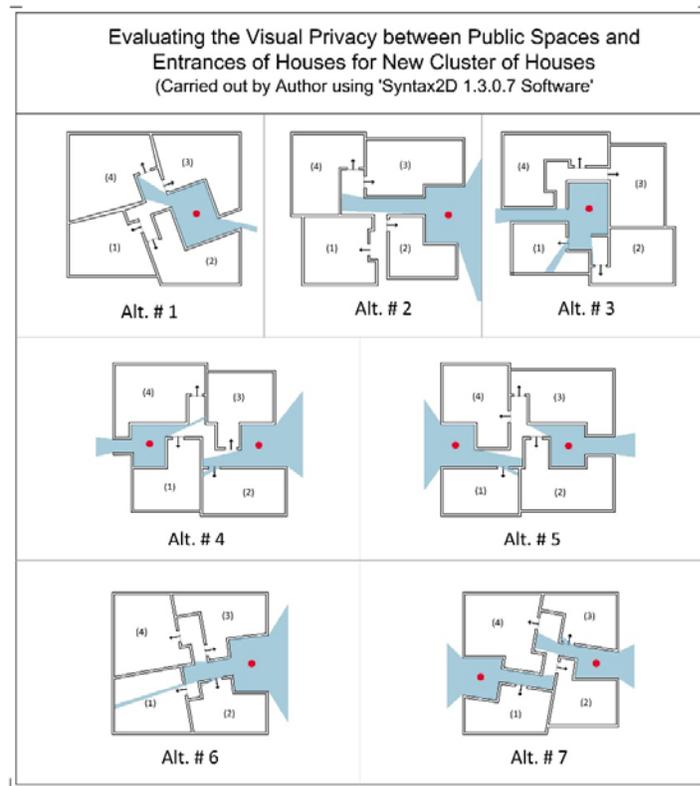


Figure 5.54: Evaluating the visual privacy between public spaces and entrances of houses for the new alternatives  
(Produced by the Researcher, using Syntax2D software)

## 5.5. Conclusion

Based on information extracted from typological, syntactical and scalar analyses for courtyard houses and traditional neighbourhoods in MENA region, a parametric grammar that reflects the different dimensions of social sustainability has been constructed. The grammar serves as a social-spatial catalogue that expresses the culture, the social life of residents, and the language of such environments. It consists of three parts: (1) vocabularies and elements of designs; (2) additive / transformational rules; and (3) parameters / descriptions for geometric / social constraints.

Each spatial element of design has different values that represent a specific social meaning. Attaching parameters and textual information to the definition of rules addresses some of the limitations found in traditional shape grammars, such as semiotic and semantic dimensions. Moreover, these descriptions and parameters add flexibility and variations to the generation process. Changing a parameter means that it will generate a set of design

solutions, rather than a single alternative. However, the control of the grammar in the generation process is in the hands of the designer at each stage, as he/she needs to identify the applicability and the prototype for each vocabulary according to the design brief and the shape or the area of the plot. For instance, number of bedrooms or living spaces are associated with the size of the family and the allowable built-up area. Orientation of galleries and *iwans* depends on the location of the courtyard, and the orientation of the overall layout. Therefore, this grammar serves as a creative design instrument that guides the emergence of socially sustainable environments.

In the next part, the constructed parametric socio-spatial grammars for horizontal quarters and vernacular houses will be used for the emergence of socially sustainable vertical residential buildings.

## Part (B): The Development of a Computational Design Tool for Socially Sustainable High-rise Residential Buildings

### **5.6. Introduction**

Design process is an iterative activity that involves the generation of a design, and the evaluation of its fittingness to predefined requirements. The early phase of such a process is seemingly chaotic and complicated, as the architect needs to think comprehensively with the context, style, program, and spatial relations (Granadeiro *et al.* 2013; D'Ino 2012; Segers *et al.* 2001). In this part, results extracted from spatial analysis of vernacular houses and neighbourhoods, and preferences of users according to the survey, are used for the emergence of a socio-spatial grammar for vertical residential developments. The aim is to provide architects with a tool that produces alternative, which have potentials of social sustainability, and respect the culture and the needs of its users.

#### **5.6.1. Design Requirements for Vertical Residential Buildings**

A socially sustainable high-rise building needs a database that identifies spatial elements, topological relationships, and social indicators. However, such structures have specific spatial requirements.

1. The first need is a transitional access from the public street domain into the building, through a well-defined entry hall. According to the results of the survey, conducted in the study area, more than 85% of residents claimed that there is a lack of such areas in their buildings.
2. The second issue is the relationship between the entrance of the building and the location of elevators and staircase. It is recommended to place these circulation features in one area than having spread them out over different locations (Ghazali *et al.* 2014).
3. The third requirement is the availability of communal spaces and gardens. In current apartment buildings, most of these areas are located around the building. However, such uncovered locations in hot-arid regions limit opportunities of social interaction between neighbours. Therefore, it is more efficient to introduce several gathering areas inside the building.
4. The fourth aspect is the arrangement of apartments on the same floor. High-rise residential buildings could have four different layouts (Figure 5.55):

- a. Single-loaded corridor: where apartments are placed in a row on one side of a corridor that is open on the opposite side.
- b. Double-loaded (central) corridor: which serves apartments on both sides.
- c. Central core: where apartments are located around a central circulation core.
- d. Interlocking internal corridors: this layout includes a double-loaded corridor that serves two rows of apartments in an interlocking arrangement.

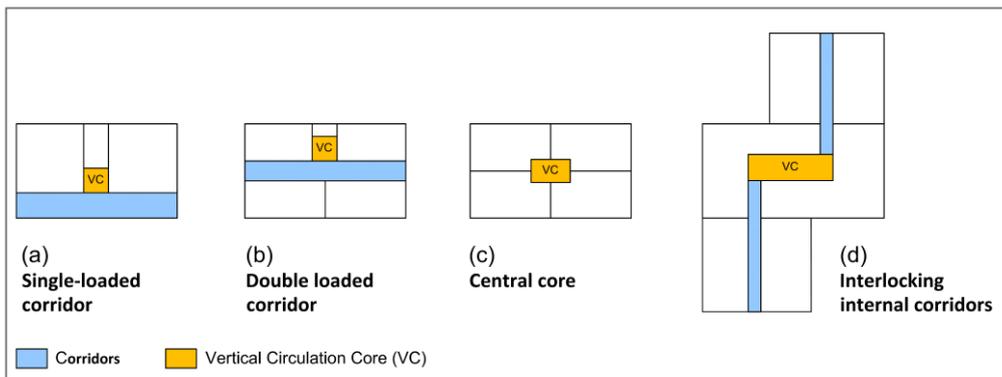


Figure 5.55: Different layouts for the arrangement of apartments in high-rise buildings

The internal double-loaded corridor could be considered the most efficient layout as the percentage of corridors relative to the area of the floor is low (approximately 8%), and at the same time serves many apartments (Ghazali *et al.* 2014). However, the single-loaded corridor has social and environmental benefits as it is connected with the outside context.

5. The fifth issue that needs to be addressed in a high-rise building is the connection with the outside context, especially for upper floors, to benefit from the natural light and views. Yet, it is essential to consider the privacy of the residents when designing glazed facades.
6. The sixth issue is that high-rise buildings require unique structural systems. According to European codes, it is recommended to design long span beams for multi-story constructions (Müller and Oppe 2008). This system, which offers spans between 5 and 13 meters (Table 5.4), has many benefits:
  - Internal columns are eliminated, and lead to more flexible and efficient use of internal space,
  - Services could be integrated within the depth of the structure. So, the floor-to-floor height is not increased,
  - 30% of the required beams could be reduced, which, therefore, reduce

- construction and installation time, and
- Fire protection costs could be reduced.

Table 5.4: Spans for different structural systems for multi-story buildings  
(Reproduced by the Author, after (Müller and Oppe 2008))

| Structural Systems                        | Span (m)  | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |  |
|---|-----------|---|---|---|---|---|----|----|----|--|
| Reinforced concrete flat slabs            | 5 to 8 m  | █ |   |   |   |   |    |    |    |  |
| Slim floor beams and deep composite slabs | 5 to 9 m  | █ |   |   |   |   |    |    |    |  |
| Integrated beams with precast slabs       | 5 to 10 m | █ |   |   |   |   |    |    |    |  |
| Post-tensioned concrete flat slabs        | 9 to 12 m |   |   |   |   | █ |    |    |    |  |
| Composite beams (with composite slabs)    | 6 to 13 m |   | █ |   |   |   |    |    |    |  |

### 5.7. Establishing a Parametric Socio-Spatial Grammar for the Design of Vertical Residential Buildings

A high-rise residential building could be defined as clusters of houses arranged vertically. On a basic level, each cluster, which is a vertical segment of the building, represents a horizontal quarter that has specific qualities (Figure 5.56). Such a vertical arrangement of horizontal neighbourhoods could highly promote the concept of hierarchy and clustering, and create a mutual responsibility for common spaces in each segment for encouraging interaction between neighbours.

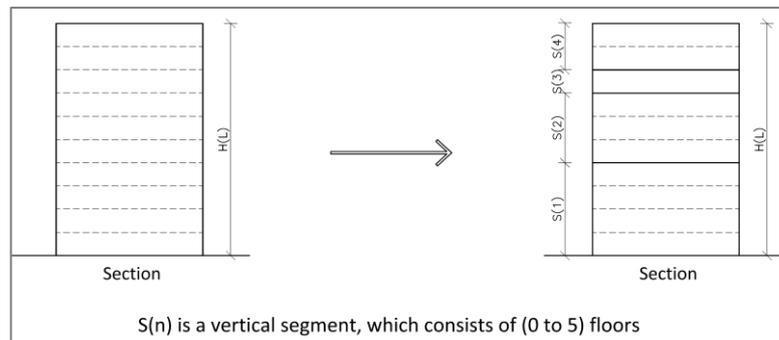


Figure 5.56: The concept of a vertical segmentation for a high-rise building into horizontal quarters

Accordingly, spatial rules that have specific social meanings extracted from the traditional model, combined with requirements of high-rise buildings, are outlined in this section. The aim is to define a database that is useful for generating contemporary-vernacular vertical developments that provide continuity to the existing world, and lead the design to be in harmony with context, climate, traditions, social needs, and requirements of the modern and future time.

### 5.7.1. Spatial Vocabularies and Social Parameters

A multi-story residential building could be divided into two main zones:

- a. A public zone; which includes a hierarchal system of common spaces: an entry hall (EN), a vertical circulation core (VC), a main public space (MPS), semi-private spaces between residential units (PVS), and pedestrian pathways (COR) that connect common spaces. To increase the environmental benefits of gathering areas inside the building, it is useful to attach the main public space with one or two edges of the layout. In MENA region, this edge could be located on East, West, or South. However, the Northern location is not a typical prototype for open spaces. On the other hand, semi-private spaces in front of apartments could be covered and considered as transitional/gathering areas.
- b. A private zone, which consists of residential units. To maintain a balance between isolation and interaction inside the apartment, it is recommended to include a private courtyard for each unit. There are different possibilities for the location of such an introverted open space (Figure 5.57). In high-rise residential buildings, the appropriate location of the courtyard is determined by two factors: (i) the location of the residential unit in relation to other units on the same floor; and (ii) on which floor the apartment is located. For instance, a central courtyard could be sufficient on top floors. However, a courtyard that is attached to one edge of the building is suitable on any floor of the building.

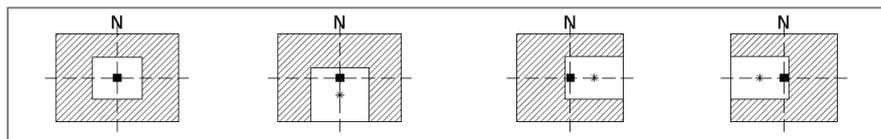


Figure 5.57: Diagrams showing possibilities for the location of the courtyard inside apartments

As creativity, flexibility, and adaptability are essential issues that need to be addressed in the design process, a ‘parametric design approach’ that guides variations is incorporated in the construction of the grammar (Aish and Woodbury 2005; Harding *et al.* 2012). Two characteristics are associated with this approach. Firstly, geometric properties and locations of design elements are defined through variables and parameters. Secondly, designers can revise parameters at any stage to modify their designs and generate different alternatives rather than one single solution (Jabi, 2013). For high-rise buildings, the following parameters are defined:

- Geometric configuration of common spaces and private courtyards;
- Percent of area for public and semi-private spaces relative to the total area of the building;
- Orientation of common spaces and private courtyards.

Accordingly, social qualities of spaces could be affected positively or negatively (Figure 5.58). For instance, social interaction and human comfort could be enhanced by increasing the width of public spaces or private courtyards. However, these areas become more crowded, and the security and safety of family and children might be decreased.

### **5.7.2. Sets of Parametric Rules**

A total of 66 parametric rules, categorised into twelve groups, define the database for the design of high-rise residential buildings (Figures 5.59 and 5.60). Mathematical expressions, which address geometric aspects, such as area, width, and orientation, are attached with rules. During the implementation process, designers need to consider the following issues:

- Rules that generate public spaces and semi-private areas between residential units could be applied for each segment according to the needs of the design.
- Rules for the configuration of corridors that connect public spaces with residential units could be applied according to the number of apartments and the overall layout of the building.
- Rules for allocating entrances for apartments and public spaces represent a guidance that needs to be applied to all doors/openings.
- The overall area of residential units could be divided into apartments according to the design brief.

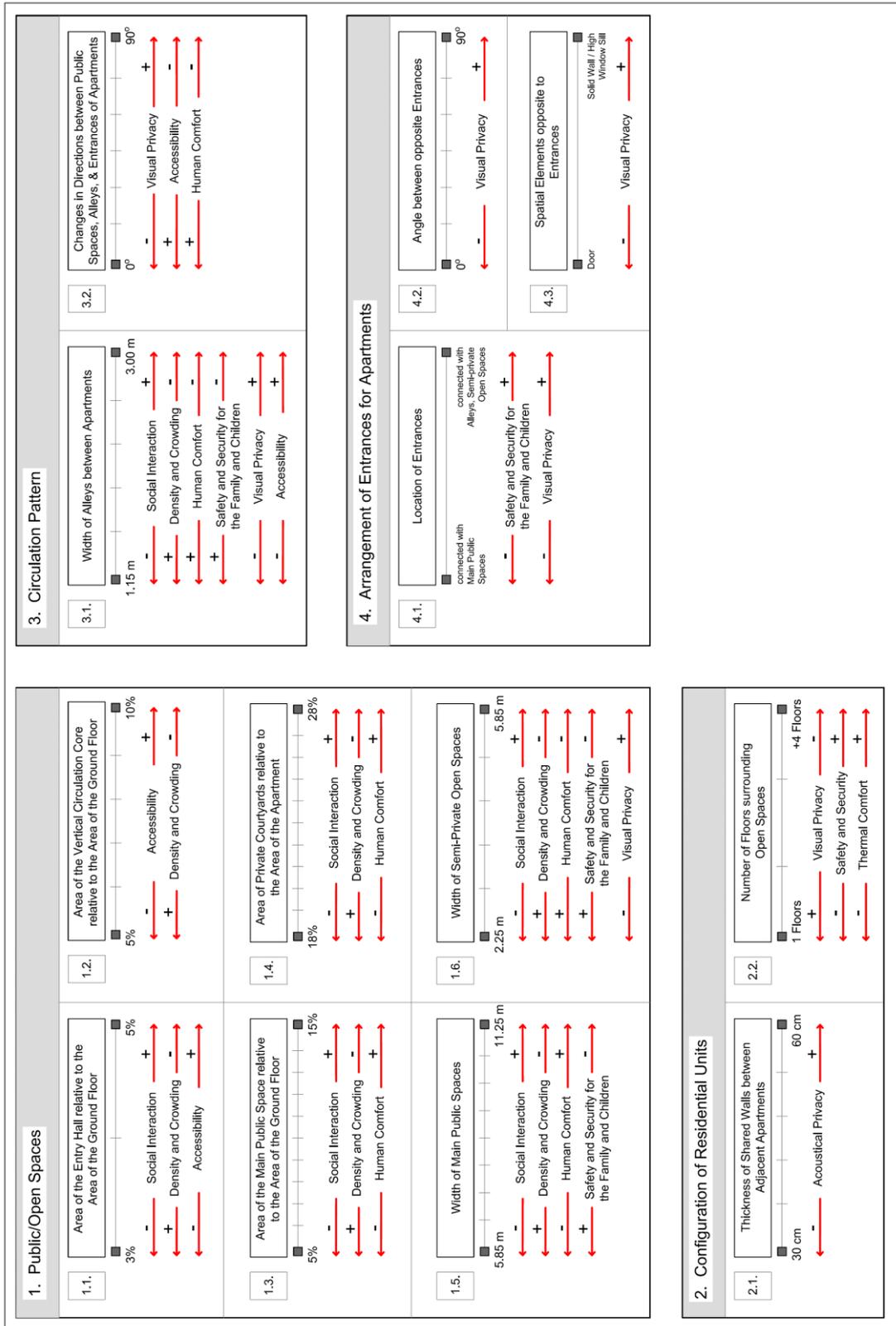


Figure 5.58: Parametric relationships between social sustainability and elements of design in residential buildings

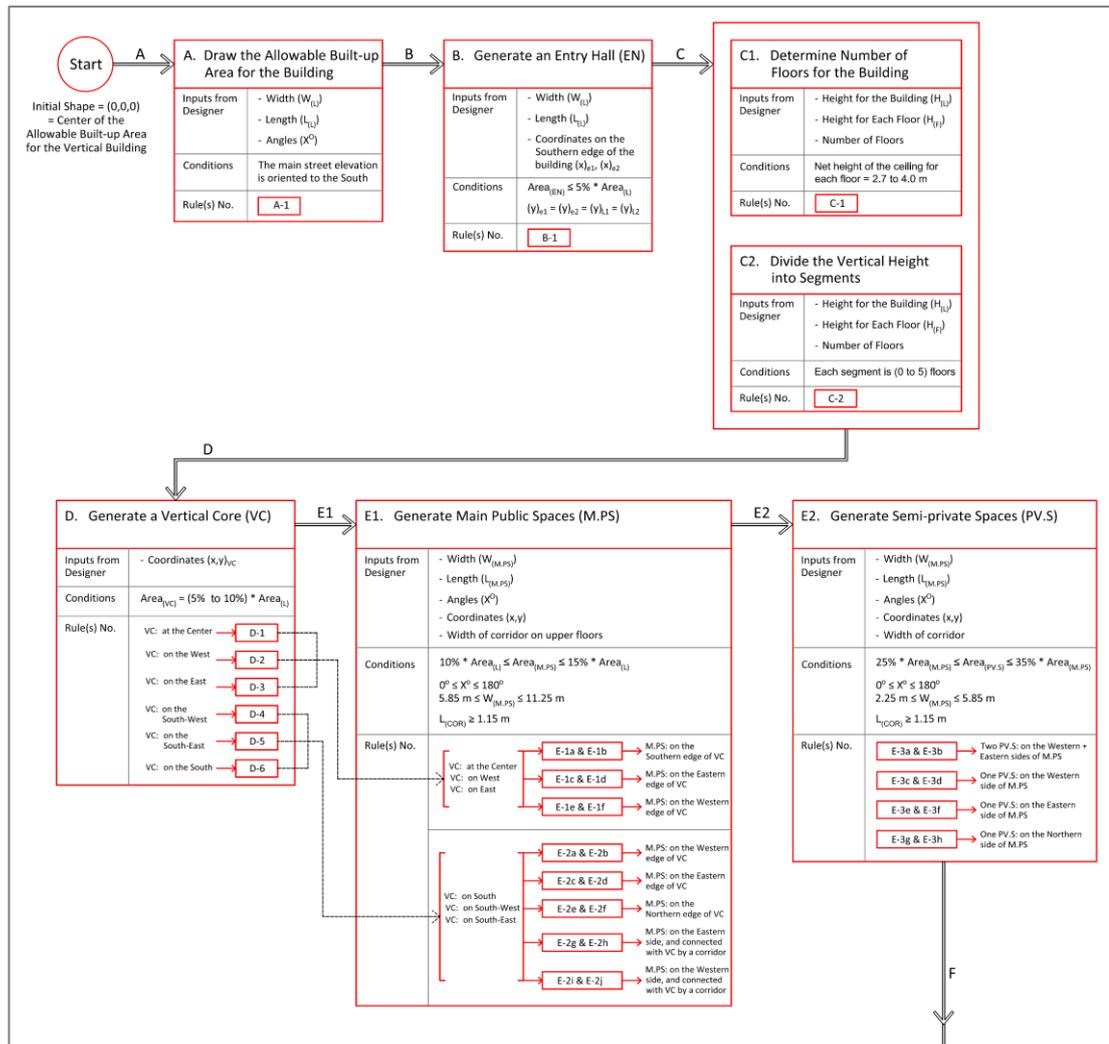


Figure 5.59: Groups of parametric rules for generating a high-rise residential building (Part 1)

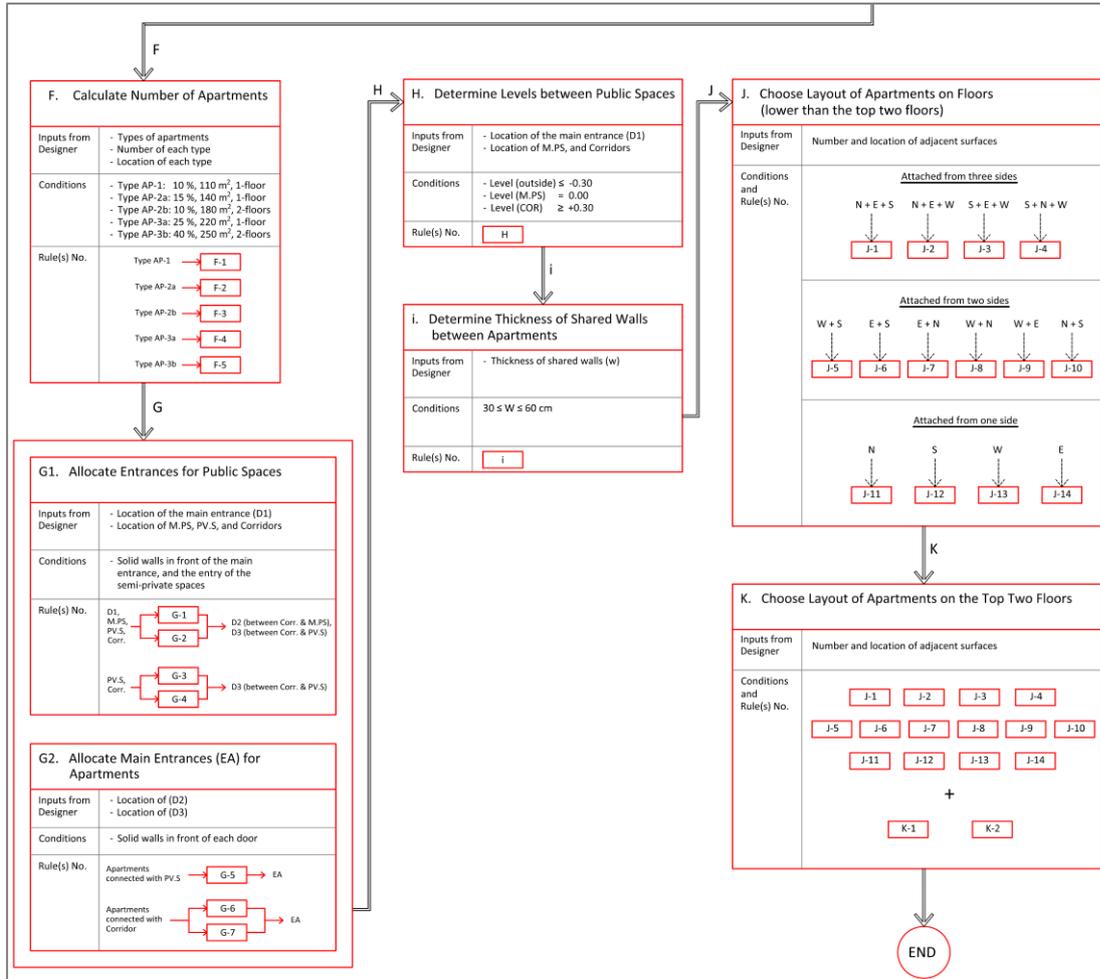


Figure 5.60: Groups of parametric rules for generating a high-rise residential building (Part 2)

The first rule in the grammar (A-1) starts on the left-hand side with a labelled point that represents the centre of the building layout. When this rule is applied, the point label (0,0,0) is replaced on the right-hand side with a parameterised polygon with vertices (L1, L2, L3, L4) that represents the corners of the building. Angles and dimensions of that shape could be changed according to the specifications attached to the rule (Figure 5.61).

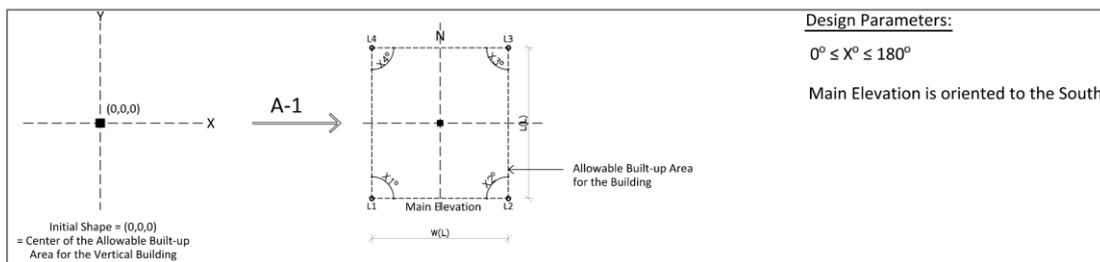


Figure 5.61: Stage (A): Rules for generating the allowable built-up area for the building

The second stage represents the rule for generating the main entry hall on the ground floor. It is attached to the street elevation, which is in this case, the south direction (Figure 5.62). The area of this space could be ranged between 3% and 5% of the total area of the floor.

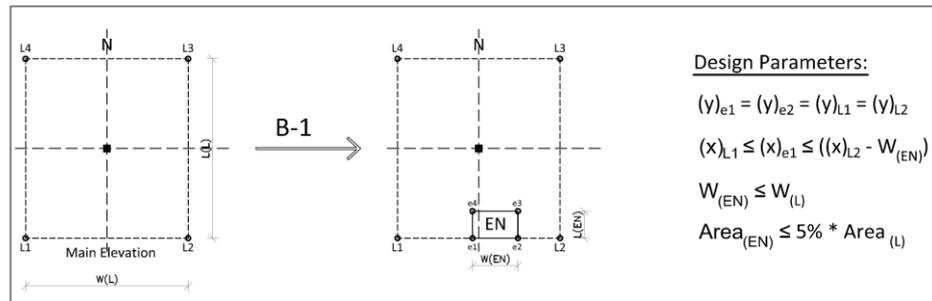


Figure 5.62: Stage (B): Rules for generating the entry hall (EN) on the ground floor

Stage (C) enables designers to specify the number of floors, the height of each floor, and then divide the building into vertical segments (Figure 5.63).

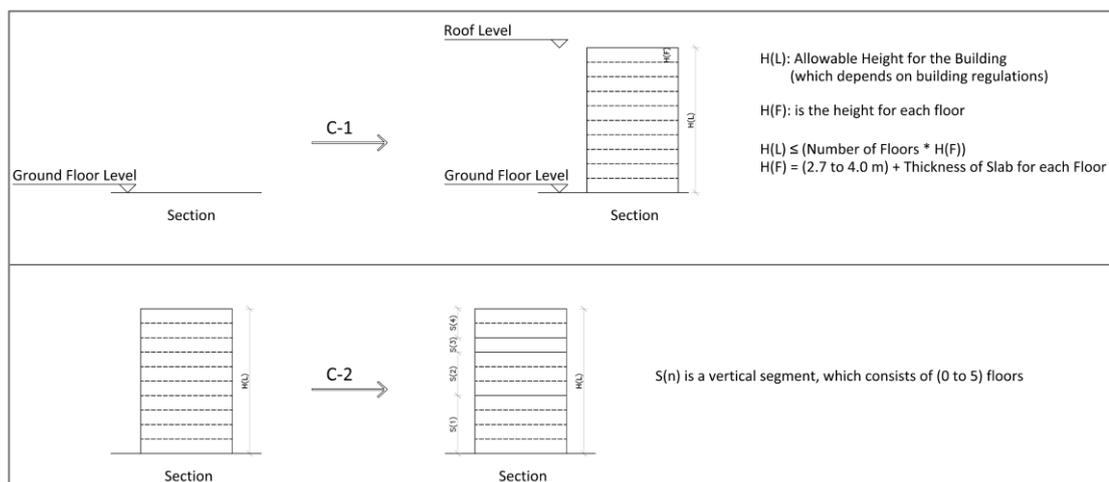


Figure 5.63: Stage (C): Rules for dividing the building into vertical segments

After the implementation of this process, a vertical circulation core, which includes staircase, elevators, and mechanical ducts, could be generated in different locations (Figure 5.64). The area of this space could be ranged between 5% and 10% of the ground floor area.

Public spaces inside the building are vital features for encouraging social interaction between residents, and offer secure spaces for children. To achieve an economic value for developers, these spaces represent 15-18% of the total area of the building. To maintain the privacy of families, such areas are arranged according to a hierarchical system on each floor. A main public gathering space (MPS) could be connected to the vertical circulation core and/or the main entrance. However, each segment could include a separate public courtyard. The area

of each main public space could be ranged between 10% and 15% from the area of each floor (Figures 5.65 and 5.66). A semi-private space (PVS), located between residential units, could be used as a transitional zone between apartments and public spaces. Number and dimensions of these spaces depend on the number of residential units on each segment. The total area of semi-private spaces on each segment is ranged between 25% to 35% from the area of the main public space (Figure 5.67).

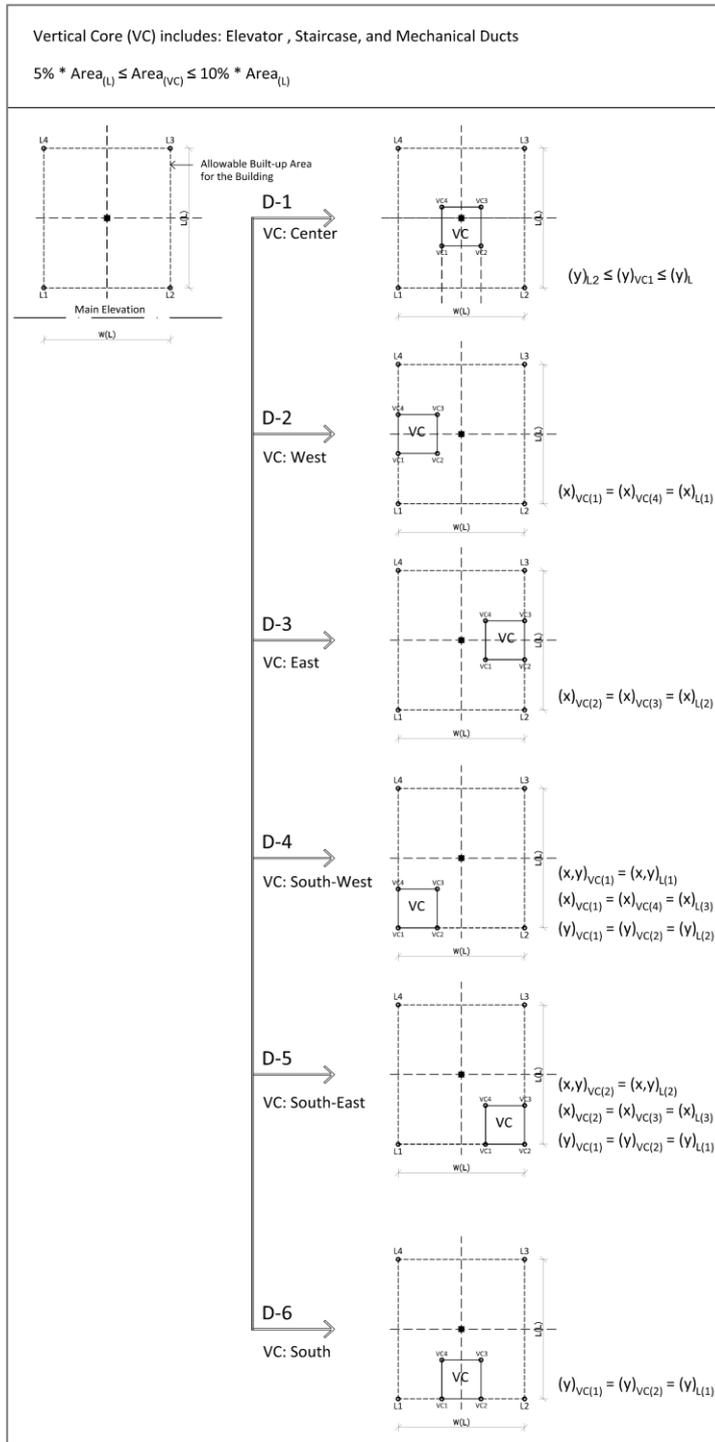


Figure 5.64: Stage (D): Rules for generating a vertical circulation core (VC)

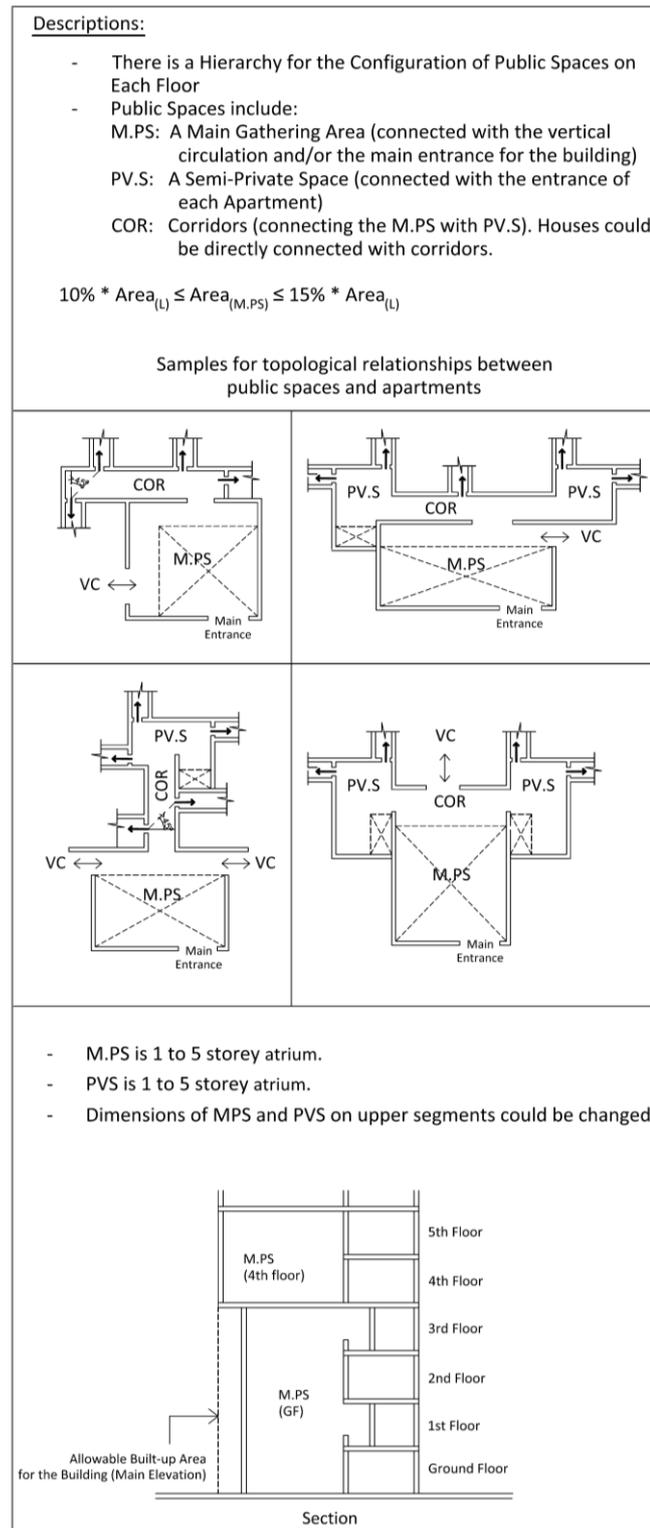


Figure 5.65: Samples of topological relationships between public spaces and apartments

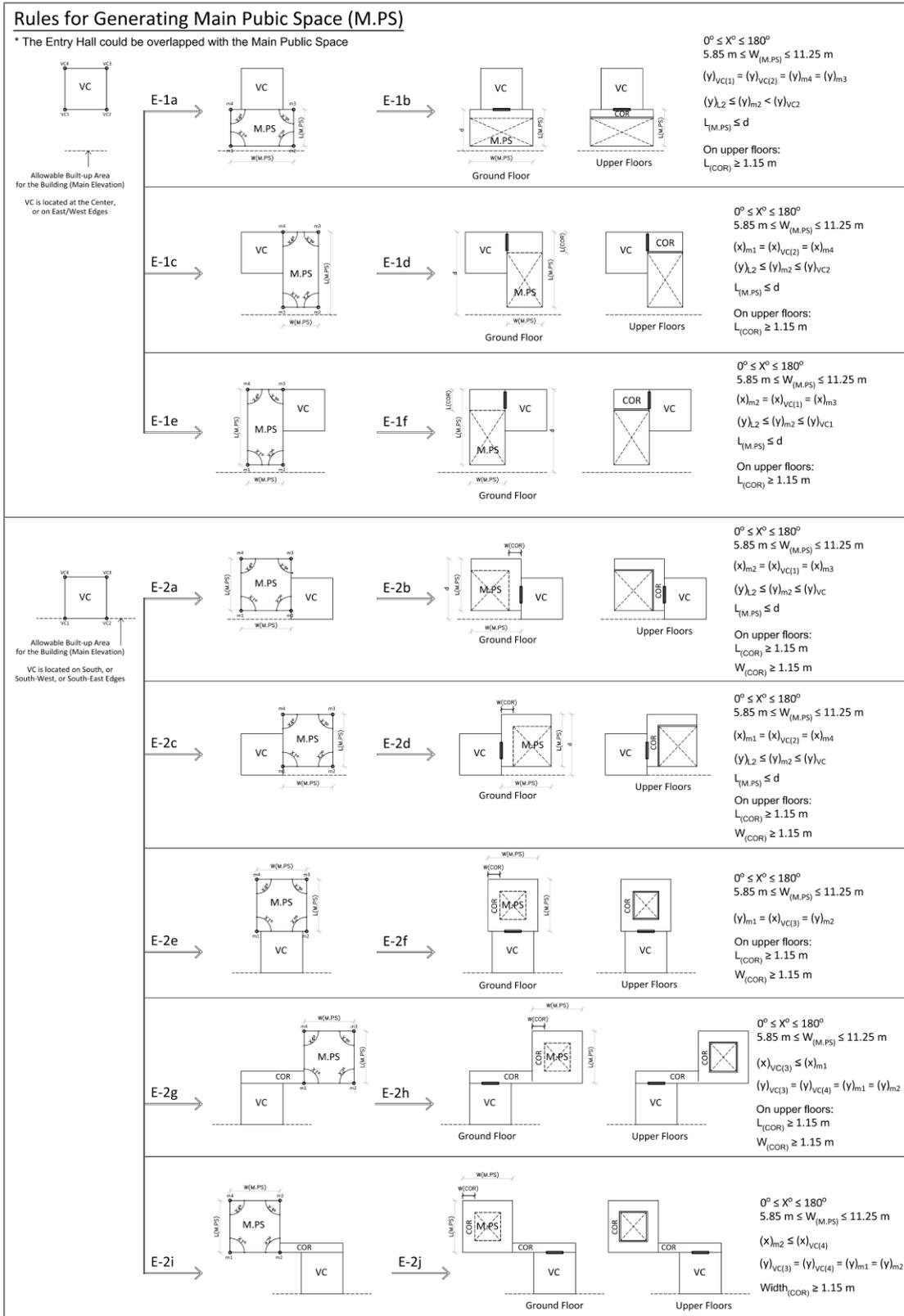


Figure 5.66: Stage (E1): Rules for generating a main public space (MPS)

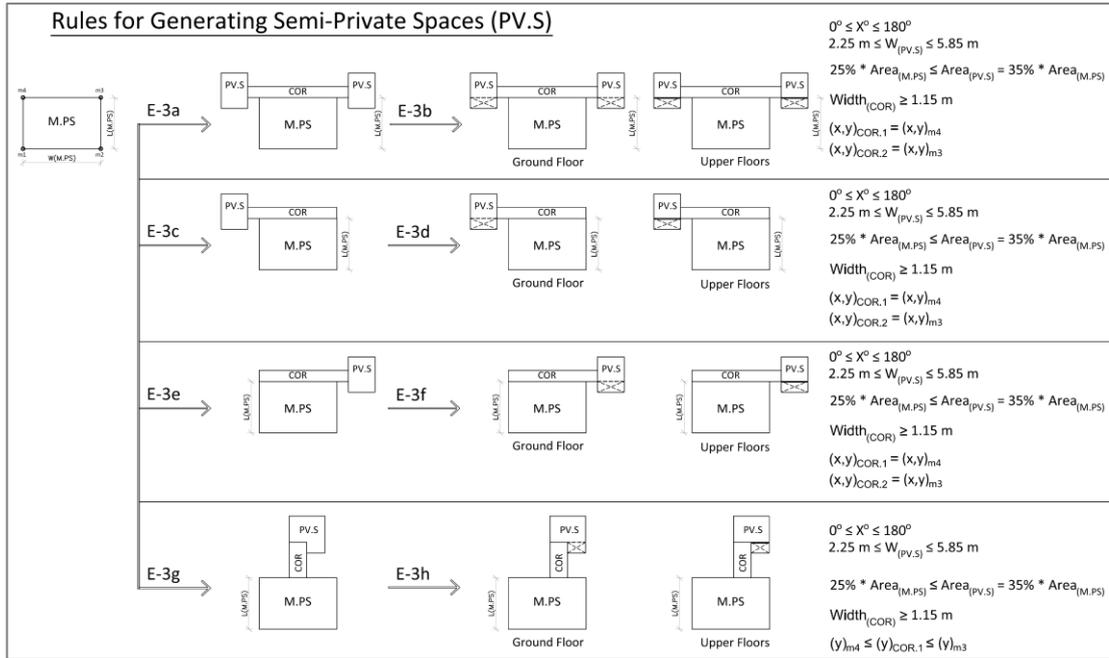


Figure 5.67: Stage (E2): Rules for generating semi-private spaces (PVS)

The next phase is to generate the layout of residential units. This stage starts with specifying the number of each type of apartments according to percentages extracted from the survey (Figure 5.68). Designers can allocate partitions between units to achieve the target area. After that, they can define location of entrances for all spaces to achieve the visual privacy for each unit (Figure 5.69). In addition, they can determine thickness of shared walls to maintain acoustical privacy between neighbours (Figure 5.70).

There are five types of apartments that could be distributed according to the following percentages:

| Type         | Number of Floors | Total Area               | Area of Each Floor       | % from the Total Number of Apartments | Number of Family Members |
|--------------|------------------|--------------------------|--------------------------|---------------------------------------|--------------------------|
| Type (AP-1)  | Single Floor     | 100 - 110 m <sup>2</sup> | 100 - 110 m <sup>2</sup> | 10 %                                  | 2 - 4                    |
| Type (AP-2a) | Single Floor     | 110 - 140 m <sup>2</sup> | 110 - 140 m <sup>2</sup> | 15 %                                  | 2 - 4                    |
| Type (AP-2b) | Two Floors       | 140 - 180 m <sup>2</sup> | 70 - 90 m <sup>2</sup>   | 10 %                                  | 4 - 6                    |
| Type (AP-3a) | Single Floor     | 180 - 220 m <sup>2</sup> | 180 - 220 m <sup>2</sup> | 25 %                                  | 4 - 6                    |
| Type (AP-3b) | Two Floors       | 220 - 250 m <sup>2</sup> | 110 - 125 m <sup>2</sup> | 40 %                                  | 5 - 8                    |

The maximum number of apartments on each floor is: Five apartments, which could be from the same type, or different types

|  |                                   |   |   |          |                                   |   |   |
|--|-----------------------------------|---|---|----------|-----------------------------------|---|---|
| $\text{Area of Apartments} = ( \text{Allowable Built-up Area for the Building} - \text{Area of Vertical Circulation} - \text{Area of Public Spaces and Corridors} ) * \text{Number of Floors}$ |                                   |   |   |          |                                   |   |   |
| Rule F-1   | Total Area of (Type AP-1)         | = | Area of Apartments * 10 %                       |          |                                   |   |   |
|  | Number of Apartments (Type AP-1)  | = | $\frac{\text{Total Area of (Type AP-1)}}{110}$  |          |                                   |   |   |
| Rule F-2   | Total Area of (Type AP-2a)        | = | Area of Apartments * 15 %                       | Rule F-3 | Total Area of (Type AP-2b)        | = | Area of Apartments * 10 %                       |
|  | Number of Apartments (Type AP-2a) | = | $\frac{\text{Total Area of (Type AP-2a)}}{140}$ |          | Number of Apartments (Type AP-2b) | = | $\frac{\text{Total Area of (Type AP-2b)}}{180}$ |
| Rule F-4   | Total Area of (Type AP-3a)        | = | Area of Apartments * 25 %                       | Rule F-5 | Total Area of (Type AP-3b)        | = | Area of Apartments * 40 %                       |
|  | Number of Apartments (Type AP-3a) | = | $\frac{\text{Total Area of (Type AP-3a)}}{220}$ |          | Number of Apartments (Type AP-3b) | = | $\frac{\text{Total Area of (Type AP-3b)}}{250}$ |

Figure 5.68: Stage (F): Rules for determining types and percentages of apartments

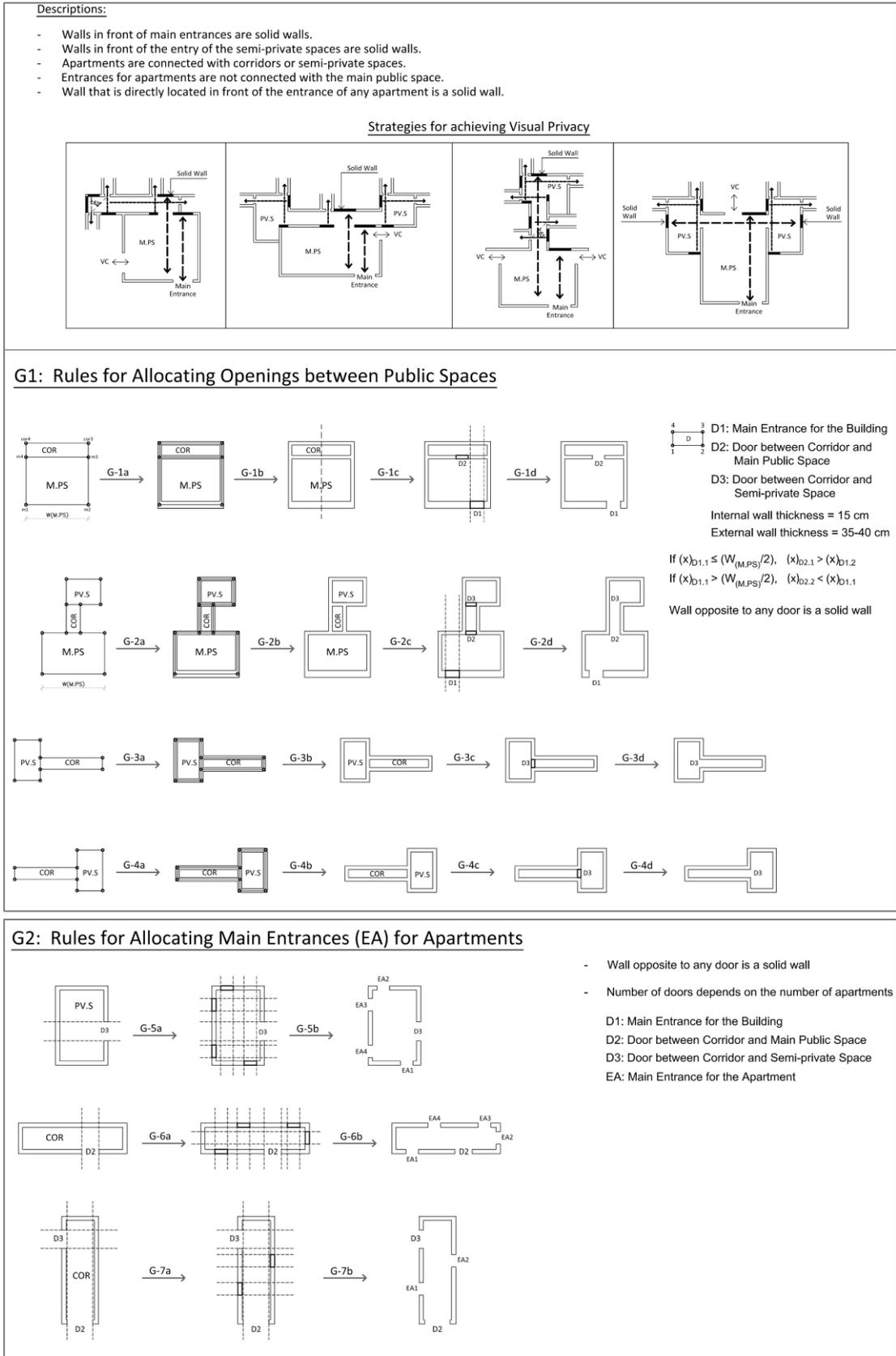


Figure 5.69: Stage (G): Rules for allocating entrances

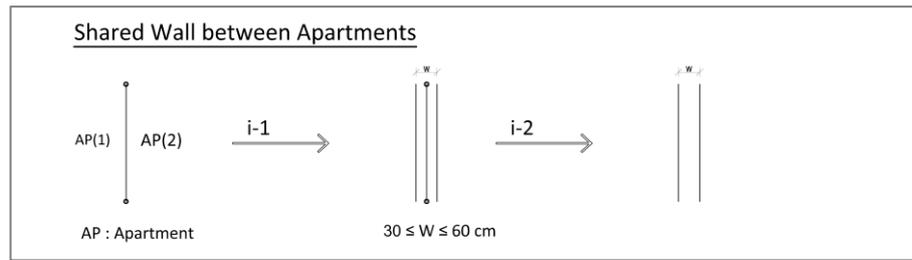


Figure 5.70: Stage (i): Rules for specifying thicknesses of shared partitions between apartments

Finally, a private courtyard could be located inside each apartment. Designers can define the suitable location of the courtyard according to a catalogue that is based on number of shared surfaces and orientation of the apartment (Figures 5.71, 5.72, 5.73, and 5.74).

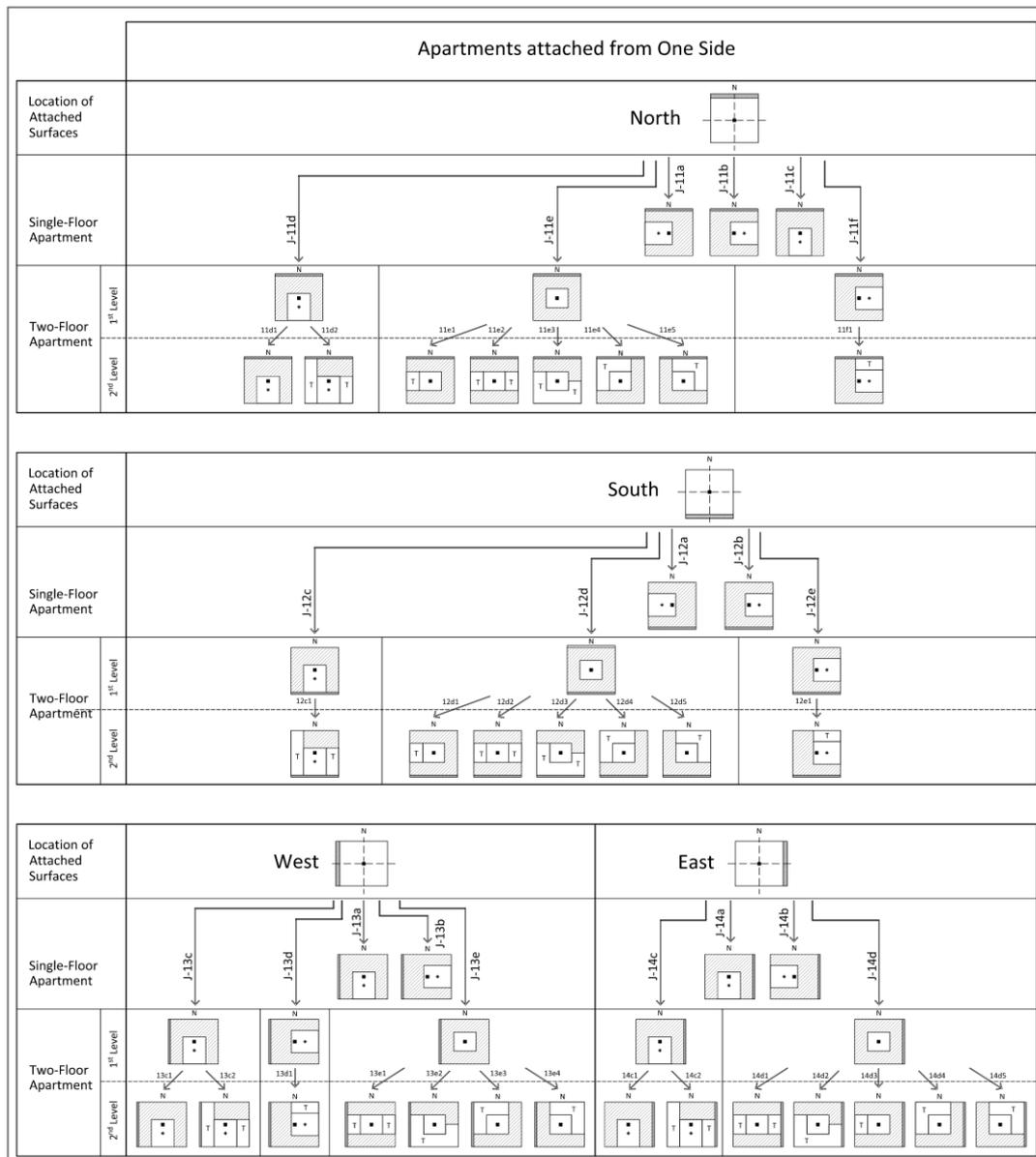


Figure 5.71: Stage (J): Rules for allocating courtyards inside apartments that are attached from one side

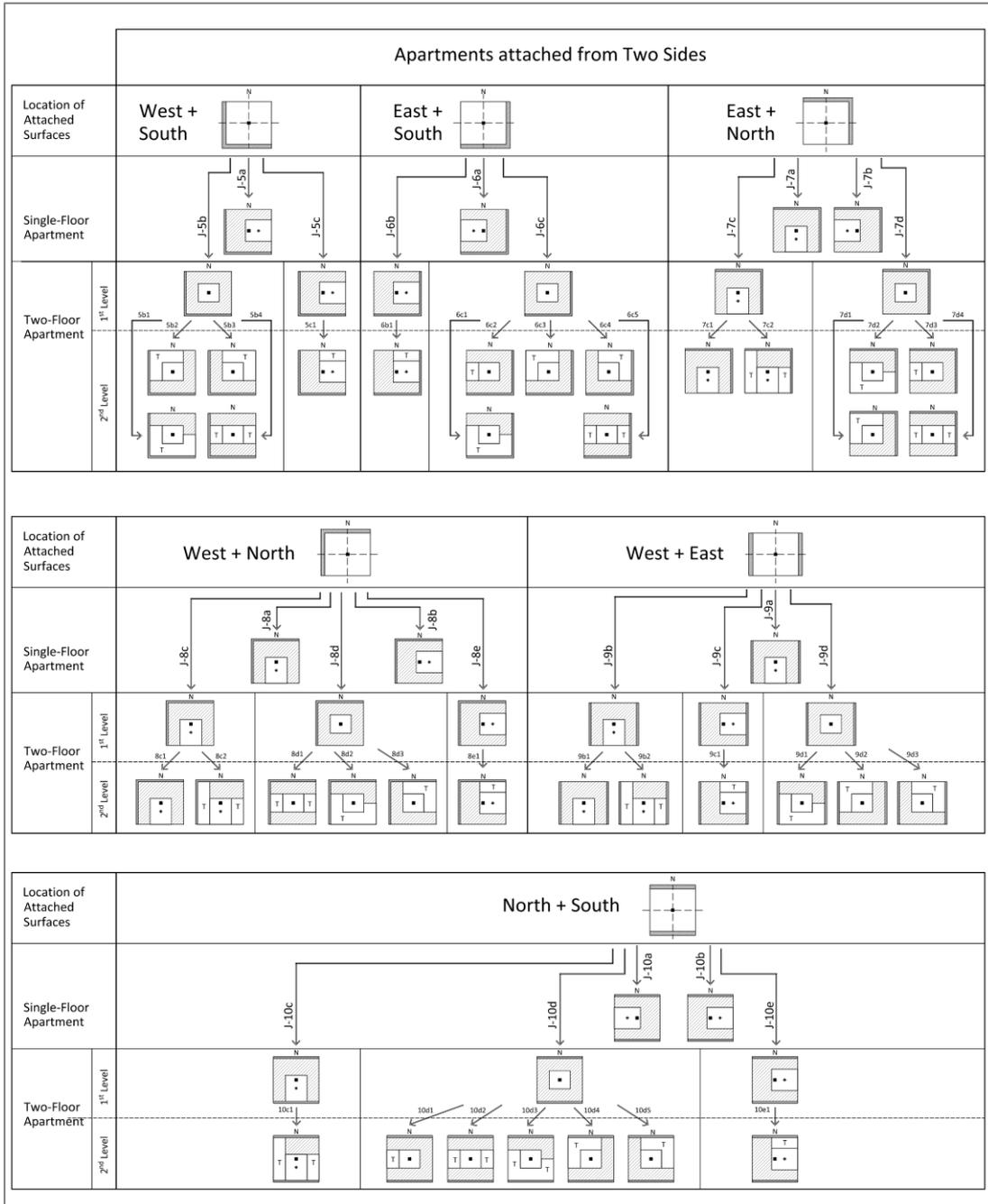


Figure 5.72: Stage (J): Rules for allocating courtyards inside apartments that are attached from two sides

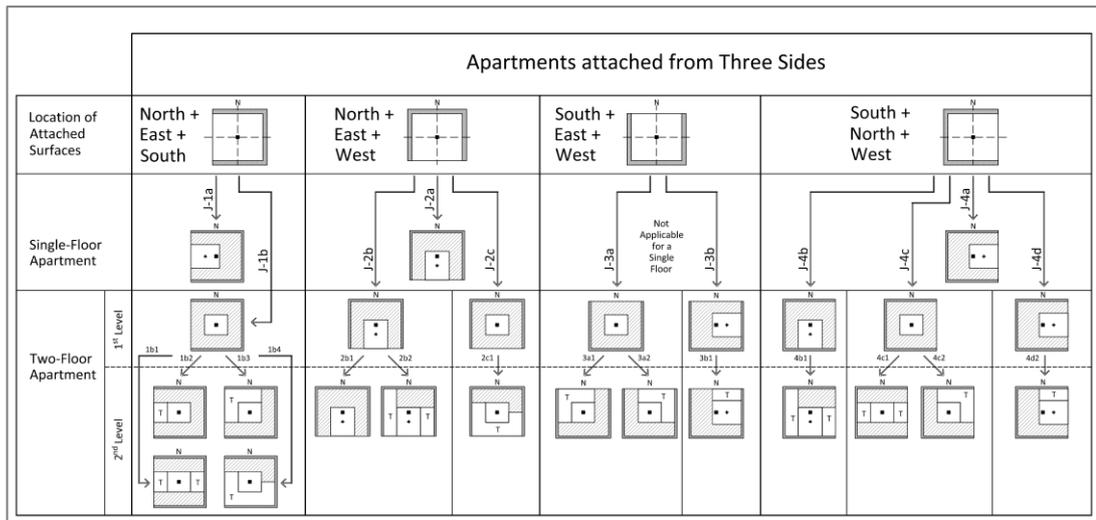


Figure 5.73: Stage (J): Rules for allocating courtyards inside apartments that are attached from three sides

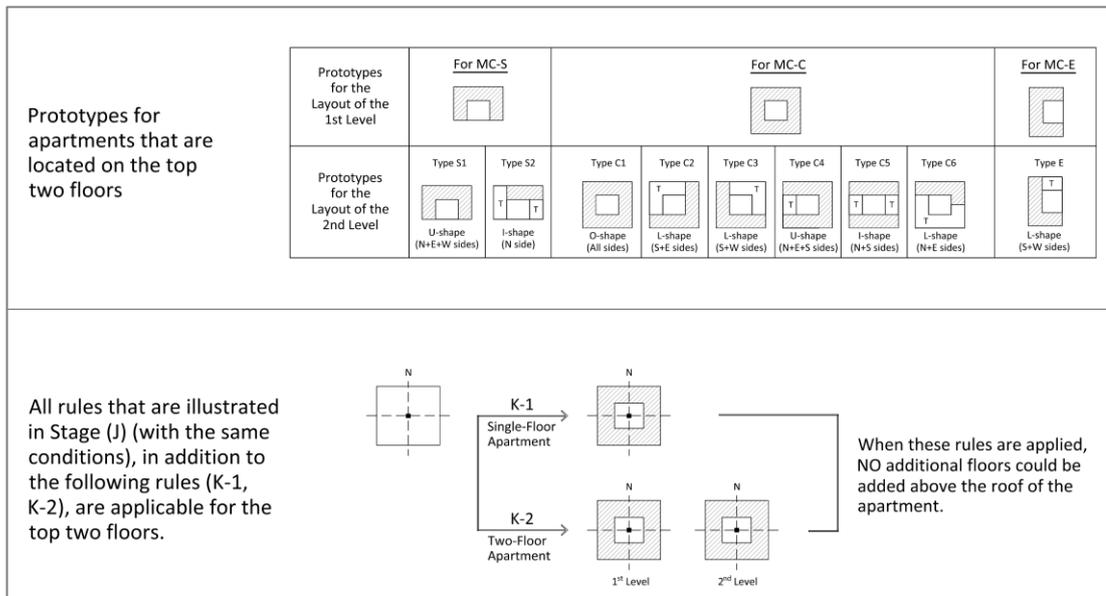


Figure 5.74: Stage (K): Rules for allocating courtyards inside apartments that are located on the top two floors

### 5.8. Developing a Computational Tool for Generating Vertical Residential Buildings

As the constructed grammar is parametric, each derivation process generates different solutions, and makes the process difficult to manage. Moreover, designers seek to express their ideas physically, and generate solutions with a high degree of accuracy in a short amount of time for execution (Segers *et al.* 2001). Therefore, the grammar has been translated into a computational interface, and coded using 2D/3D CAD modelling software

“Rhinoceros 3D”, with its plugin “Grasshopper”.

Most of the current computational models could be used for designing any artefact. However, recognising the design brief, and considering the context or a building type are not resolved yet (Achten 1997). The tool aims to model the specific type of traditional houses and neighbourhoods for generating high-rise residential buildings. The target is to support and stimulate architects in the early stage of the design process to generate such structures that are related to the context of the study, and have potentials of social sustainability.

The interface addresses the following objectives:

1. Provide designers with a catalogue of main spaces.
2. Embed spatial rules, constraints, and topological relationships governing the different spaces of the building.
3. Allow designers to create different alternatives by modifying geometric properties and location of design elements.
4. Search for better solutions according to predefined criteria.

### **5.8.1. Implementation Strategy**

A performative design approach has been adopted as a mechanism for the construction of the model. It is a synthesis of two computational design processes: geometric generation; and performance simulation (Oxman 2009). This approach depends on embedding different parameters that are related to the design problem, such as social, environmental, geometric, or economic, to generate optimised solutions (Kolarevic 2005).

To simplify the complexity of the model, and to keep the process manageable, the tool suggests a list of 10 procedural tasks that guide the user through an interactive interface (Figure 5.75). Each task aims to generate a space, or group of spaces that have the same function. Moreover, it allows the designer the ability to control geometric parameters and conditions that respond to different design patterns, through dialogue boxes and entities, such as checkboxes, number sliders, and buttons (Figure 5.76).

The design strategy adopted in this tool is to split the building into vertical segments. The maximum number of segments is six, and each segment could be reached up to five floors. The total number of floors that could be generated is 30 floors. As there are similarities in some rules in the grammar, the same group of components was used for each segment of the building, with only changing topological or geometric parameters. For example, components that generate the layout of a private courtyard on the ground floor are similar

to those that generate a courtyard on the 4<sup>th</sup> segment. However, the user can change the width, the length, and the location of that space (see Figure 5.77).

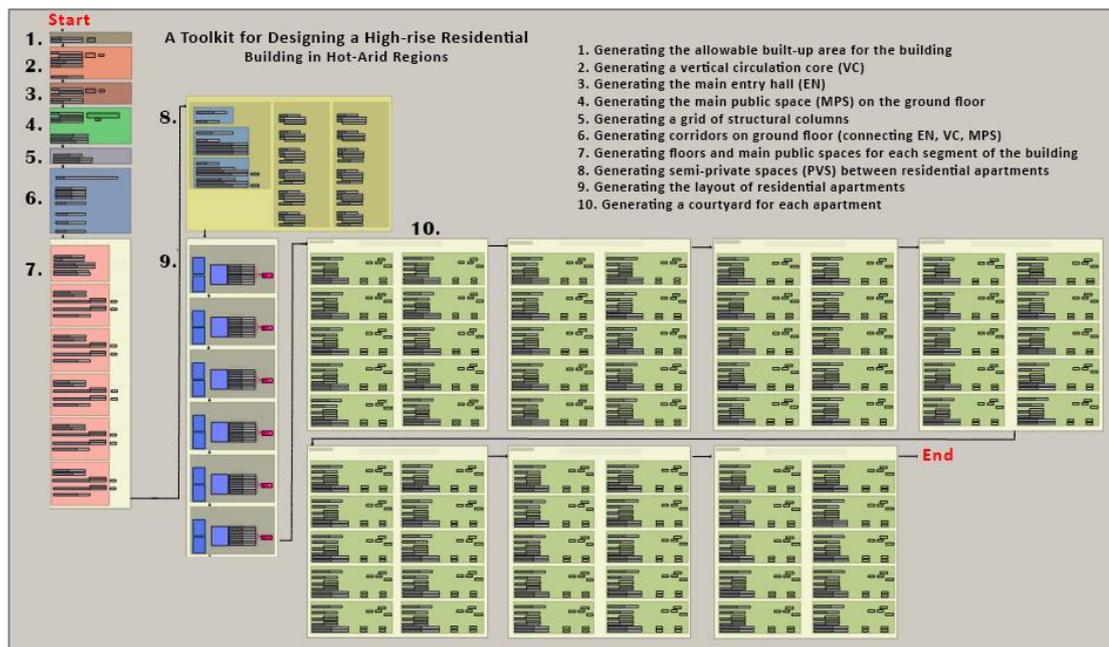


Figure 5.75: A screenshot of the interface for designing a high-rise residential building in hot-arid regions

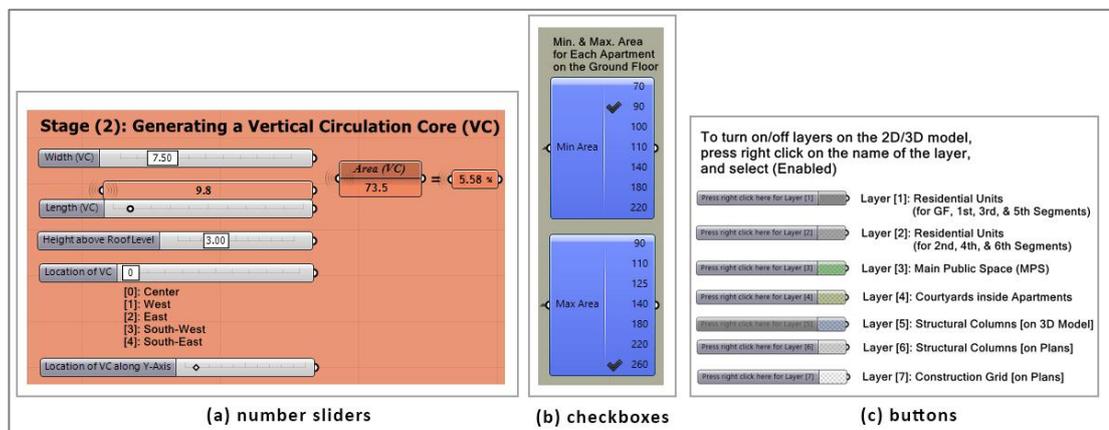


Figure 5.76: Types of dialog boxes and entities to control geometric parameters and conditions

**Ground Floor: Apartment # (1-W)**

Location of Apartment # (1-W) [Not Applicable]

Location of Courtyard [2] [0]: No Courtyard  
[1]: on West  
[2]: on South  
[3]: at the Center

Width of Courtyard [7.14]

Length of Courtyard [7.14]

Position of Courtyard along X-Axis [ ]

Position of Courtyard along Y-Axis [ ]

Total Area of Apartment (# 1-W) = [155.5]

Courtyard Area = [51.0] = [32.8] %

Area of Apartment (excluding Courtyard) = [104.6]

Width of Rooms (surrounding the courtyard)

on West: [5.21] on East: [8.65]

on North: [4.59] on South: [0.0]

---

**4th Segment: Apartment # (1-W)**

Location of Apartment # (1-W) [Not Applicable]

Location of Courtyard [1] [0]: No Courtyard  
[1]: on West  
[2]: on South  
[3]: at the Center

Width of Courtyard [3.45]

Length of Courtyard [3.45]

Position of Courtyard along X-Axis [ ]

Position of Courtyard along Y-Axis [ ]

Total Area of Apartment (# 1-W) = [122.2]

Courtyard Area = [11.9] = [9.8] %

Area of Apartment (excluding Courtyard) = [110.2]

Width of Rooms (surrounding the courtyard)

on West: [0.0] on East: [3.9]

on North: [5.69] on South: [7.48]

Figure 5.77: Parameters that enable the user to change width, length, and location of a private courtyard in an apartment that is located on: (a) the ground floor, and (b) the 4<sup>th</sup> segment of the building

It is important to mention that the implementation of the computational model is not intended as a shape grammar interpreter, which should be able to recognise and detect shapes, and then apply operations to those shapes (Correia 2013; Trescak *et al.* 2012). However, the Grasshopper model allows the generation of different design solutions, through manipulating parameters for shapes. These shapes have predefined topological relations according to the constructed parametric grammar.

### 5.8.2. Code Flowchart and the User Interface

The computational process of form generation requires three elements: (a) conditions and parameters (inputs); (b) a generative mechanism (rules and algorithms); and (c) results (outputs) (Figure 5.78). This mechanism starts with a finite set of inputs, which could take one value or a set of values, executes a finite number of rules and actions to fulfil a defined purpose, and finally produces the result or a set of results as outputs (Dino 2012). The following section illustrates the code flowchart that includes these components to generate high-rise buildings.

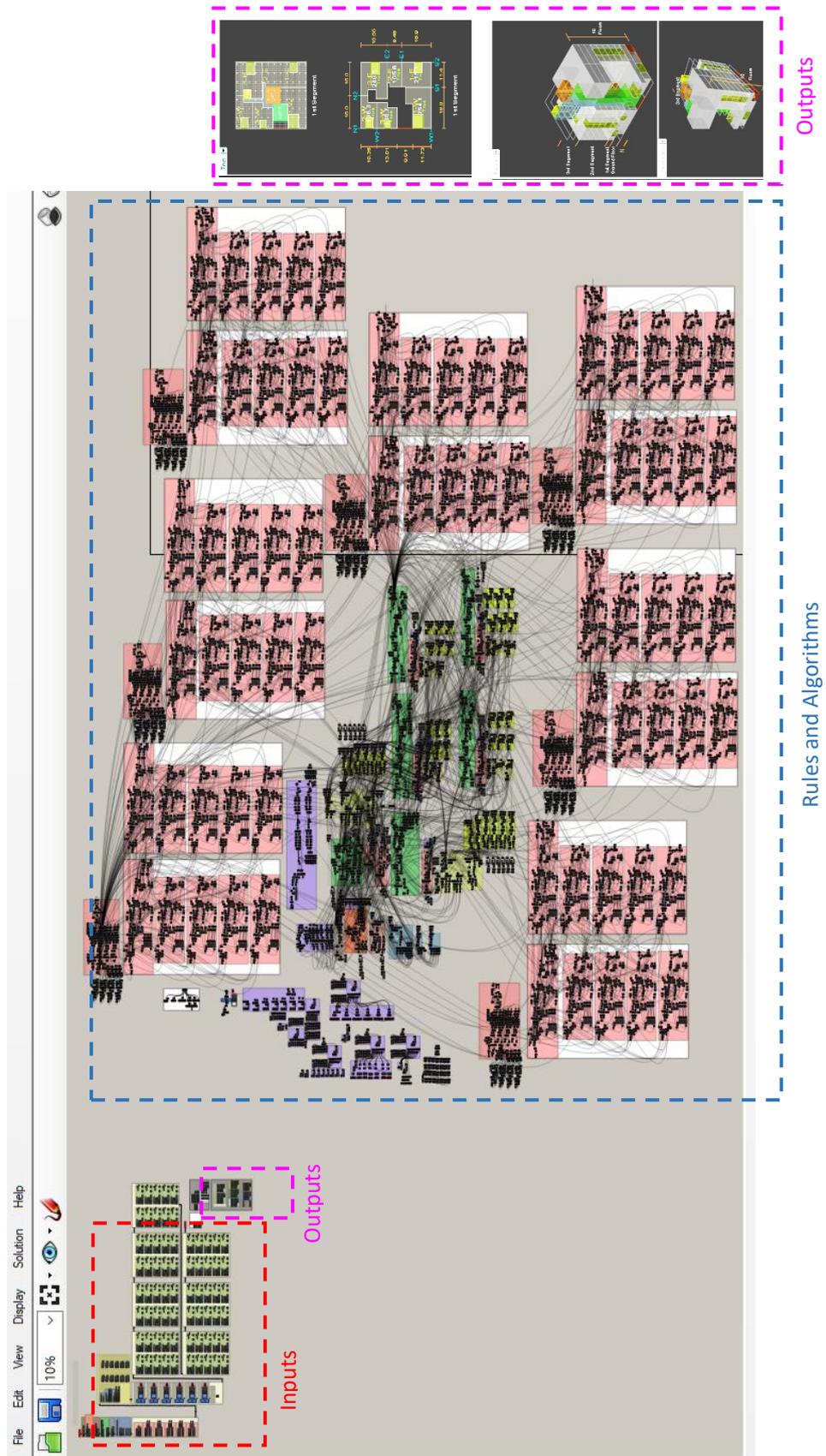


Figure 5.78: A screenshot of the computational process of form generation showing: inputs, outputs, rules and algorithms

### a. Input Parameters

Grasshopper, by McNeel and Associates, is a visual scripting tool that helps the design process, and allows input data to be passed from one component to another via connecting wires. The interface is structured interactively; where the designer can modify a total of 66 unique parameters (see Table 5.5).

Table 5.5: Parameters and conditions for each stage in the computational tool for generating a high-rise residential building

| Stages of Design   | Inputs and Conditions  | Number of Parameters |
|--|--|----------------------|
| 1. Generating the allowable built-up area for the building                   | . Width<br>. Length  | 2                    |
| 2. Generating a vertical circulation core (VC)                               | . Width<br>. Length<br>. Height above roof level<br>. Location   | 5                    |
| 3. Generating the main entry hall (EN)                                       | . Width<br>. Length<br>. Location  | 3                    |
| 4. Generating the main public space (MPS) on the ground floor                | . Width<br>. Length<br>. Location  | 5                    |
| 5. Generating a grid of structural columns                                   | . Size of columns<br>. Distances between columns (X-axis)<br>. Distances between columns (Y-axis)  | 3                    |
| 6. Generating corridors on the ground floor (connecting EN, VC, MPS)         | . Width<br>. Location  | 6                    |
| 7. Generating floors and main public spaces for each segment of the building | . Height of each floor<br>. Number of floors on each segment<br>. Width and length of the MPS on each segment<br>. Alternatives for the connection of the MPS with the outside | 11                   |
| 8. Generating semi-private spaces (PVS) between residential apartments       | . Width and length of corridors connected with PVS,<br>. Width and length of PVS<br>. Location of PVS  | 16                   |
| 9. Generating the layout of residential apartments                           | . Maximum and minimum Area of apartments on each segment<br>. Width and length of apartments   | 10                   |
| 10. Generating a courtyard inside each apartment                             | . Width<br>. Location  | 5                    |
| <b>Total Number of Parameters</b>  |  | <b>66</b>            |

Regarding the different alternatives for the location of each space, different options are shown for each transformation. However, users can only select one option, and subsequently, it will be used for the next step. During the implementation process, thicknesses of walls are ignored, and a different legend is assigned automatically to the

centre point of the space.

- *Stage (1): Generating the Allowable Built-up Area for the Building*

The first step requires users to specify the width and the length of the allowable built-up area for the building (Table 5.6). The upper limit for each value is 50 meters. The coordinate for the centre of the layout is specified as (0,0,0). After determining the width and the length of the layout using number sliders, the user can see the total allowable area of the ground floor on the right side of these sliders.

Table 5.6: Parameters and conditions for the layout of the building

| Parameters for the Allowable Built-up Area for the Building | Domain of Numeric Range (Inputs) | Type of Input Data |
|---|----------------------------------|--------------------|
| Width   | (5.00 to 50.00) meters           | Float number       |
| Length  | (5.00 to 50.00) meters           | Float number       |

- *Stage (2): Generating a Vertical Circulation Core (VC)*

The vertical circulation core includes staircase, elevator(s), and mechanical ducts for the building. Regarding geometric properties, the user needs to specify the width and the length of this space (Table 5.7). However, the length is associated with the percentage of the core area relative to the total area of the ground floor. Area of the vertical circulation core, and its percentage from the area of the floor are calculated automatically and appeared on the right side of the interface.

Furthermore, there are different possibilities for the location of the vertical core (Figure 5.79). Each prototype is associated with a number, so that the user can select that number on the slider. Finally, the height of the vertical core is associated with the total height of all floors, and will be adjusted automatically on the three-dimensional view. Yet, the height of the vertical core above the roof level could be changed by the designer.

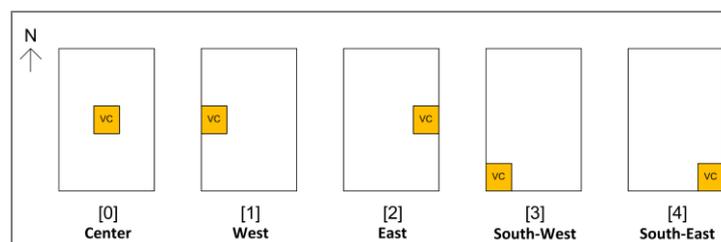


Figure 5.79: Diagrams showing possibilities for the location of the vertical circulation core (VC)

Table 5.7: Parameters and conditions for the vertical circulation core (VC)

| Parameters for the Vertical Circulation Core (VC)   | Domain of Numeric Range (Inputs)                                       | Type of Input Data |
|---|--|--------------------|
| Width   | (5.00 to 15.00) meters   | Float number       |
| Length: based on the percentage of the VC area relative to the total area of the ground floor = (5.00 to 10.00 %) | Factor, range = (0.00 to 1.00)   | Float number       |
| Height above roof level   | (2.50 to 4.00) meters  | Float number       |
| Alternatives for the location   | [0] Center<br>[1] West<br>[2] East<br>[3] South-West<br>[4] South-East | Integer            |
| Position along Y-axis   | Factor, range = (0 to 100)   | Integer            |

- *Stage (3): Generating the Main Entry Hall (EN)*

In this stage, the user can determine the geometric properties of the main entry hall (Table 5.8). This space is attached to the main elevation of the building. As a sample, the Southern edge of the layout has been selected for the implementation of the model. However, the user can change the position along the X-axis based on the location of the VC. Area of the main entry hall, and its percentage from the area of the floor will appear for the user.

Table 5.8: Parameters and conditions for the main entry hall (EN)

| Parameters for the Main Entry Hall (EN)  | Domain of Numeric Range (Inputs) | Type of Input Data |
|--|----------------------------------|--------------------|
| Width  | (3.00 to 15.00) meters           | Float number       |
| Length: based on the percentage of the VC area relative to the total area of the ground floor = (3.00 to 5.00 %) | Factor, range = (0.00 to 1.00)   | Float number       |
| Position along X-axis:   |                                  |                    |
| 5. If the VC is located at Center, East, or West   | Factor, range = (0 to 100)       | Integer            |
| 6. If the VC is located on the South-East, or South-West   | Factor, range = (0 to 100)       | Integer            |

- *Stage (4): Generating a Main Public Space (MPS) on the Ground Floor*

To generate a main public space (MPS) on the ground floor, the user needs to specify the width and the length of that space (Table 5.9). However, the length is linked with the percentage of the area of the MPS relative to the allowable area of the layout, which is ranged between 5% and 15%. Alternative for the location of the MPS are related to the configuration of the vertical circulation core, as both of them are public zones (Figure 5.80). Yet, designers can change the position along (X) and (Y) axes through selecting a

factor ranging between 1 and 100. Area of the MPS, and its percentage from the area of the floor are performed automatically for the user.

Table 5.9: Parameters and conditions for the main public space (MPS)

| Parameters for the Main Public Space (MPS)   | Domain of Numeric Range (Inputs)  | Type of Input Data |
|--|---|--------------------|
| Width  | (5.85 to 11.25) meters  | Float number       |
| Length: based on the percentage of the MPS area relative to the total area of the ground floor = (5.00 to 15.00 %) | Factor, range = (0.00 to 1.00)  | Float number       |
| Alternatives for the location of the MPS in relation to the VC   | [0] West<br>[1] East<br>[2] South-West<br>[3] South-East<br>[4] South<br>[5] North-West<br>[6] North-East | Integer            |
| Position along Y-axis:   |   |                    |
| 7. If the MPS is located on East or West   | Factor, range = (0 to 100)  | Integer            |
| 8. If the MPS is located on North or South   | Factor, range = (0 to 100)  | Integer            |
| Position along X-axis:   |   |                    |
| 9. If the MPS is located on North or South   | Factor, range = (0 to 100)  | Integer            |

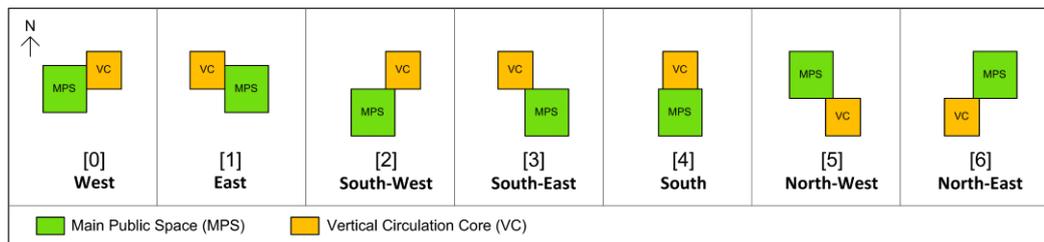


Figure 5.80: Diagrams showing alternatives for the location of the main public space (MPS)

- *Stage (5): Generating a Grid of Structural Columns*

To have a schematic layout for the location of structural columns, designers can specify size of columns, and spans along X and Y axes (Table 5.10).

Table 5.10: Parameters and conditions for the grid of structural columns

| Parameters for the grid of structural columns | Domain of Numeric Range (Inputs) | Type of Input Data |
|---|----------------------------------|--------------------|
| Dimensions of each column (width and length)  | (0.20 to 1.00) meters            | Float number       |
| Distance between columns in the X-axis        | (4.00 to 12.00) meters           | Float number       |
| Distance between columns in the Y-axis        | (4.00 to 12.00) meters           | Float number       |

- *Stage (6): Generating Corridors between EN, VC, and MPS on the Ground Floor*

The horizontal transition from public zones inside the building to private areas (apartments) needs a hierarchical and accessible system of movement. Such an organisation could be realised through the design of transitional spaces. Yet, developers wish to reduce the area of such pathways and increase the area of residential units. Therefore, the tool offers the user a list of different locations for corridors on the ground floor along (X) and (Y) axes, according to the location of the entry hall, the main public space, and the vertical circulation core (Figure 5.81, and Table 5.11). Once the selected location matches correctly the layout of these spaces, the colour of the corridor turns into blue. Otherwise, the colour remains grey. Designers can change the position, and the width of these corridors, which ranges between 1.15 and 3.00 meters, based on the area and the layout of the building.

Table 5.11: Parameters and conditions for corridors connecting EN, VC, & MPS on the ground floor

| Parameters for Corridors connecting EN, VC, & MPS                      | Domain of Numeric Range (Inputs)   | Type of Input Data |
|--|--|--------------------|
| <b><i>Corridors connected with EN &amp; VC (on Y-axis) (COR.Y)</i></b> |  |                    |
| Alternatives for corridors (COR.Y)                                     | [0] Not applicable<br>[1] Connecting VC & the Eastern edge of MPS<br>[2] Connecting VC & the Western edge of MPS<br>[3] Connecting VC & the Southern edge of MPS<br>[4] Connecting EN & VC<br>[5] Connecting EN & the Southern-East edge of MPS<br>[6] Connecting EN & the Southern-West edge of MPS | Integer            |
| Position of corridors (COR.Y) for alternatives [3], [4], [5], [6]      | Factor, range = (0 to 100)   | Integer            |
| Width of corridors (COR.Y)   | (1.15 to 3.00) meters  | Float number       |
| <b><i>Corridors connected with EN or MPS (on X-axis) (COR.X)</i></b>   |  |                    |
| Alternatives for corridors that are connected with EN                  | [0] Not applicable<br>[1] or [4] on the Eastern edge of EN<br>[2] or [3] on the Western edge of EN   | Integer            |
| Alternatives for corridors that are connected with MPS                 | [0] Not applicable<br>[1] or [4] on the Eastern edge of MPS<br>[2] or [3] on the Western edge of MPS   | Integer            |
| Width of corridors (COR.X)   | (1.15 to 3.00) meters  | Float number       |

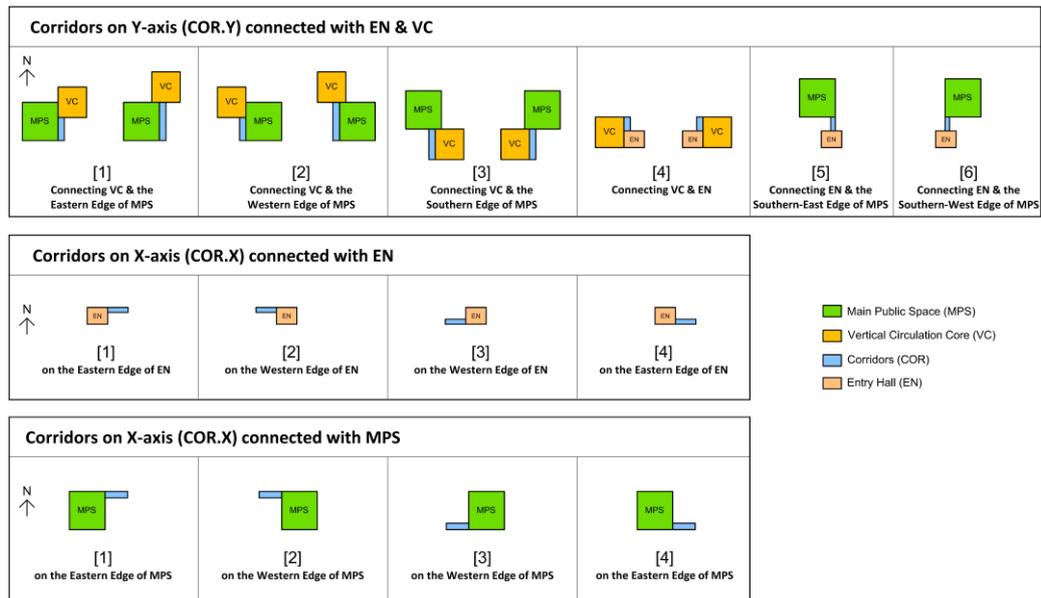


Figure 5.81: Diagrams showing possibilities for the location of corridors that are connected with EN, VC, and MPS

- *Stage (7): Generating Floors and Main Public Spaces for Each Segment of the Building*

As mentioned earlier, the design strategy adopted for translating the horizontal fabric of traditional neighbourhoods into high-rise developments is to split the building into vertical segments. This stage aims to generate these divisions through determining number of floors for each one. Moreover, it allows designers to include a public courtyard on each segment. All main public spaces (MPS) inside the building are connected vertically through a shared open volume located at the corner of these spaces. However, geometric properties of the MPS and voids could be varied according to predefined parameters (Table 5.12). Moreover, the tool offers the opportunity for changing type of connection between the main public space and the external context (Figure 5.82). Thus, flexibility and creativity could be achieved in the design of the building.

For each segment, area of apartments on each floor, its percentage from the area of the floor, and the total area of residential units on each segment are performed automatically for the user.

Table 5.12: Parameters and conditions for floors and main public spaces on each segment of the building

| Parameters for Floors  | Domain of Numeric Range (Inputs)   | Type of Input Data |
|--|--|--------------------|
| <b>Floors on the Ground Floor and the 1<sup>st</sup> Segment of the Building</b>   |  |                    |
| Thickness of slab for all floors   | (0.40 to 0.60) meters  | Float number       |
| Number of floors above the ground floor (1 <sup>st</sup> segment)  | (0), (1), (2), (3), (4)  | Integer            |
| Height of the ground floor   | (2.70 to 4.00) meters  | Float number       |
| Height of each floor on the 1 <sup>st</sup> segment  | (2.70 to 4.00) meters  | Float number       |
| Facades connected with the MPS on the ground floor   | [0] East or West<br>[1] East/West and South<br>[2] East, South, and West<br>[3] South-East or South-West corners | Integer            |
| Facades connected with the MPS on the 1 <sup>st</sup> segment  | [0] East or West<br>[1] East/West and South<br>[2] East, South, and West<br>[3] South-East or South-West corners | Integer            |
| <b>Floors on the 2<sup>nd</sup>, 3<sup>rd</sup>, 4<sup>th</sup>, 5<sup>th</sup>, and 6<sup>th</sup> Segments of the Building</b> |  |                    |
| Number of floors on each segment   | (0), (1), (2), (3), (4), (5)   | Integer            |
| Height of each floor on each segment   | (2.70 to 4.00) meters  | Float number       |
| % of the MPS length relative to the length of MPS on the ground floor  | (50% to 100%)  | Float number       |
| % of void length relative to the length of the MPS on the same segment   | (25% to 50%)   | Float number       |
| Facades connected with the MPS on each segment   | [0] East or West<br>[1] East/West and South<br>[2] East, South, and West<br>[3] South-East or South-West corners | Integer            |

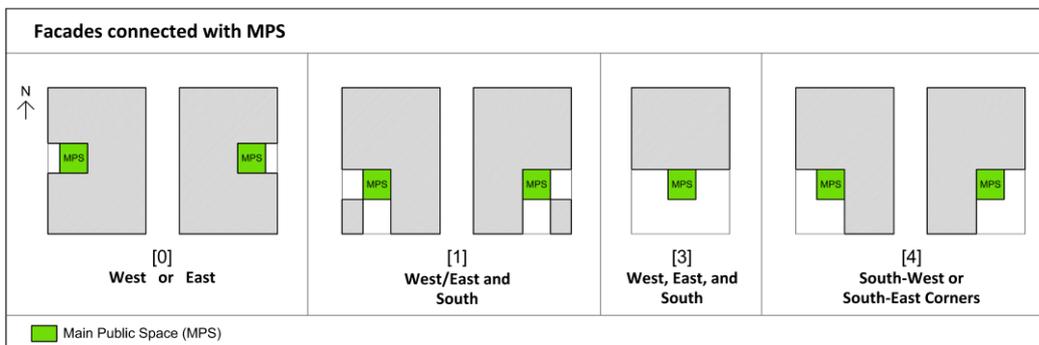


Figure 5.82: Diagrams showing alternative for the connection of the main public space with the outside environment

- Stage (8): Generating Semi-Private Spaces (PVS) between Residential Apartments

Achieving a hierarchical transition from public spaces to private zones, and maintaining the privacy of residents, semi-private spaces are required in front of residential units. This stage allows the generation of such areas. According to the analysis extracted from traditional neighbourhoods, the area of semi-private spaces (PVS) relative to the area of the main public space represents 25% to 35%. Moreover, these spaces could be connected with the main courtyard through corridors. Users can choose the suitable layout of these connections by selecting the number of the alternative (Figure 5.83). Also, they can control length and width of corridors (Table 5.13).

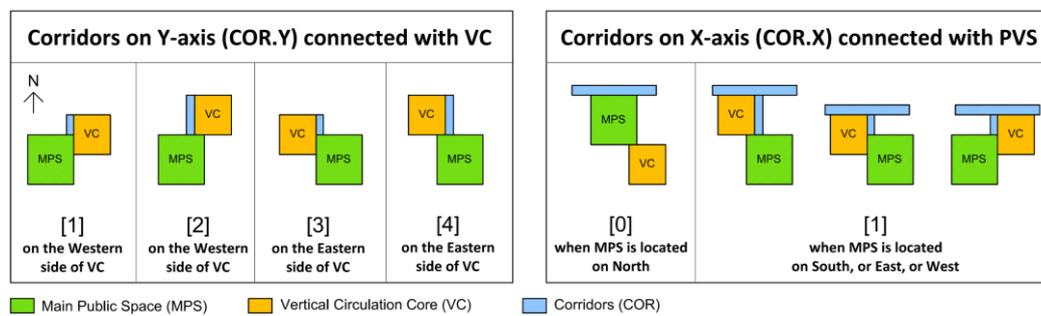


Figure 5.83: Diagrams showing alternatives for the location of corridors that are connected with VC and PVS

Regarding location of semi-private spaces, different possibilities are provided for the user (Figure 5.84). The selection process depends on the applicability of corridors, connected with the PVS, on the X-axis or the Y-axis. However, designers can include more than one semi-private space on each segment. Moreover, they can change the width, the length, and the position along (X) and (Y) axes for each space separately (Table 5.14).

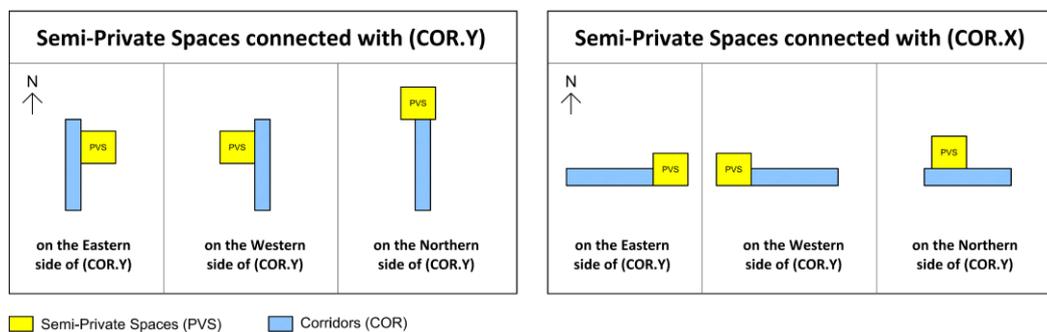


Figure 5.84: Diagrams showing alternative for the location of semi-private spaces (PVS)

Table 5.1: Parameters and conditions for corridors connected with semi-private spaces (PVS)

| Parameters for Corridors connected with Semi-Private Spaces (PVS)           | Domain of Numeric Range (Inputs)   | Type of Input Data |
|---|--|--------------------|
| <b><i>Corridors (on the Y-axis) connecting MPS and VC</i></b>               |  |                    |
| Alternatives for the location of corridors (COR.Y)                          | [0] Not applicable<br>[1] or [2] on the Western side of the VC<br>[3] or [4] on the Eastern side of the VC | Integer            |
| Width of corridors (COR.Y)  | (1.15 to 3.00) meters  | Float number       |
| <b><i>Corridors (on the X-axis) connected with PVS</i></b>                  |  |                    |
| Applicability of corridors (COR.X)  | [0] when MPS is located on North<br>[1] when MPS is located on East, or West or South                      | Integer            |
| Width of corridors (COR.X)  | (1.15 to 3.00) meters  | Float number       |
| Extension of (COR.X) towards West direction:                                |  |                    |
| a. For GF, 1 <sup>st</sup> , 3 <sup>rd</sup> , and 5 <sup>th</sup> segments | Factor, range = (0 to 100)   | Integer            |
| b. For 2 <sup>nd</sup> , 4 <sup>th</sup> , and 6 <sup>th</sup> segments     | Factor, range = (0 to 100)   | Integer            |
| Extension of (COR.X) towards East direction:                                |  |                    |
| a. For GF, 1 <sup>st</sup> , 3 <sup>rd</sup> , and 5 <sup>th</sup> segments | Factor, range = (0 to 100)   | Integer            |
| b. For 2 <sup>nd</sup> , 4 <sup>th</sup> , and 6 <sup>th</sup> segments     | Factor, range = (0 to 100)   | Integer            |
| <b><i>Corridors (on the Y-axis) connected with PVS</i></b>                  |  |                    |
| Width of corridors (COR.Y)  |  |                    |
| Applicability of (COR.Y):   |  |                    |
| a. GF, 1 <sup>st</sup> , 3 <sup>rd</sup> , and 5 <sup>th</sup> segments     | [0] Yes, [1] No  | Integer            |
| b. 2 <sup>nd</sup> , 4 <sup>th</sup> , and 6 <sup>th</sup> segments         | [0] Yes, [1] No  | Integer            |
| Length of (COR.Y):  |  |                    |
| a. GF, 1 <sup>st</sup> , 3 <sup>rd</sup> , and 5 <sup>th</sup> segments     | Factor, range = (0 to 100)   | Integer            |
| b. 2 <sup>nd</sup> , 4 <sup>th</sup> , and 6 <sup>th</sup> segments         | Factor, range = (0 to 100)   | Integer            |
| Position of (COR.Y):  |  |                    |
| a. GF, 1 <sup>st</sup> , 3 <sup>rd</sup> , and 5 <sup>th</sup> segments     | Factor, range = (0 to 100)   | Integer            |
| b. 2 <sup>nd</sup> , 4 <sup>th</sup> , and 6 <sup>th</sup> segments         | Factor, range = (0 to 100)   | Integer            |

Table 5.2: Parameters and conditions for semi-private spaces (PVS)

| Parameters for Semi-Private Spaces (PVS)   | Domain of Numeric Range (Inputs) | Type of Input Data |
|--|----------------------------------|--------------------|
| <i>Semi-private spaces (PVS) on GF, 1<sup>st</sup>, 3<sup>rd</sup>, and 5<sup>th</sup> segments</i>                  |                                  |                    |
| <i>Semi-private spaces (PVS) on 2<sup>nd</sup>, 4<sup>th</sup>, and 6<sup>th</sup> segments</i>                      |                                  |                    |
| <i>When PVS is located on the Eastern side of (COR.X)</i>  |                                  |                    |
| 10. Applicability  | [0] Yes, [1] No                  | Integer            |
| 11. Width  | (2.25 to 5.85) meters            | Float number       |
| 12. Length (*)   | Factor, range = (0 to 100)       | Integer            |
| <i>When PVS is located on the Western side of (COR.X)</i>  |                                  |                    |
| 13. Applicability  | [0] Yes, [1] No                  | Integer            |
| 14. Width  | (2.25 to 5.85) meters            | Float number       |
| 15. Length (*)   | Factor, range = (0 to 100)       | Integer            |
| <i>When PVS is located on the Northern side of the (COR.X)</i>   |                                  |                    |
| 16. Applicability  | [0] Yes, [1] No                  | Integer            |
| 17. Width  | (2.25 to 5.85) meters            | Float number       |
| 18. Length (*)   | Factor, range = (0 to 100)       | Integer            |
| 19. Position along X-axis  | Factor, range = (0 to 100)       | Integer            |
| <i>When PVS is located on the Northern side of the (COR.Y)</i>   |                                  |                    |
| 20. Applicability  | [0] Yes, [1] No                  | Integer            |
| 21. Width  | (2.25 to 5.85) meters            | Float number       |
| 22. Length (*)   | Factor, range = (0 to 100)       | Integer            |
| 23. Position along X-axis  | Factor, range = (0 to 100)       | Integer            |
| <i>When PVS is located on the Eastern side of the (COR.Y)</i>  |                                  |                    |
| 24. Applicability  | [0] Yes, [1] No                  | Integer            |
| 25. Width  | (2.25 to 5.85) meters            | Float number       |
| 26. Length (*)   | Factor, range = (0 to 100)       | Integer            |
| 27. Position along Y-axis  | Factor, range = (0 to 100)       | Integer            |
| <i>When PVS is located on the Western side of the (COR.Y)</i>  |                                  |                    |
| 28. Applicability  | [0] Yes, [1] No                  | Integer            |
| 29. Width  | (2.25 to 5.85) meters            | Float number       |
| 30. Length (*)   | Factor, range = (0 to 100)       | Integer            |
| 31. Position along Y-axis  | Factor, range = (0 to 100)       | Integer            |
| (*) Length is based on the percentage of the PVS area relative to the area of MPS on the ground floor = (25% to 35%) |                                  |                    |

- *Stage (9): Generating the Layout of Residential Apartments*

Parametric modelling has great potential in addressing performative issues concerning measurable criteria (Dino 2012). Exploration of the layout of residential units depends on a 'space partitioning' mechanism (Knecht and Konig 2010). It is about splitting a region into sub-spaces (cells). This geometric representational technique, using non-manifold topology (NMT), defines topological relations between adjacent spaces without any void (Jabi 2016). The process starts with determining lower and upper limits for the area of each apartment by the user (Table 5.15). Two points are allocated on each edge of the layout, and numbered according to their direction (East, West, North, and South). For example, points S1 and S2 are located on the Southern edge of the

layout. Each point represents the start of a partition between two apartments. By moving these points along the X-axis and the Y-axis, the overall layout of residential units will be split into cells, through extending a line from that point to the nearest point on the opposite side of the layout. This process of design exploration could occur by adjusting metric sliders either manually, or automatically using an optimisation algorithm in combination with multi-objective performance criteria.

Table 5.3: Parameters and conditions for the layout of residential units

| Parameters for the layout of residential units on the ground floor and each segment | Values (Inputs)                                 | Type of Input Data |
|---|---|--------------------|
| Minimum area for each apartment (*)   | 70, 90, 100, 110, 140, 180, 220 m <sup>2</sup>  | Integer            |
| Maximum area for each apartment (*)   | 90, 110, 125, 140, 180, 220, 260 m <sup>2</sup> | Integer            |
| Position of divider (S1) on South   | Factor, range = [0 to 100)                      | Float number       |
| Position of divider (S2) on South   | Factor, range = [0 to 100)                      | Float number       |
| Position of divider (N1) on North   | Factor, range = [0 to 100)                      | Float number       |
| Position of divider (N2) on North   | Factor, range = [0 to 100)                      | Float number       |
| Position of divider (E1) on East  | Factor, range = [0 to 100)                      | Float number       |
| Position of divider (E2) on East  | Factor, range = [0 to 100)                      | Float number       |
| Position of divider (W1) on West  | Factor, range = [0 to 100)                      | Float number       |
| Position of divider (W2) on West  | Factor, range = [0 to 100)                      | Float number       |

(\*) These areas are determined according to residents' preferences.

The process of optimisation, processed by 'Galapagos' evolutionary solver component of Grasshopper, is based on genetic algorithm technique that aims to manage a large number of variables for a pre-defined problem (Kitchley and Srivathsan 2014; Renner and Ekárt 2003). This mechanism provides lists of optimal solutions that are not known in advance. Unlike shape grammar, which is a deterministic process, the genetic algorithm needs a fitness measure to be implemented for achieving efficiency that is needed to be maximised or minimised (Narahara and Terzidis 2000). In this case, the area of an individual apartment is selected as a fitness function to be evaluated (Figure 5.85). Once the area of the cell equals a number within the range determined by the user, a grey colour, the word 'true', the area of the apartment, and a number according to its location (East or West) are assigned automatically to the centre point of each cell. If not, a red colour and the word 'false' are appeared (Figure 5.86). However, designers can refine and change the location of each partition, manually, according to their needs. The whole process should be repeated for each segment to generate the layout of residential units.

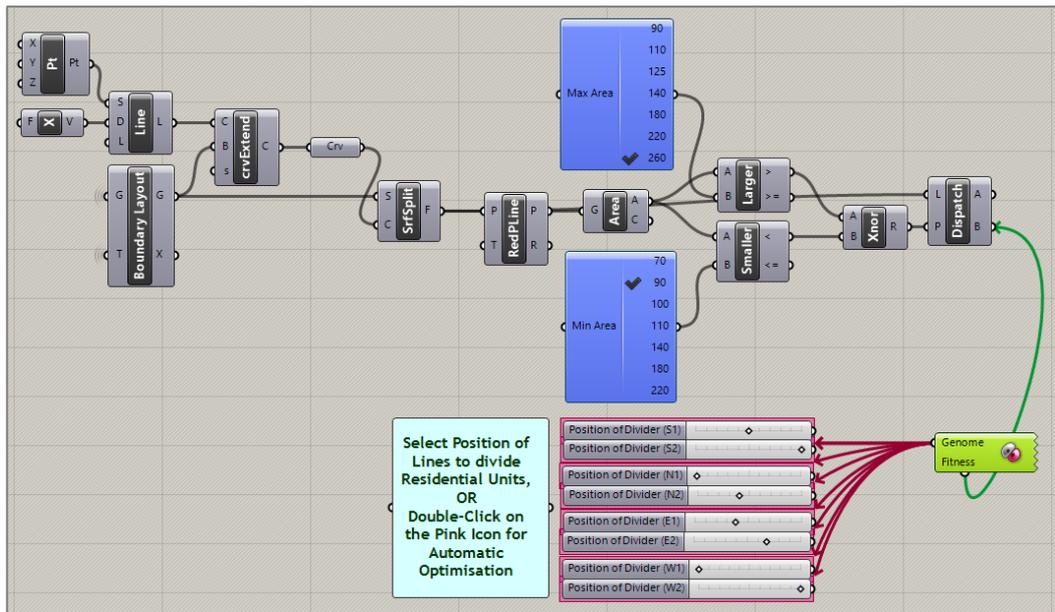


Figure 5.85: Part of the script for generating the layout of residential units

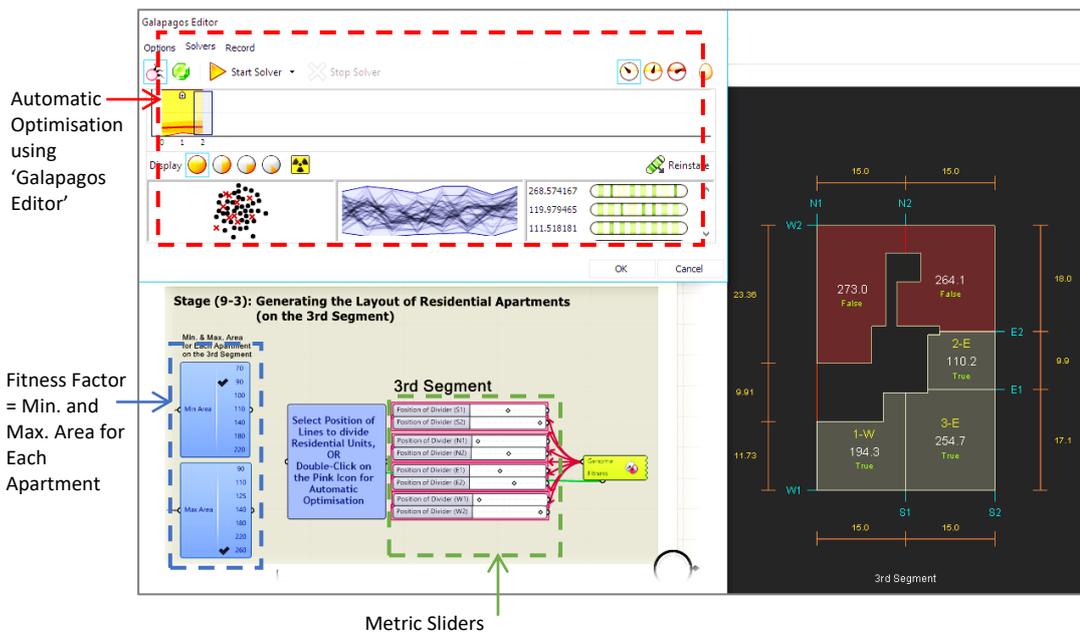


Figure 5.86: A sample for the optimisation process for generating the layout of apartments

- *Stage (10): Generating a Private Courtyard inside Each Apartment*

The final stage corresponds to the generation of a courtyard inside each apartment. Designers could include this space if the area of the residential unit allowed. Each unit has a set of parameters that are grouped and numbered according to its location in the building (i.e. on which segment it is located), and based on the cell number appeared at

the centre of the unit on the two-dimensional layout. Different alternatives for the location of the courtyard could be selected (Figure 5.87). The user can change the width, the length, and the position of each courtyard separately (Table 5.16). However, the width of the courtyard is related to the width of the apartment. This proportion could be ranged between (1 : 0.26) and (1 : 0.51) according to the proportions extracted from traditional houses in MENA region. Moreover, the length of the courtyard is connected with its width according to a predefined proportion, which is ranged between (1 : 0.50) to (1 : 1).

For each apartment, the user can evaluate different outputs for the courtyard, such as area, the percentage of area, and width of rooms surrounding it (Figure 5.88).



Figure 5.87: Diagrams for the location of the courtyard inside a residential unit

Table 5.4: Parameters and conditions for the courtyard inside each apartment

| Parameters for the courtyard inside each apartment  | Values (Inputs)  | Type of Input Data |
|---|--|--------------------|
| Alternatives for the location of the courtyard  | [0] No courtyard<br>[1] on West or East<br>[2] on South<br>[3] at the Center | Integer            |
| Width: based on the proportion of the width of courtyard to the width of the apartment = (0.26 to 0.51) | Factor = (0 to 100)  | Float number       |
| Length: based on the proportion of the width to the length of courtyard = (0.50 to 1.00)                | Factor = (0 to 100)  | Float number       |
| Position along X-axis   | Factor = (0 to 100)  | Float number       |
| Position along Y-axis   | Factor = (0 to 100)  | Float number       |

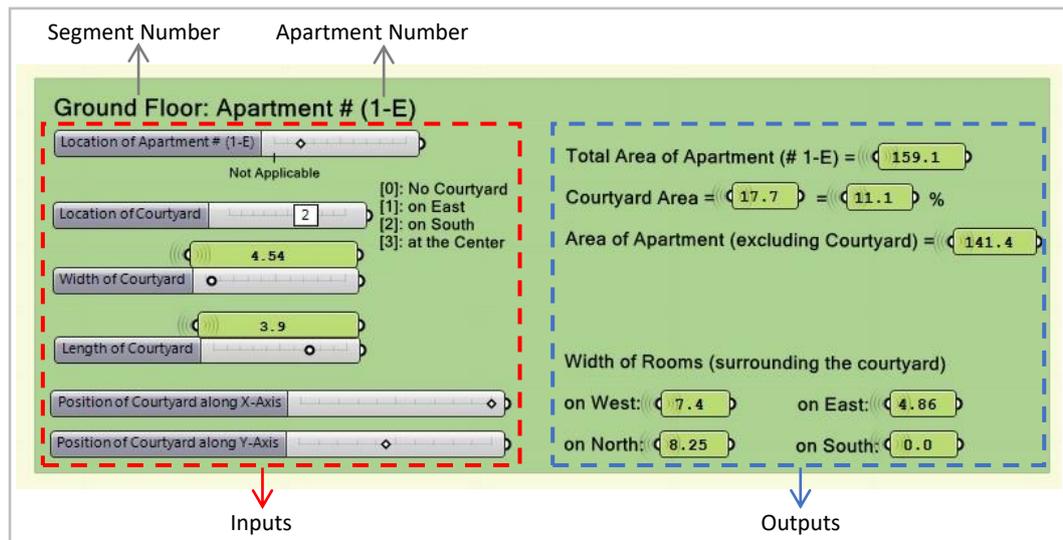


Figure 5.88: Inputs and outputs for generating a courtyard inside a residential unit

## b. Outputs

The tool offers architects the ability to evaluate their designs through two types of outputs: (i) drawings and diagrams; and (ii) design metrics.

### i. Drawings and Diagrams

Three-dimensional views and two-dimensional layouts are produced simultaneously in Rhino3D according to the input data by users. However, these representations are schematic rather than detailed drawings.

Each type of spaces has a distinct layer and colour. Designers can turn on or off these layers based on the type of drawings they need (Figure 5.89). For example, analytical diagrams that include common spaces could be produced by turning off the layer of the layout of residential apartments (Figure 5.90).

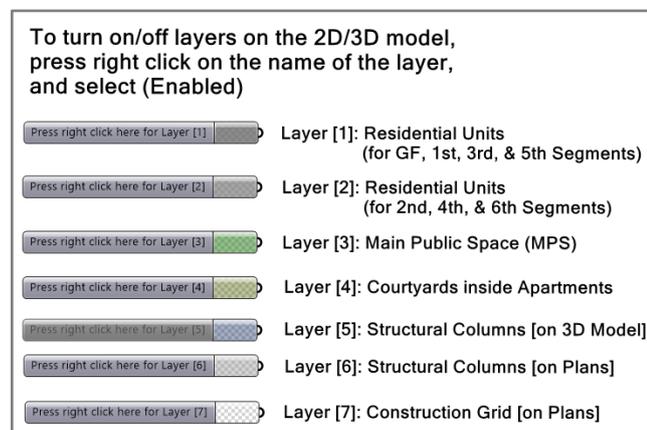


Figure 5.89: Layers of the 2D/3D model



*ii. Design Metrics*

To measure the practicality of any generative tool and the performance of each design solution, it is crucial to offer quantifiable and computable metrics that could be used for the evaluation process (Villaggi *et al.* 2017). Therefore, the tool has been developed to produce different measurements and output values automatically (Figure 5.91). These include:

1. Detailed calculations for the building:
  - Total allowable area for the building (m<sup>2</sup>),
  - Total designed area of the building (m<sup>2</sup>),
  - Total area of common spaces on all floors (m<sup>2</sup>), and its percentage from the total designed area,
  - Total area of residential apartments on all floors (m<sup>2</sup>), and its percentage from the total designed area,
  - Total number of floors,
  - Total height of the building (m),
  - A detailed table showing the calculations mentioned above for each segment.
2. Detailed calculations for residential units:
  - Private courtyards inside apartments:
  - Area of courtyards on each floor, and on each segment
  - Percentage of the area of courtyards from the area of apartments on each floor, and on each segment,
  - Percentage of the area of courtyards from the total area of the floor, the segment, and the building.
  - Area of apartments (including courtyards)
3. Detailed calculations for common spaces (main public spaces, semi-private spaces, the entry hall, the vertical circulation core, and corridors) inside the building. For each type of these space, the following are the output metrics:
  - Area of the space on each floor, and on each segment,
  - Area of the space on all floors of the segment,
  - Percentage of the area from the total area of the floor, and the building.

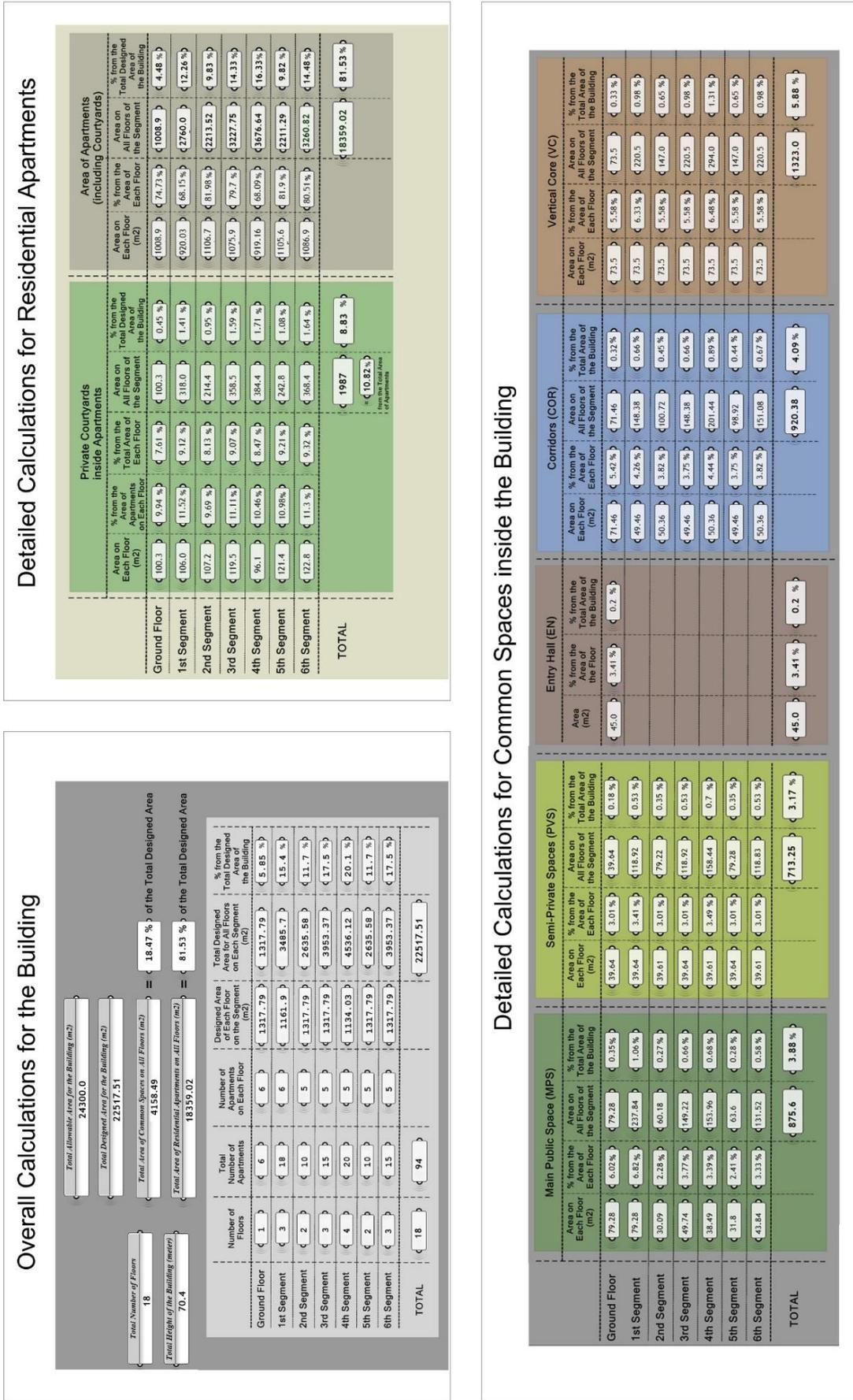


Figure 5.91: A screenshot showing design metrics produced by the tool

## 5.9. Summary

Achieving social sustainability in residential developments requires a holistic approach to clarify spatial qualities that affect the social life inside the building. Information gained from the analytical reasoning process for traditional neighbourhoods in MENA region, combined with technical requirements for high-rise buildings, such as vertical cores, circulation patterns, and structural systems, have been used as a methodology for systematising a set of social and spatial algorithmic relations that inform the location and the geometric properties of each space. Rules that control the social aspects of residential environments, such as the hierarchical system of movement, privacy, and social interaction, have been translated into measurements, and associated with the spatial design of the building.

The proposed computational tool for designing a high-rise residential building, embodied in Rhino/Grasshopper, with the possibility of changing geometric and spatial parameters, offers an alternative method for implementing strategies of social sustainability, and at the same time adds flexibility and creativity to the generation process. Moreover, the model supports the recognition of the design brief that is needed for the design of a high-rise residential building, and considers the specific social and cultural context.

In the next part, different alternatives for high-rise buildings, generated by the tool, will be validated. The target is to examine the efficiency of the tool for the emergence of socially sustainable high-rise residential buildings. Also, the tool will be tested through asking a group of professionals and architecture students to evaluate the practicality of the model in early stages of the design.

## Part (C): The Generation of New Solutions, Validation of Results, and Usability Evaluation for the Tool

### **5.10. Introduction**

The design of a computational tool needs at the final stage a process of testing and usability evaluation. Testing includes the use of the tool for generating different solutions, and then validation of the results, to check the efficiency and reliability of the model, and its ability to achieve the actual need. Usability evaluation concerns with examining clarity, functionality, accessibility, and flexibility of the tool (Easterbrook 2010; Carley 1996; Simon 2013).

This part aims to examine and evaluate the developed computational tool for the emergence of high-rise residential buildings. Two sets of new solutions were produced and evaluated. The first set, which includes five alternatives, was generated by the researcher. These designs were tested against spatial and social qualities. The second set includes alternatives produced by different users through an experimental study. A total of 11 professionals and architecture students from Cardiff University were asked to use the tool for the design of a multi-story residential building. Four solutions from this experimental study; two designed by professionals, and two produced by 3<sup>rd</sup>-year architecture students, were selected randomly, and analysed according to the same process of socio-spatial analysis.

Finally, a usability evaluation, which assesses the efficiency of the tool in the early stage of design, has been conducted through distributing a questionnaire to the same sample of participants.

### **5.11. Using the Computational Tool for Generating New Solutions**

The developed tool was run by the researcher to check its credibility for generating socially sustainable high-rise alternatives. Five different solutions were produced. To examine the flexibility of the system, all cases have the same size of the overall layout (30 m x 45 m). Moreover, the total height and number of floors on each segment are fixed parameters for all solutions (see Table 5.17).

Table 5.17: Fixed geometric parameters for all cases

| Aspects of Design                                      | Fixed Parameters for All Solutions   |
|--|--|
| Dimensions of the ground floor                         | Width = 30 meters, Length = 45 meters  |
| Total height   | 70.4 meters  |
| Total number of floors                                 | 18 floors  |
| Total allowable area for the building                  | 24,300 m <sup>2</sup>  |
| Number of floors in each segment:                      |  |
| - 1 <sup>st</sup> segment (including the ground floor) | 4 floors   |
| - 2 <sup>nd</sup> segment                              | 2 floors   |
| - 3 <sup>rd</sup> segment                              | 3 floors   |
| - 4 <sup>th</sup> segment                              | 4 floors   |
| - 5 <sup>th</sup> segment                              | 2 floors   |
| - 6 <sup>th</sup> segment                              | 3 floors   |
| Height of each floor                                   | 4.0 m (GF), 2.8 m (1 <sup>st</sup> segment),<br>3.5 m (2 <sup>nd</sup> , 3 <sup>rd</sup> , 4 <sup>th</sup> , 5 <sup>th</sup> , 6 <sup>th</sup> segments) |

All solutions have the same type of common spaces. However, different dimensions and locations were assigned to these spaces (Table 5.18, and Figure 5.92). Such a strategy aims to test effects of the spatial design on the different aspects of social sustainability. For instance, variations in the movement system from the entry hall towards residential units could affect the visual privacy of families. Moreover, changes on the arrangement of common spaces could have impacts on integration and connectivity values for these areas. Differences in the area of main public spaces and semi-private areas could affect the economic value of the building.

To generate the layout of residential units, minimum and maximum areas for each apartment were defined as 70 m<sup>2</sup> and 260 m<sup>2</sup>, respectively. These numbers are fixed for all segments and for all cases. The following figures (5.93, 5.94, 5.95, 5.96, and 5.97) show the layout of each segment for the different alternative, in addition to three-dimensional views for the building.

Table 5.18: Variations in parameters for common spaces

| Common Spaces                                     | Parameters                     | Case (1)               | Case (2)   | Case (3)   | Case (4)   | Case (5)   |
|---|--------------------------------|------------------------|------------|------------|------------|------------|
| Main Entry Hall (EN)                              |                                |                        |            |            |            |            |
|   | Width                          | 6.00 m (for all cases) |            |            |            |            |
|   | Length                         | 7.50 m (for all cases) |            |            |            |            |
|   | Location                       | South                  | South      | South      | South      | South-West |
| Vertical Circulation Core (VC)                    |                                |                        |            |            |            |            |
|   | Width                          | 7.50 m (for all cases) |            |            |            |            |
|   | Length                         | 9.80 m (for all cases) |            |            |            |            |
|   | Location                       | Centre                 | West       | South-West | Centre     | South      |
| Corridors   |                                |                        |            |            |            |            |
|   | Width                          | 2.00 m (for all cases) |            |            |            |            |
| Main Public Space (MPS)                           |                                |                        |            |            |            |            |
| - All segments                                    | Width                          | 8.00 m                 | 9.00 m     | 8.00 m     | 9.00 m     | 8.00 m     |
| - Ground floor and 1 <sup>st</sup> segment        | Length                         | 9.91 m                 | 10.20 m    | 10.12 m    | 7.50 m     | 10.12 m    |
|   | Location (in relation to VC)   | West                   | South      | North-West | North-East | North-West |
|   | Connections (GF)               | West                   | South-West | West       | East       | South-West |
|   | Connections (1 <sup>st</sup> ) | South-West             | South      | South-West | East       | South-West |
| - 2 <sup>nd</sup> segment                         | Length                         | 5.95 m                 | 6.12 m     | 6.07 m     | 7.50 m     | 10.12 m    |
|   | Connections                    | West                   | -          | West       | East       | West       |
| - 3 <sup>rd</sup> segment                         | Length                         | 9.91 m                 | 10.20 m    | 10.12 m    | 7.50 m     | 10.12 m    |
|   | Connections                    | West                   | -          | West       | East       | West       |
| - 4 <sup>th</sup> segment                         | Length                         | 7.43 m                 | 10.20 m    | 7.59 m     | 7.50 m     | 7.59 m     |
|   | Connections                    | South-West             | South-East | South-West | East       | South-West |
| - 5 <sup>th</sup> segment                         | Length                         | 6.19 m                 | 10.20 m    | 6.32 m     | 7.50 m     | 10.12 m    |
|   | Connections                    | West                   | South      | West       | East       | West       |
| - 6 <sup>th</sup> segment                         | Length                         | 8.42 m                 | 8.67 m     | 7.59 m     | 7.50 m     | 10.12 m    |
|   | Connections                    | West                   | -          | West       | East       | West       |
| Semi-Private Space (PVS) # 1                      |                                |                        |            |            |            |            |
| Ground floor, 1 <sup>st</sup> segment,            | Width                          | 4.56 m                 | 4.56 m     | 4.56 m     | 3.50 m     | 4.56 m     |
|   | Length                         | 4.35 m                 | 5.03 m     | 4.44 m     | 4.82 m     | 4.44 m     |
| 3 <sup>rd</sup> segment, 5 <sup>th</sup> segment  | Location                       | East                   | East       | East       | North      | East       |
| 2 <sup>nd</sup> segment, 4 <sup>th</sup> segment, | Width                          | 4.50 m                 | 4.50 m     | 5.00 m     | 4.00 m     | 4.50 m     |
|   | Length                         | 4.40 m                 | 5.10 m     | 4.05 m     | 4.22 m     | 4.50 m     |
| 6 <sup>th</sup> segment                           | Location                       | East                   | East       | North-East | West       | East       |
| Semi-Private Space (PVS) # 2                      |                                |                        |            |            |            |            |
| Ground floor, 1 <sup>st</sup> segment,            | Width                          | 4.05 m                 | 4.50 m     | 4.05 m     | -          | 4.05 m     |
|   | Length                         | 4.89 m                 | 5.10 m     | 5.00 m     | -          | 5.00 m     |
| 3 <sup>rd</sup> segment, 5 <sup>th</sup> segment  | Location                       | North                  | North-West | North      | -          | North      |
| 2 <sup>nd</sup> segment, 4 <sup>th</sup> segment, | Width                          | 5.31 m                 | -          | -          | 4.80 m     | 5.00 m     |
|   | Length                         | 3.73 m                 | -          | -          | 3.52 m     | 4.18 m     |
| 6 <sup>th</sup> segment                           | Location                       | North-West             | -          | -          | North      | North-East |



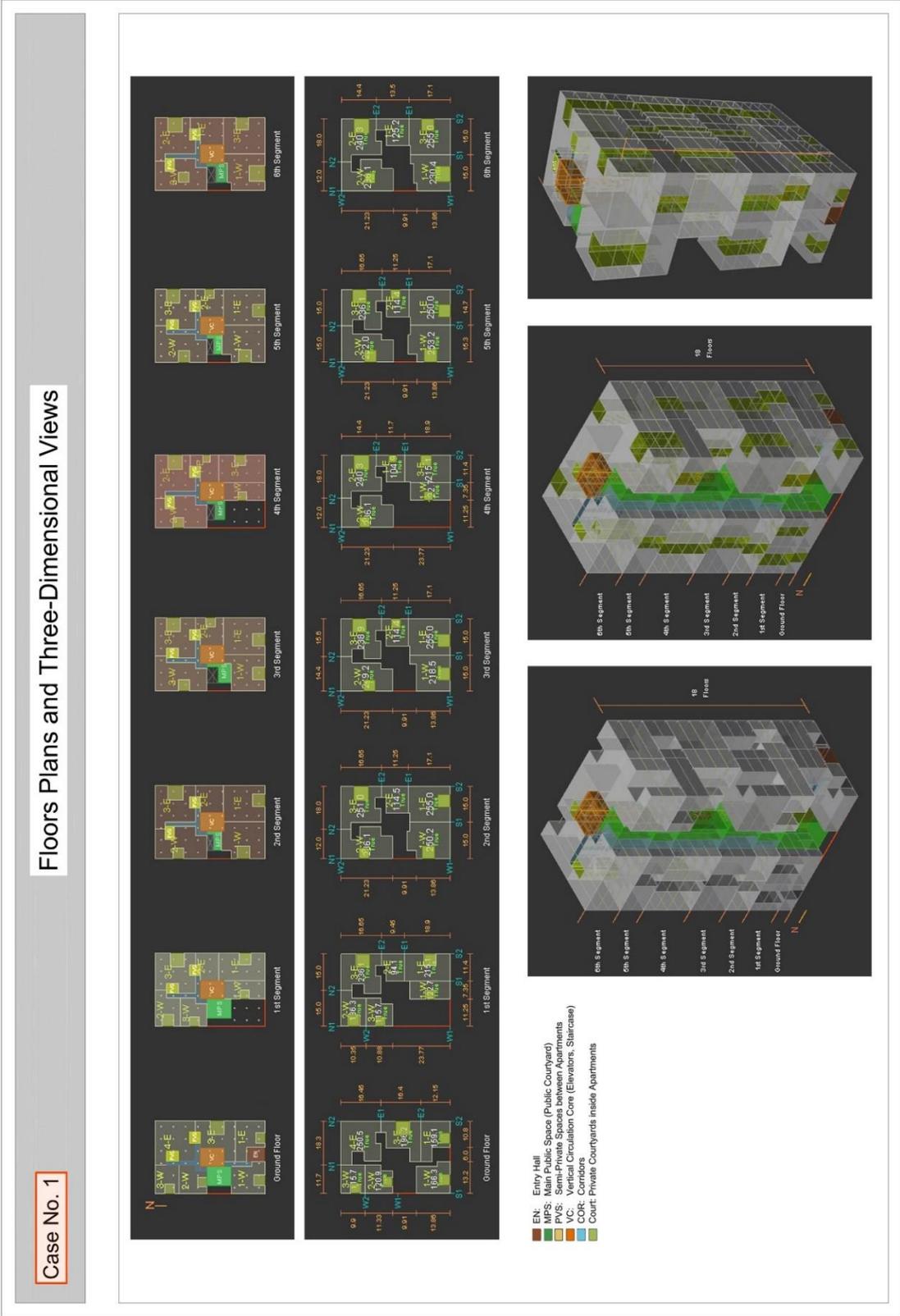


Figure 5.93: Three-dimensional views and the layout of the different segments for Case # 1

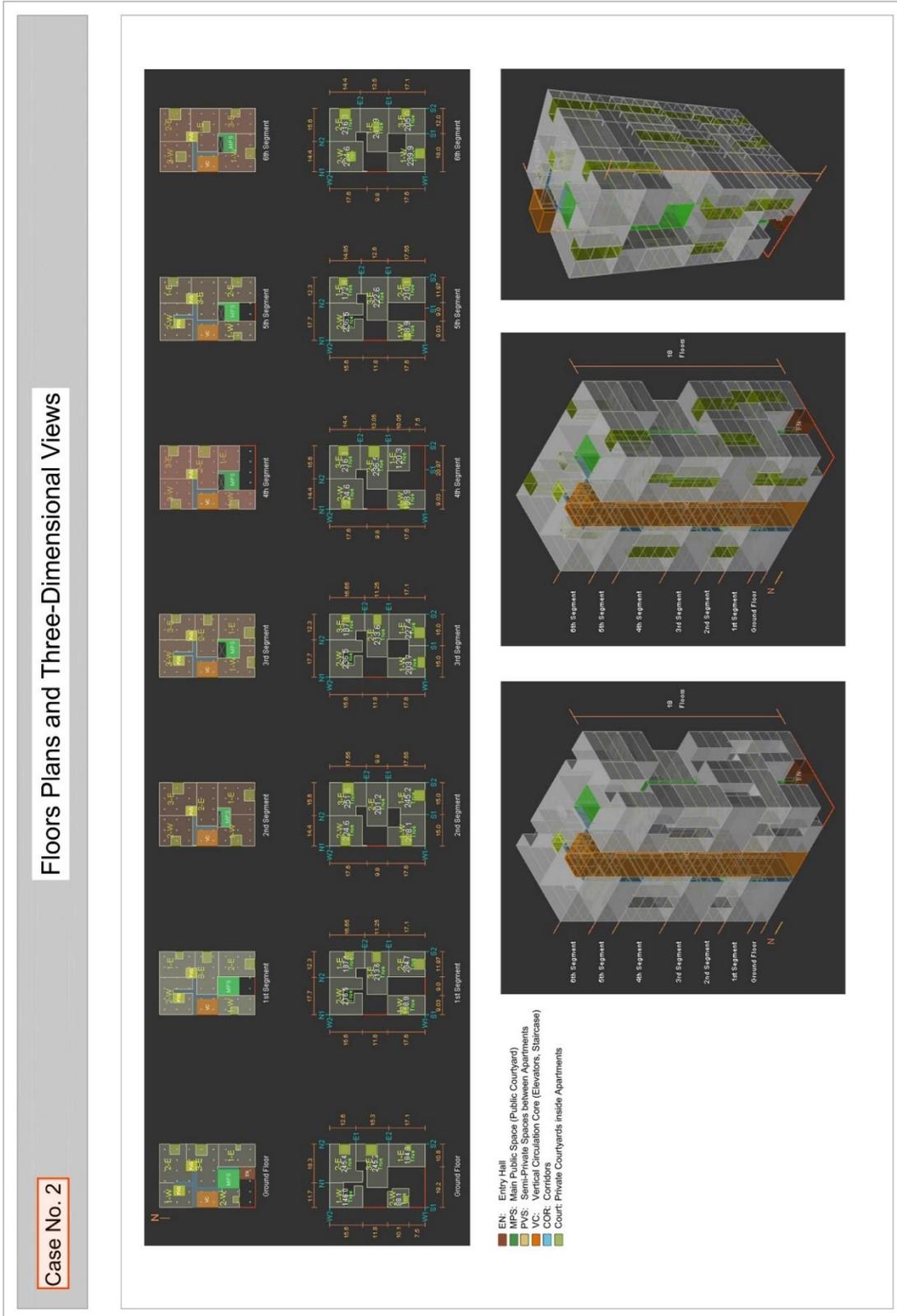


Figure 5.94: Three-dimensional views and the layout of the different segments for Case # 2

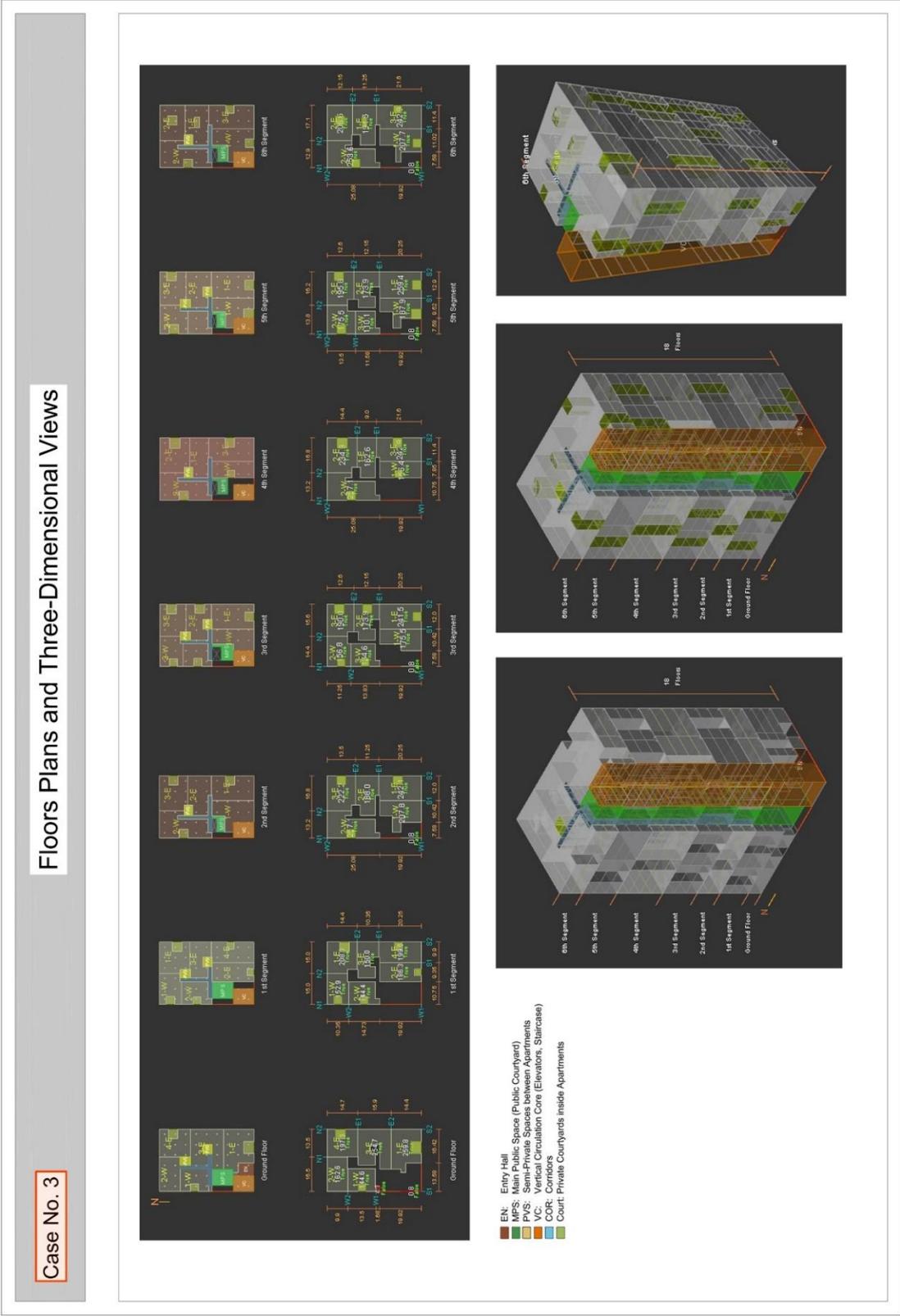


Figure 5.95: Three-dimensional views and the layout of the different segments for Case # 3

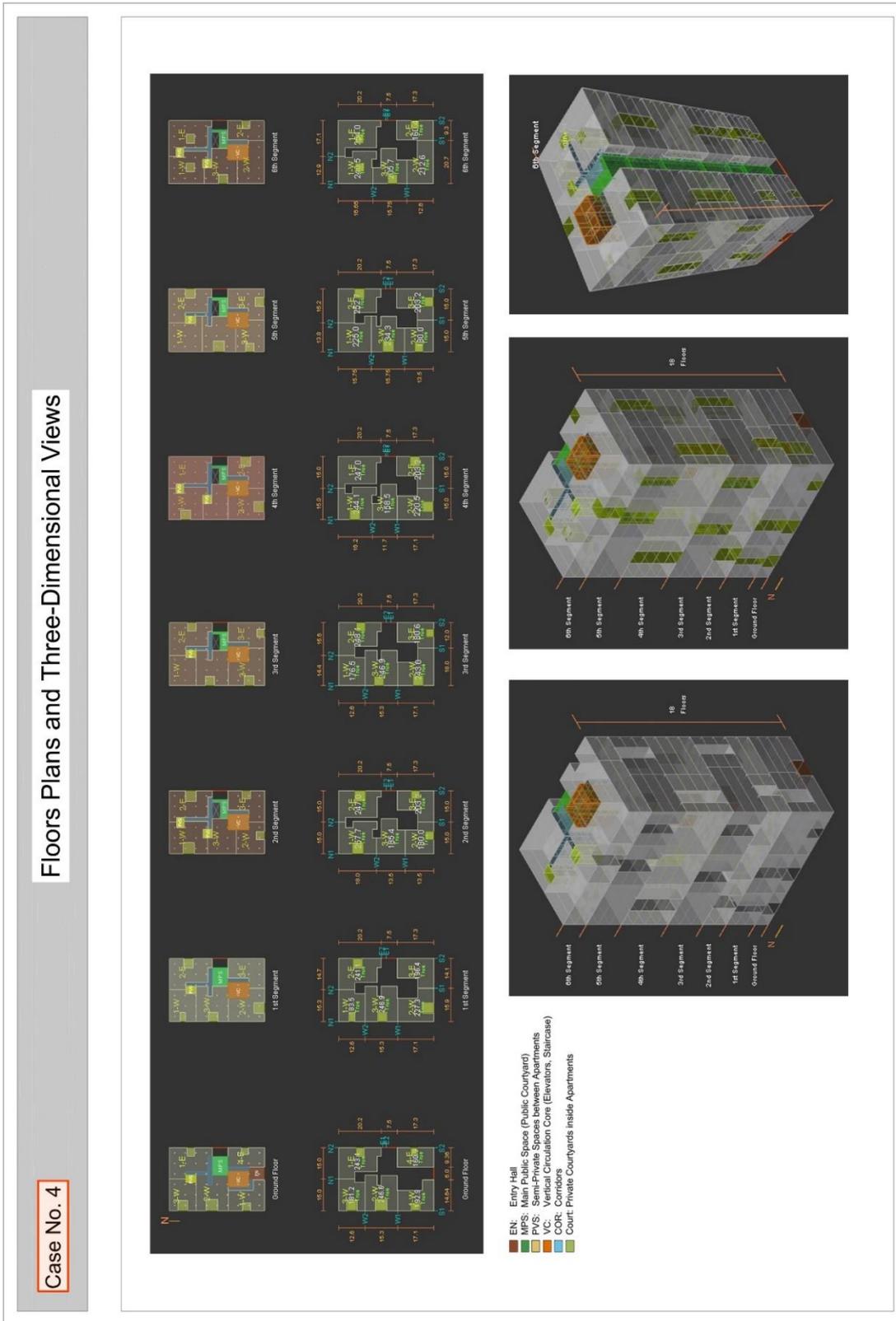


Figure 5.96: Three-dimensional views and the layout of the different segments for Case # 4

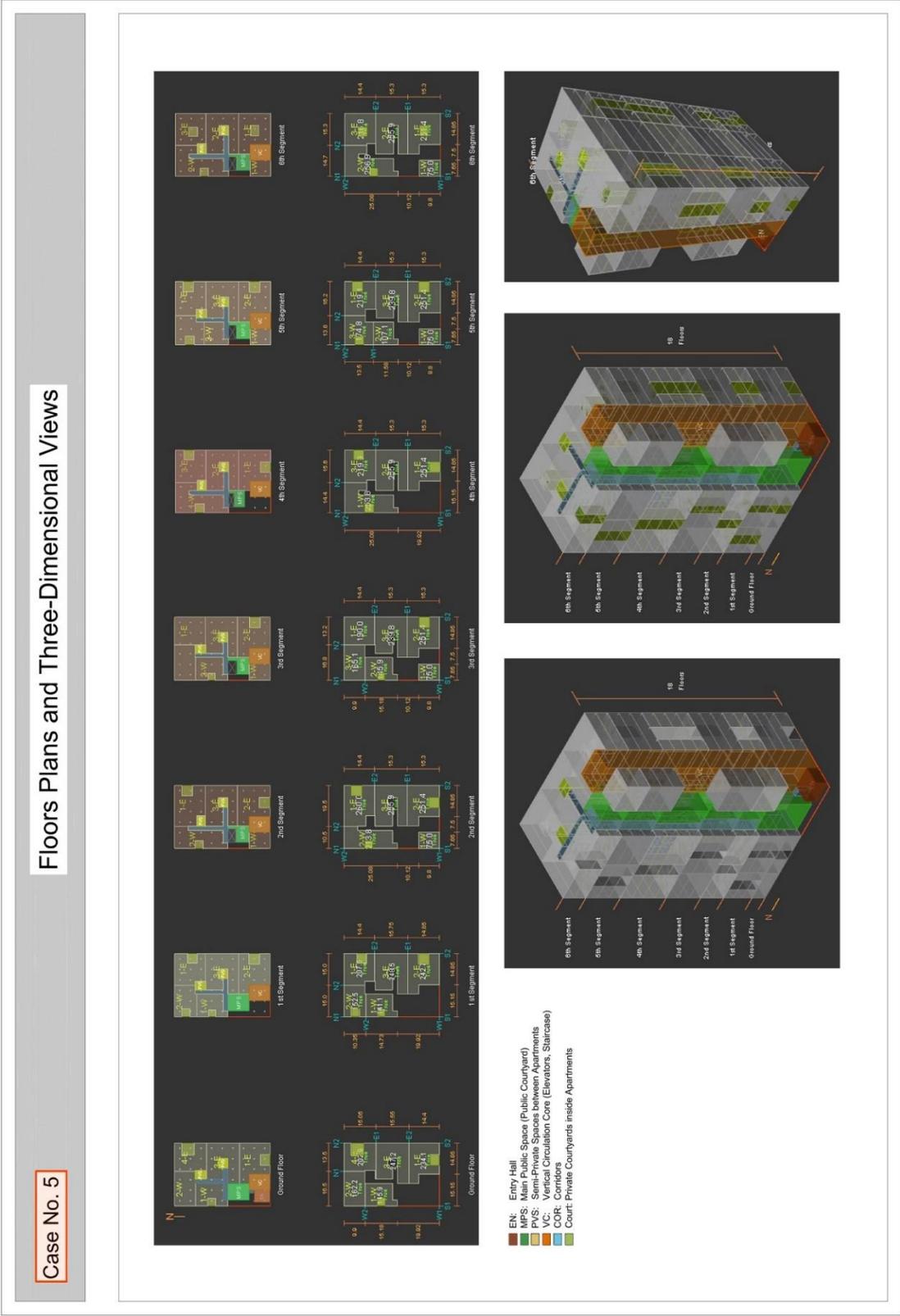


Figure 5.97: Three-dimensional views and the layout of the different segments for Case # 5

## 5.12. Evaluating Design Qualities of New Solutions

The different layouts of the five alternatives have been analysed spatially to evaluate social, environmental and economic qualities of the design.

### 5.12.1. Social Qualities

A detailed spatial-syntactical analysis was conducted for the five cases. Three segments from each building; including the ground floor, the 6<sup>th</sup> segment, and a randomly-selected in-between segment, were evaluated against seven social indicators. These aspects were selected as they represent the most critical issues in current high-rise residential buildings.

- Social Indicator (1): Population Density and Crowding.
- Social Indicator (2): Hierarchy of spaces.
- Social Indicator (3): Social interaction.
- Social Indicator (5): Accessibility.
- Social Indicator (6): Visual privacy.
- Social Indicator (10): Security and Safety.
- Social Indicator (11): Views to the Exterior.

Two types of analysis were used to explore these qualities:

- a. *Isovist* analysis that addresses the visual fields of a person from the centre of each common area inside the building, and along the movement path that links these spaces together. This test explores the visual privacy between public and private zones, which is a major indicator of social sustainability in residential buildings.
- b. *A Visibility Graph Analysis (VGA)* that investigates the spatial configuration of the interior environment through conducting:
  - Connectivity analysis for common areas, which creates visibility connections between these spaces to evaluate the hierarchical arrangement of public and semi-public zones.
  - Integration analysis, which specifies the degree of integration between common areas and apartments.
  - Agent analysis, which indicates patterns of movement and the frequent use of spaces released from the centre of each common area.

Figures (5.98, 5.99, and 5.100) show these two types of analysis for the ground floor, a typical floor on the 1<sup>st</sup> segment, and a typical floor on the 6<sup>th</sup> segment for (Case # 1). Detailed spatial analysis for each case is included in (Volume 2 - Appendix (5-C-1)).

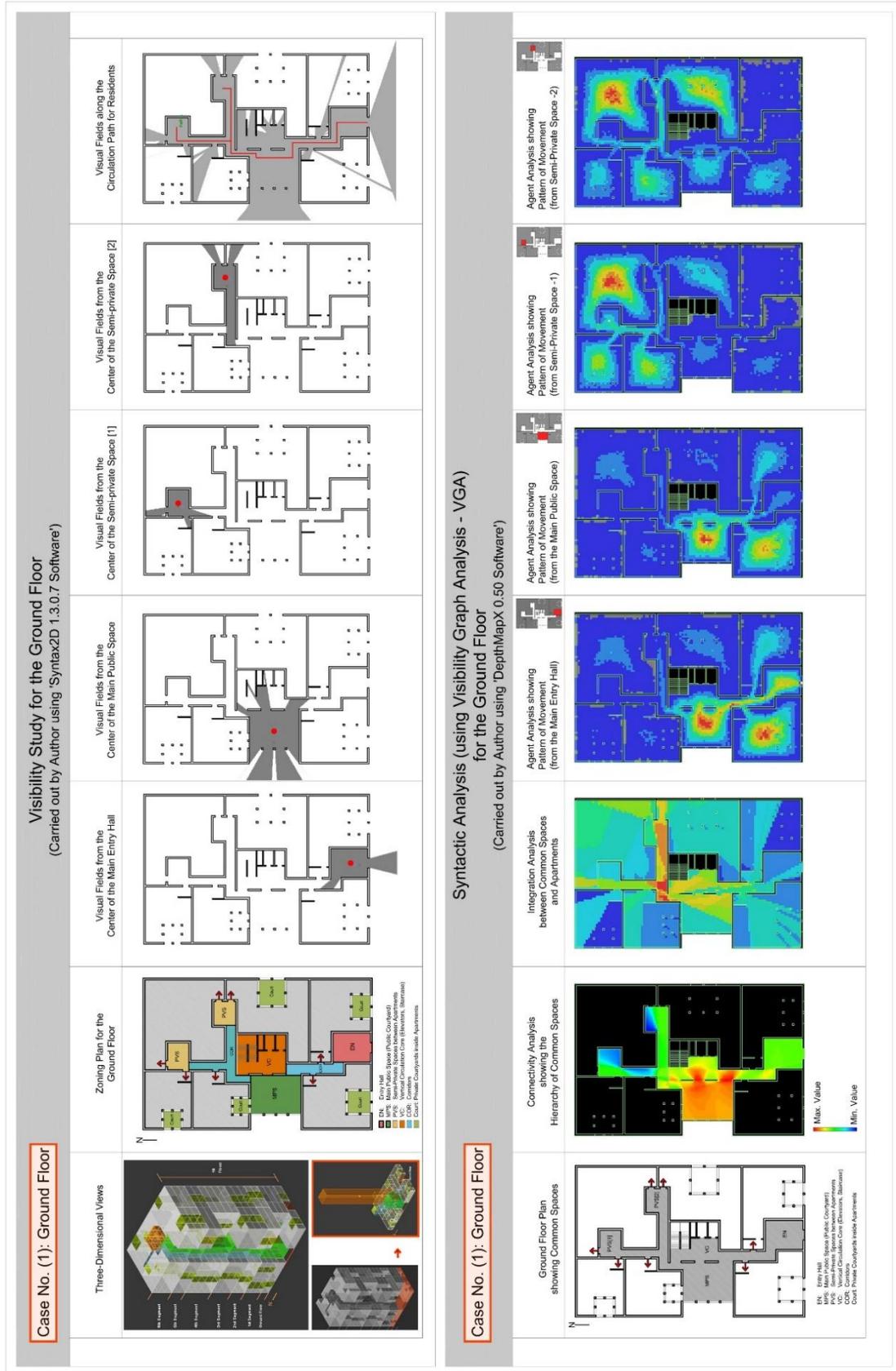


Figure 5.98: Visibility study and syntactic analysis for the ground floor for Case # 1

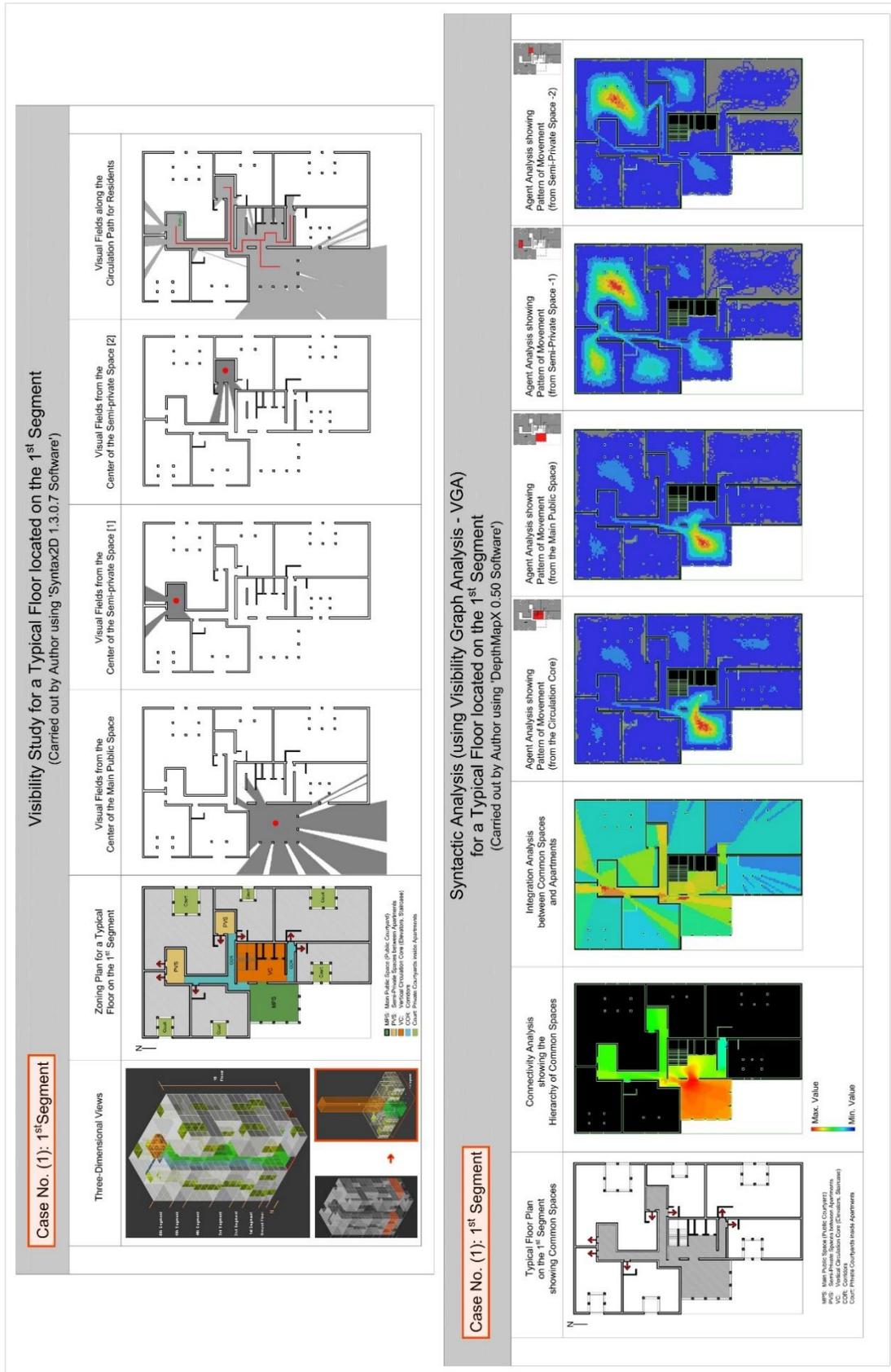


Figure 5.99: Visibility study and syntactic analysis for a typical floor on the 1<sup>st</sup> segment for Case # 1

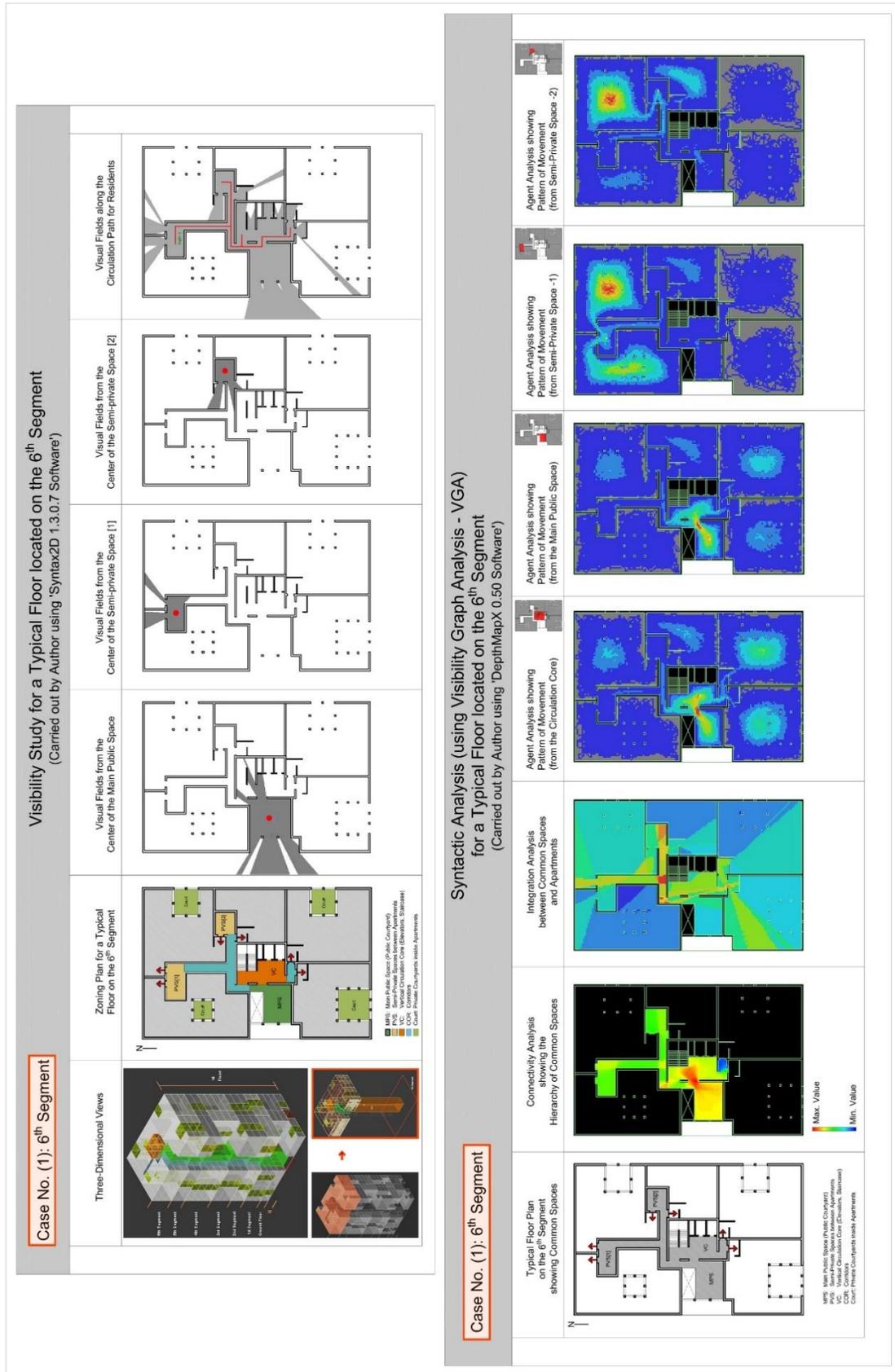


Figure 5.100: Visibility study and syntactic analysis for a typical floor on the 6<sup>th</sup> segment for Case # 1

- *Social Indicator (2): Hierarchy of Spaces*

The tool suggests different alternatives for the location of common spaces. However, the design of the script offers a guarantee for the designer to arrange these spaces in a hierarchical system from public to semi-private to private zones. The syntactic analysis for all cases showed that the main public space (MPS), the entry hall (EN), and the vertical circulation core (VC) have great connectivity values in comparison to semi-private transitional areas, which are connected directly with residential units (Table 5.19). These values are ranged between (10.17 and 13.17) for main public spaces, and between (3.00 and 3.55) for semi-private spaces on the ground floor (Table 5.20).

Table 5.19: Hierarchy of common spaces based on connectivity values

| Cases    | No. of Segment          | Hierarchy of Common Spaces based on Connectivity Values |
|----------|-------------------------|---|
| Case # 1 | Ground Floor            | VC > MPS > PVS-2. > EN > PVS-1.                         |
|          | 1 <sup>st</sup> Segment | MPS > VC > PVS-2. > PVS-1.                              |
|          | 6 <sup>th</sup> Segment | MPS > VC > PVS-1. > PVS-2.                              |
| Case # 2 | Ground Floor            | MPS > EN > VC > PVS-2. > PVS-1.                         |
|          | 4 <sup>th</sup> Segment | MPS > VC > PVS-1.                                       |
|          | 6 <sup>th</sup> Segment | MPS > VC > PVS-1.                                       |
| Case # 3 | Ground Floor            | MPS > EN > PVS-2. > VC > PVS-1.                         |
|          | 1 <sup>st</sup> Segment | MPS > VC > PVS-2. > PVS-1.                              |
|          | 6 <sup>th</sup> Segment | MPS > VC > PVS-1.                                       |
| Case # 4 | Ground Floor            | MPS > EN > VC > PVS-1.                                  |
|          | 5 <sup>th</sup> Segment | MPS > VC > PVS-1.                                       |
|          | 6 <sup>th</sup> Segment | MPS > VC > PVS-2. > PVS-1.                              |
| Case # 5 | Ground Floor            | MPS > EN > VC > PVS-2. > PVS-1.                         |
|          | 1 <sup>st</sup> Segment | MPS > VC > PVS-2. > PVS-1.                              |
|          | 6 <sup>th</sup> Segment | MPS > VC > PVS-2. > PVS-1.                              |

Key: MPS: Main Public Space, PVS-1: Semi-Private Space (#1), EN: Entry Hall  
VC: Vertical Circulation Core, PVS-2: Semi-Private Space (#2)

Table 5.20: Connectivity values for common spaces

| Cases    | No. of Segment          | Connectivity Values for Common Spaces |                       |                 |                            |                            |
|----------|-------------------------|---------------------------------------|-----------------------|-----------------|----------------------------|----------------------------|
|          |                         | Main Public Space (MPS)               | Circulation Core (VC) | Entry Hall (EN) | Semi-Private Space (PVS-1) | Semi-Private Space (PVS-2) |
| Case # 1 | Ground Floor            | 10.17                                 | 11.21                 | 6.13            | 3.53                       | 7.64                       |
|          | 1 <sup>st</sup> Segment | 10.38                                 | 5.84                  | -               | 2.91                       | 3.36                       |
|          | 6 <sup>th</sup> Segment | 5.38                                  | 4.73                  | -               | 2.82                       | 2.67                       |
| Case # 2 | Ground Floor            | 13.17                                 | 4.96                  | 9.48            | 3.55                       | 4.79                       |
|          | 4 <sup>th</sup> Segment | 7.73                                  | 4.28                  | -               | 3.74                       | -                          |
|          | 6 <sup>th</sup> Segment | 7.71                                  | 4.33                  | -               | 3.67                       | -                          |
| Case # 3 | Ground Floor            | 12.63                                 | 5.58                  | 8.41            | 3.18                       | 5.99                       |
|          | 1 <sup>st</sup> Segment | 12.61                                 | 9.83                  | -               | 3.12                       | 6.02                       |
|          | 6 <sup>th</sup> Segment | 8.29                                  | 6.24                  | -               | 3.03                       | -                          |
| Case # 4 | Ground Floor            | 11.68                                 | 8.06                  | 8.40            | 3.11                       | -                          |
|          | 5 <sup>th</sup> Segment | 5.87                                  | 4.59                  | -               | 3.00                       | -                          |
|          | 6 <sup>th</sup> Segment | 5.86                                  | 4.08                  | -               | 2.43                       | 3.06                       |
| Case # 5 | Ground Floor            | 12.31                                 | 5.57                  | 7.65            | 3.00                       | 3.45                       |
|          | 1 <sup>st</sup> Segment | 12.88                                 | 9.08                  | -               | 3.04                       | 4.30                       |
|          | 6 <sup>th</sup> Segment | 13.05                                 | 10.39                 | -               | 3.14                       | 4.51                       |

Key: The highest connectivity value ..... The lowest connectivity value

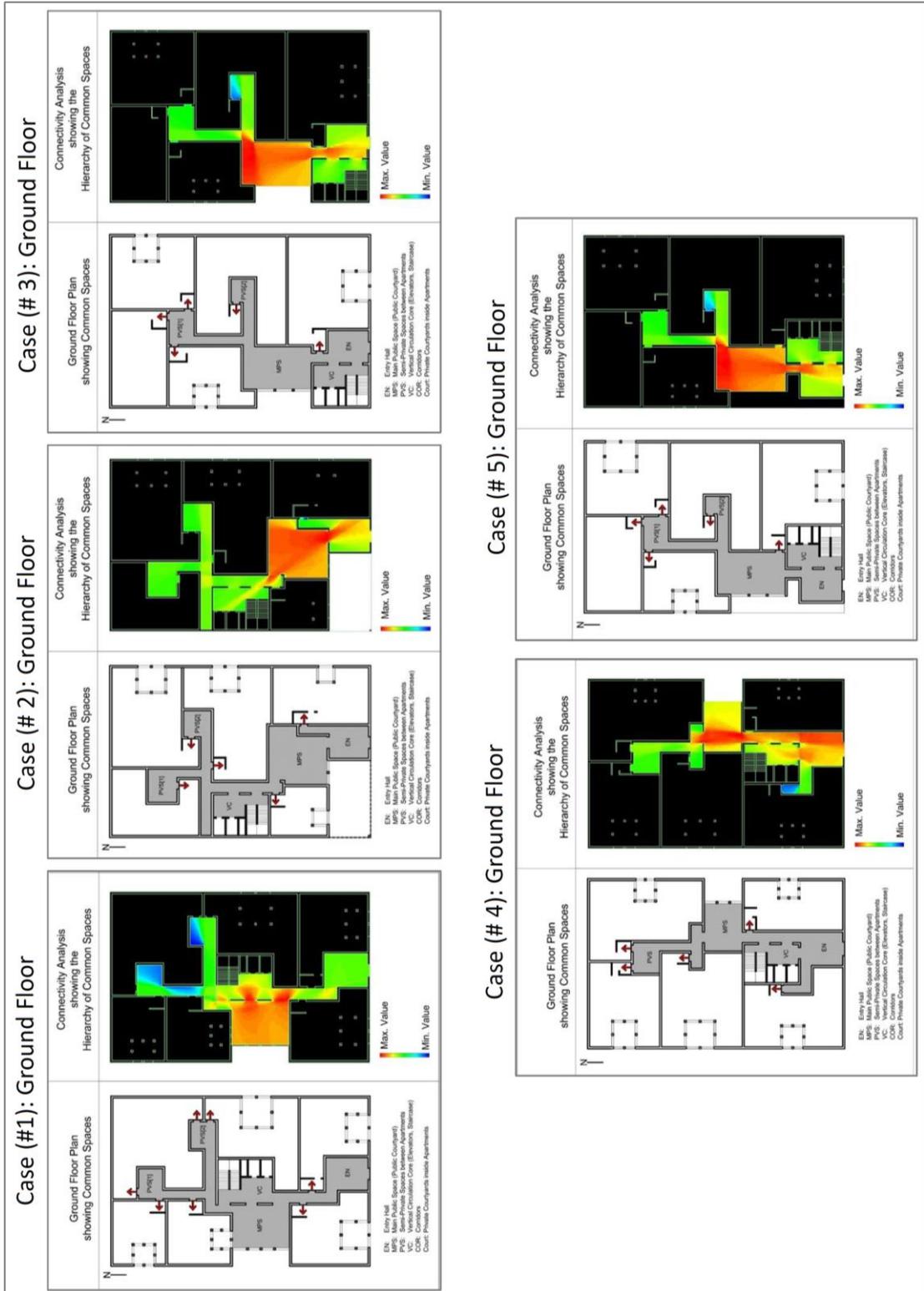


Figure 5.11: Connectivity analysis showing hierarchy of common spaces on the ground floor for the five cases

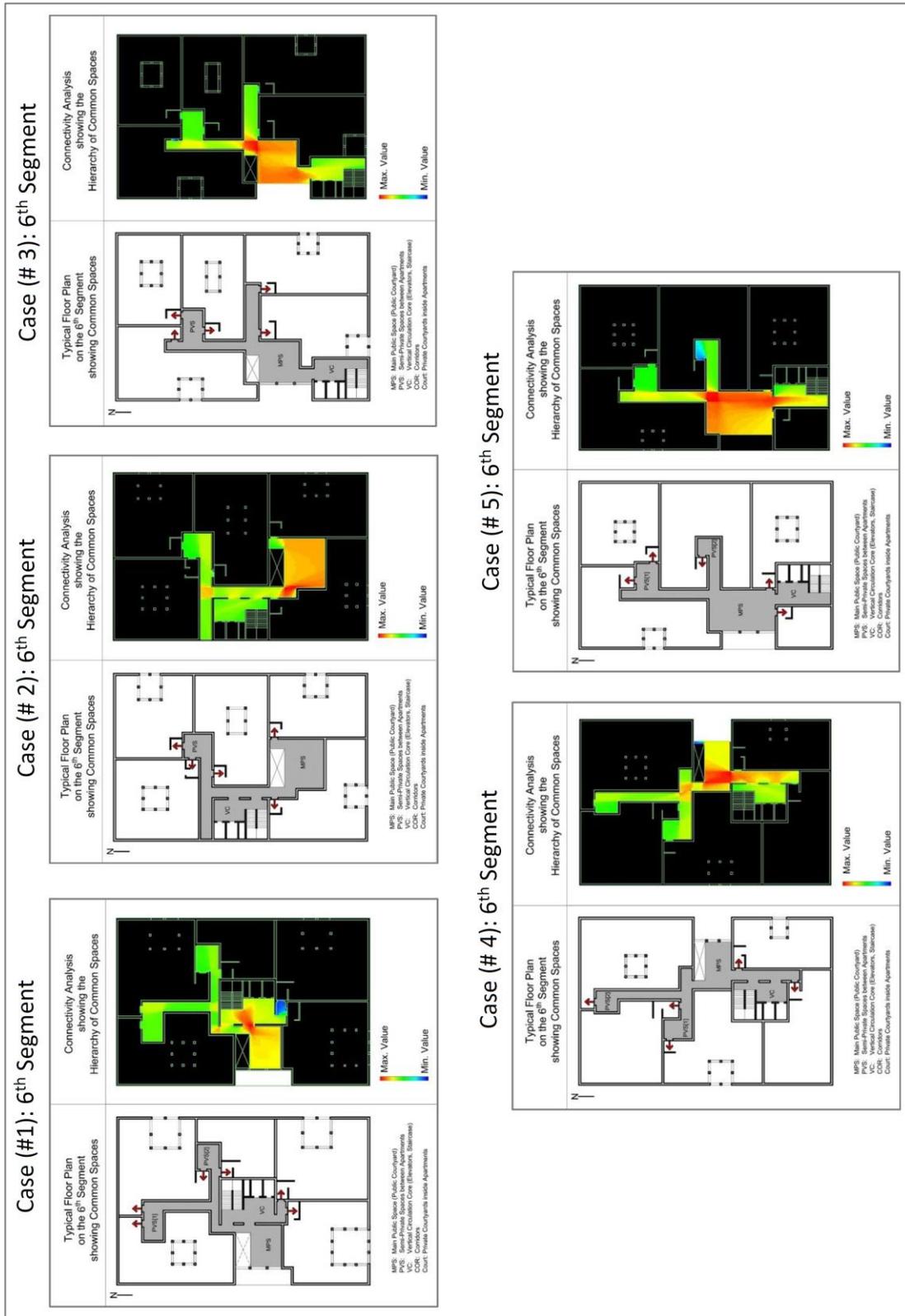


Figure 5.102: Connectivity analysis showing hierarchy of common spaces on a typical floor on the 6<sup>th</sup> segment for the five cases

As illustrated in (Figures 5.101 and 5.102), spaces that are in red/orange colours have great connectivity values, which means that these areas are more public. In contrast, the blue colour indicates lower values of connectivity and more privacy for spaces. Transitional areas, such as the entry hall and corridors, which are in green colour, have moderate values as they connect public and semi-private zones.

Regarding the hierarchical movement from common areas to apartments, the integration analysis showed that public and semi-private spaces in most cases have higher values than residential units (Table 5.21). For instance, integration values for the main public space, the vertical circulation core, the semi-private space, and the entry hall for the ground floor in (Case # 4) are 4.07, 4.08, 3.85, and 3.61, respectively (Table 5.22). In contrast, residential units on the same floor have lower values, which are ranged between 2.38 and 3.44. In this way, a high degree of privacy for families could be achieved (Figures 5.103 and 5.104).

Table 5.21: Hierarchy of spaces based on integration values

| Cases    | No. of Segment          | Hierarchy of Spaces based on Integration Values             |
|----------|-------------------------|---|
| Case # 1 | Ground Floor            | VC > MPS > PVS-2 > AP. 1+2+3 > PVS-1 > AP. 4+5 > EN > AP. 6 |
|          | 1 <sup>st</sup> Segment | VC > PVS-1 > MPS > PVS-2 > AP. 1+2+3+4+5+6                  |
|          | 6 <sup>th</sup> Segment | VC > PVS-2 > PVS-1 > AP.1+2 > MPS > AP. 3+4+5               |
| Case # 2 | Ground Floor            | PVS-2 > MPS > PVS-1 > VC > AP. 1+2 > EN > AP. 3+4+5         |
|          | 4 <sup>th</sup> Segment | PVS-1 > MPS > AP. 1+2 > VC > AP. 3+4+5                      |
|          | 6 <sup>th</sup> Segment | PVS-1 > MPS > VC > AP. 1+2+3+4+5                            |
| Case # 3 | Ground Floor            | PVS-2 > PVS-1 > MPS > EN > AP.1 > VC > AP. 2+3+4+5          |
|          | 1 <sup>st</sup> Segment | PVS-2 > PVS-1 > MPS > AP. 1 > VC > AP. 2+3+4+5+6            |
|          | 6 <sup>th</sup> Segment | PVS-1 > MPS > AP. 1 > VC > AP. 2+3+4+5                      |
| Case # 4 | Ground Floor            | VC > MPS > PVS-1 > EN > AP. 1+2+3+4+5                       |
|          | 5 <sup>th</sup> Segment | VC > PVS-1 > MPS > AP. 1+2+3+4+5                            |
|          | 6 <sup>th</sup> Segment | PVS-2 > VC > PVS-1 > MPS > AP. 1+2+3+4+5                    |
| Case # 5 | Ground Floor            | PVS-2 > PVS-1 > MPS > EN > AP. 1+2+3 > VC > AP. 4+5         |
|          | 1 <sup>st</sup> Segment | PVS-2 > PVS-1 > MPS > VC > AP. 1+2+3+4+5                    |
|          | 6 <sup>th</sup> Segment | VC > PVS-2 > MPS > PVS-1 > AP. 1+2+3+4+5                    |

Key: MPS: Main Public Space, PVS-1: Semi-Private Space (#1), EN: Entry Hall  
 VC: Vertical Circulation Core, PVS-2: Semi-Private Space (#2), AP: Apartments

Table 5.22: Integration values for the different spaces in the building

| Cases    | No. of Segment          | Integration Values for the Different Spaces in the Building |                                |                 |                            |                            |                                    |
|----------|-------------------------|---|--------------------------------|-----------------|----------------------------|----------------------------|------------------------------------|
|          |                         | Main Public Space (MPS)                                     | Vertical Circulation Core (VC) | Entry Hall (EN) | Semi-Private Space (PVS-1) | Semi-Private Space (PVS-2) | Residential Units (Apartments)     |
| Case # 1 | Ground Floor            | 4.80  | 5.17                           | 3.32            | 3.53                       | 4.49                       | 4.17, 4.16, 3.95, 3.90, 3.46, 3.18 |
|          | 1 <sup>st</sup> Segment | 4.26  | 5.13                           | -               | 4.46                       | 4.18                       | 3.90, 3.88, 3.63, 3.59, 3.40, 3.38 |
|          | 6 <sup>th</sup> Segment | 3.23  | 4.13                           | -               | 3.57                       | 3.79                       | 3.51, 3.33, 3.14, 2.86, 2.85       |
| Case # 2 | Ground Floor            | 3.63  | 3.32                           | 2.89            | 3.37                       | 3.92                       | 3.23, 2.94, 2.85, 2.47, 2.45       |
|          | 4 <sup>th</sup> Segment | 3.74  | 3.55                           | -               | 6.27                       | -                          | 3.65, 3.59, 3.48, 3.30, 2.85       |
|          | 6 <sup>th</sup> Segment | 4.04  | 3.75                           | -               | 5.81                       | -                          | 3.43, 3.31, 3.14, 3.09, 2.72       |
| Case # 3 | Ground Floor            | 4.23  | 3.59                           | 4.05            | 4.30                       | 4.43                       | 3.65, 3.38, 3.31, 3.10, 2.32       |
|          | 1 <sup>st</sup> Segment | 3.98  | 3.95                           | -               | 4.37                       | 5.01                       | 4.03, 3.55, 3.43, 3.34, 3.04, 2.93 |
|          | 6 <sup>th</sup> Segment | 3.67  | 2.91                           | -               | 4.44                       | -                          | 3.01, 2.76, 2.71, 2.62, 2.58       |
| Case # 4 | Ground Floor            | 4.07  | 4.08                           | 3.61            | 3.85                       | -                          | 3.44, 2.85, 2.81, 2.52, 2.38       |
|          | 5 <sup>th</sup> Segment | 4.01  | 4.34                           | -               | 4.31                       | -                          | 3.69, 3.42, 3.28, 3.13, 2.67       |
|          | 6 <sup>th</sup> Segment | 3.21  | 3.38                           | -               | 3.24                       | 4.61                       | 3.19, 2.65, 2.63, 2.56, 2.41       |
| Case # 5 | Ground Floor            | 4.19  | 3.03                           | 4.01            | 4.23                       | 4.39                       | 3.67, 3.33, 3.27, 3.01, 2.23       |
|          | 1 <sup>st</sup> Segment | 4.17  | 3.94                           | -               | 4.23                       | 4.46                       | 3.75, 3.48, 3.03, 2.70, 2.35       |
|          | 6 <sup>th</sup> Segment | 3.98  | 4.63                           | -               | 3.92                       | 4.25                       | 3.06, 3.02, 2.58, 2.52, 2.29       |

Key: ■ The highest integration value  
■ The lowest integration value

### a. Social Indicators (1) and (5): Crowding and Accessibility

Another important issue for achieving social sustainability in multi-story residential buildings is the availability of an accessible system of movement. The tool offers designers the ability to generate different sizes of transitional spaces, which include corridors and public/semi-private gathering areas. Agent analyses for different solutions showed that each two or three apartments are connected with a transitional space (Figures 5.105 and 5.106). Such a mechanism decreases crowding inside the building, as public gathering areas are distributed on the different vertical segments. Moreover, results of the analysis indicated that the vertical circulation core is not connected directly with entrances of apartments, which adds a social value to the design through preserving the privacy of each family.

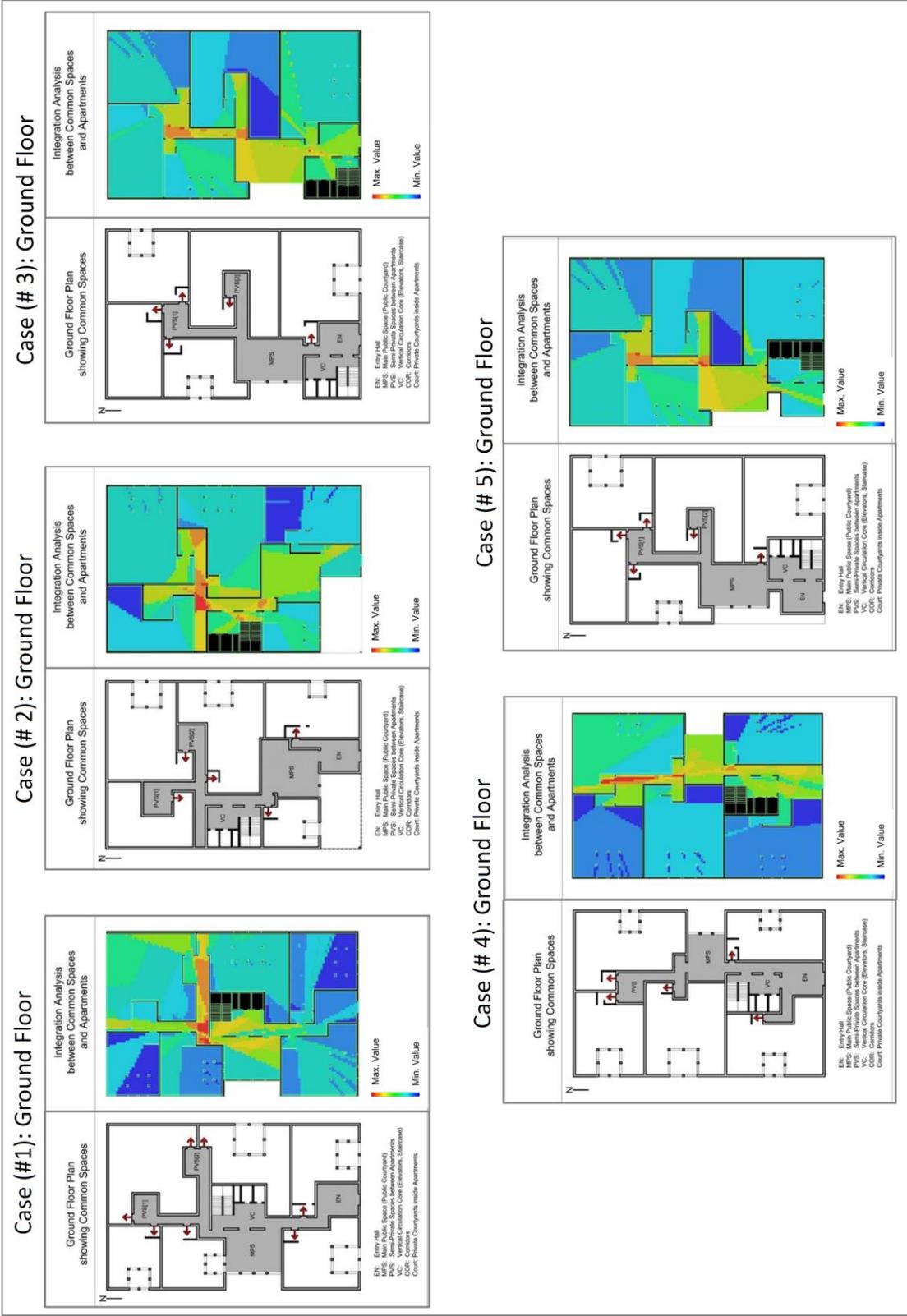


Figure 5.103: Integration analysis between common spaces and apartments on the ground floor for the five cases

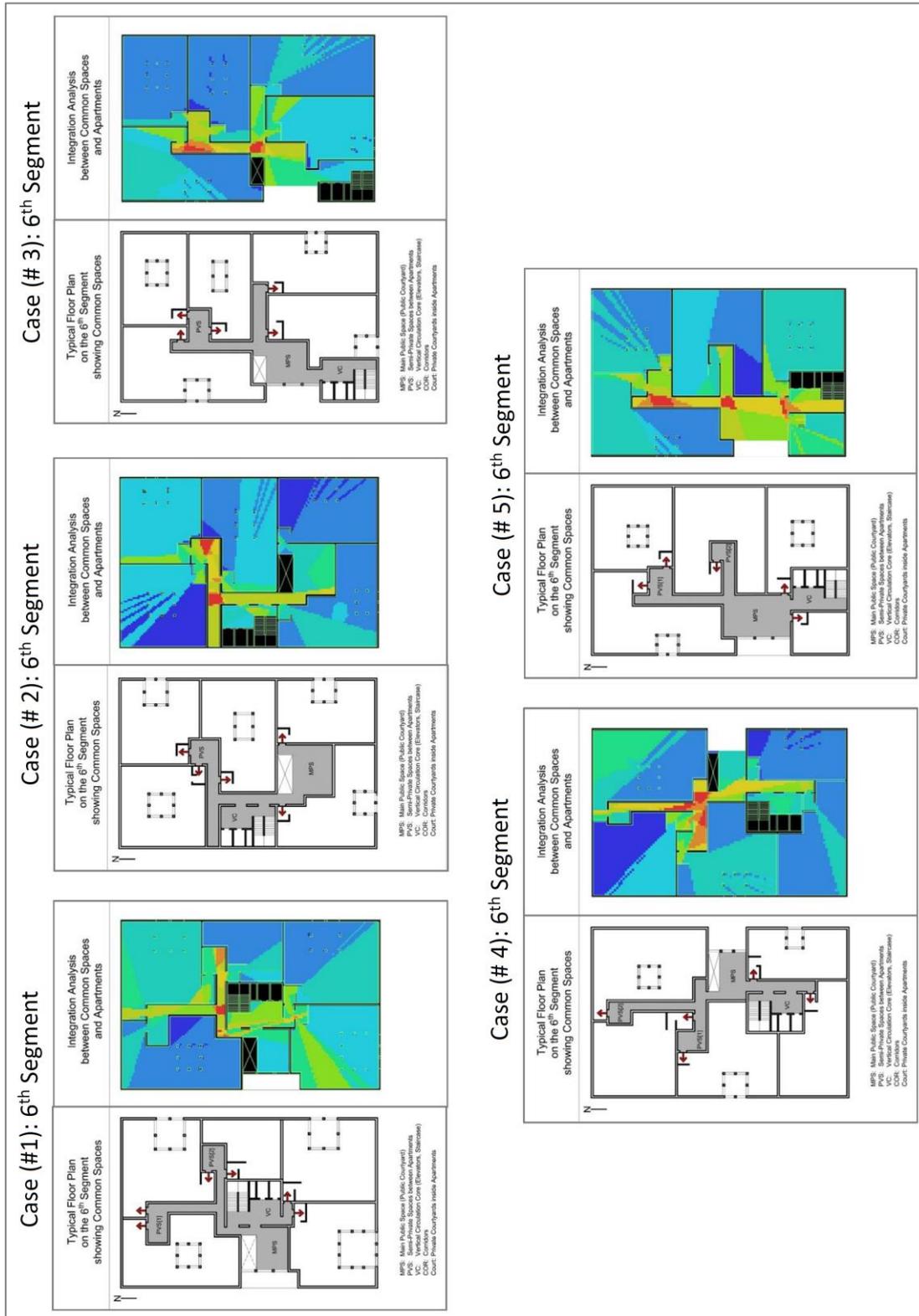


Figure 5.104: Integration analysis between common spaces and apartments on a typical floor on the 6<sup>th</sup> segment for the five cases

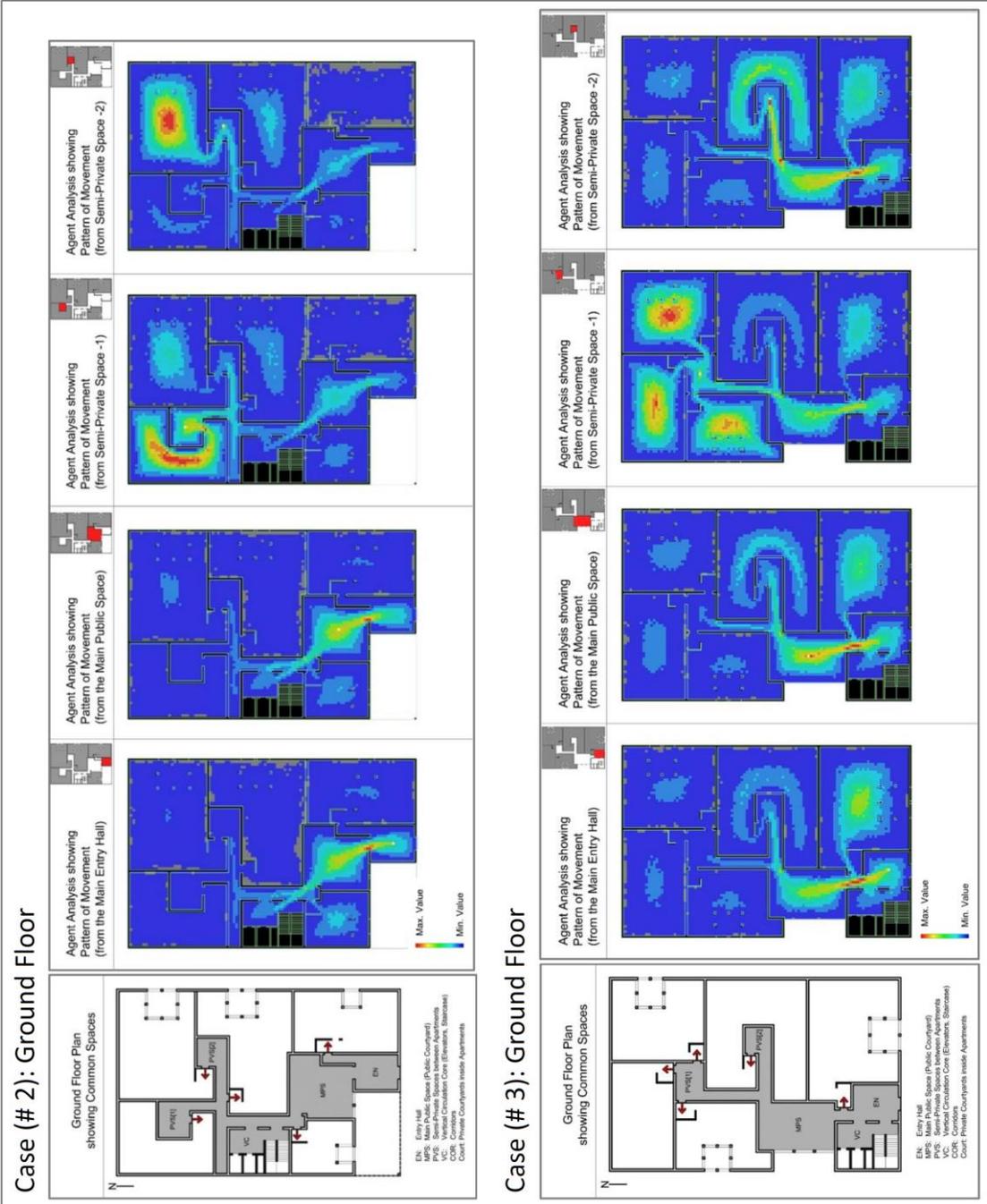


Figure 5.105: Agent analysis from the centre of each common area on the ground floor for Case # 2 and Case # 3

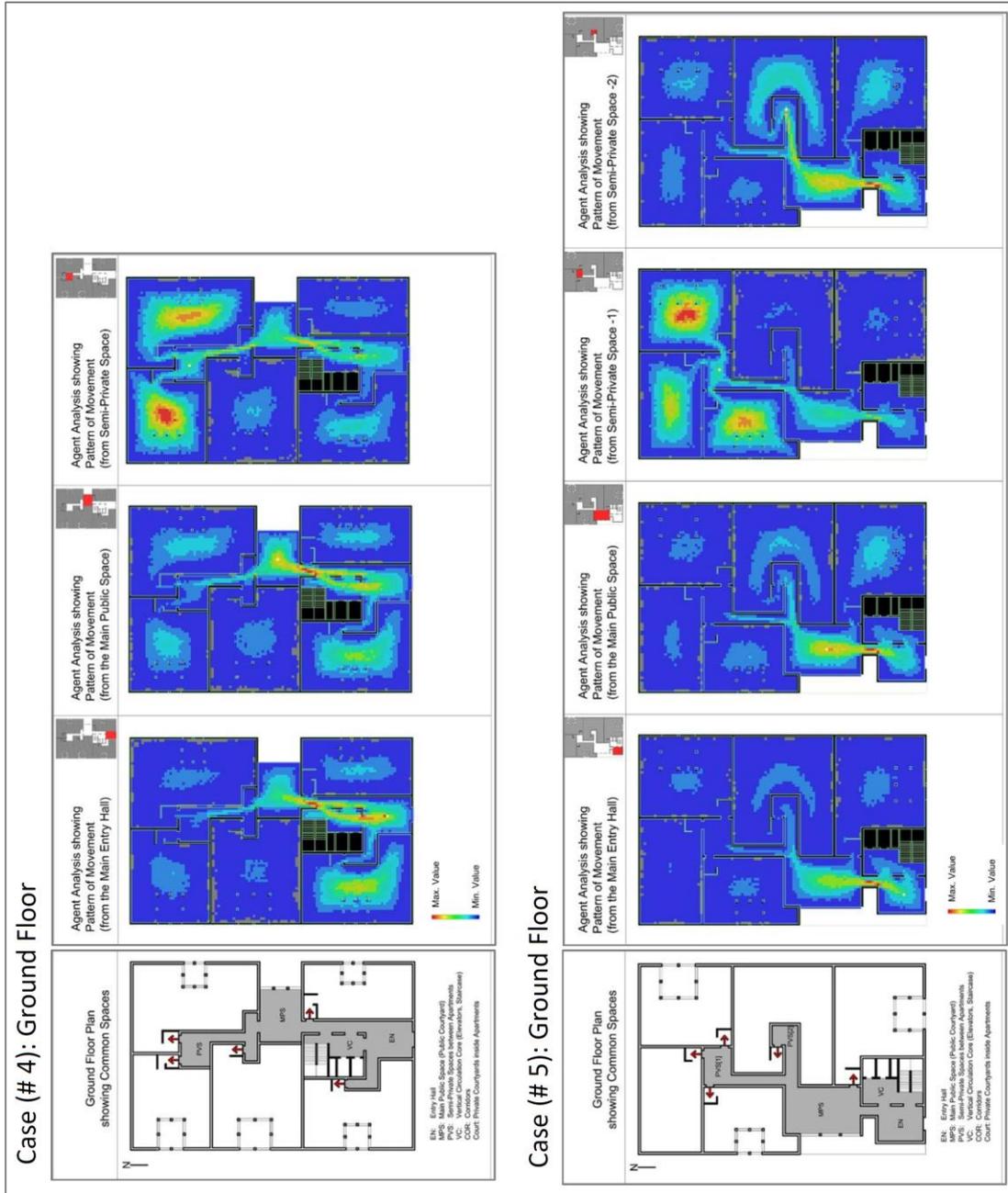


Figure 5.106: Agent analysis from the centre of each common space on the ground floor for Case # 4 and Case # 5

***b. Social Indicator (3) and (10): Social Interaction and Security***

Enhancing social interaction between residents inside the building could be achieved through offering gathering areas. The tool allows the generation of a main public space and two to three semi-private areas between apartments on each segment of the building. Such a variety of spaces could also be used as secure areas for children to meet and play, as parents prefer to keep their children indoor due to safety concerns.

***c. Social Indicator (6): Visual Privacy***

The isovist analysis of the different solutions showed that the visual fields from the centre of common spaces towards apartments are preserved (Figures 5.107 and 5.108). Same results were observed from the analysis of the visual fields along the movement path between apartments. Such a quality could be achieved through different mechanisms:

- Common spaces are arranged in a non-linear pattern, which, therefore, breaks the visual fields inside the building.
- Entrances are arranged in a staggered pattern, which maintains the privacy of the family.
- Entrances are connected with corridors or semi-private spaces. Such topological relationships allow for a balance between social interaction and isolation.
- The use of solid walls in front of entrances, which prevents a direct view towards the inside of the apartment.

***d. Social Indicator (11): Views to the Exterior***

A major strategy adopted in the construction of the computational model is the visual connection between the main public space, which is a public courtyard inside the building, and the outside. This mechanism allows users to enjoy the outside views, and at the same time connects the building with the natural environment. Moreover, private courtyards inside apartments increase the visual links between living spaces and the context.



Figure 5.107: Isovist analysis for Case # 2 and Case # 3, showing visual fields from the centre of common spaces and along the movement path for residents



Figure 5.108: Isovist analysis for Case # 4 and Case # 5, showing visual fields from the centre of common spaces and along the movement path for residents

### 5.12.2. Environmental Qualities

Examining other dimensions of sustainability increases the credibility of the developed tool. An environmental analysis for the five solutions was carried out, through running a radiation analysis for the building using *Ladybug* plugin in Grasshopper, to examine potentials of the design for reducing energy (Figure 5.109). Such a test is useful for studying solar heat gain, which is a shortwave radiation from the sun that heats a building through an opening or the fabric of the building (i.e. roof and external walls) (Lechner 2015). Higher values of solar gain cause overheating for the building. As a result, this could affect human comfort inside buildings (Social Indicator (4): Human Comfort).

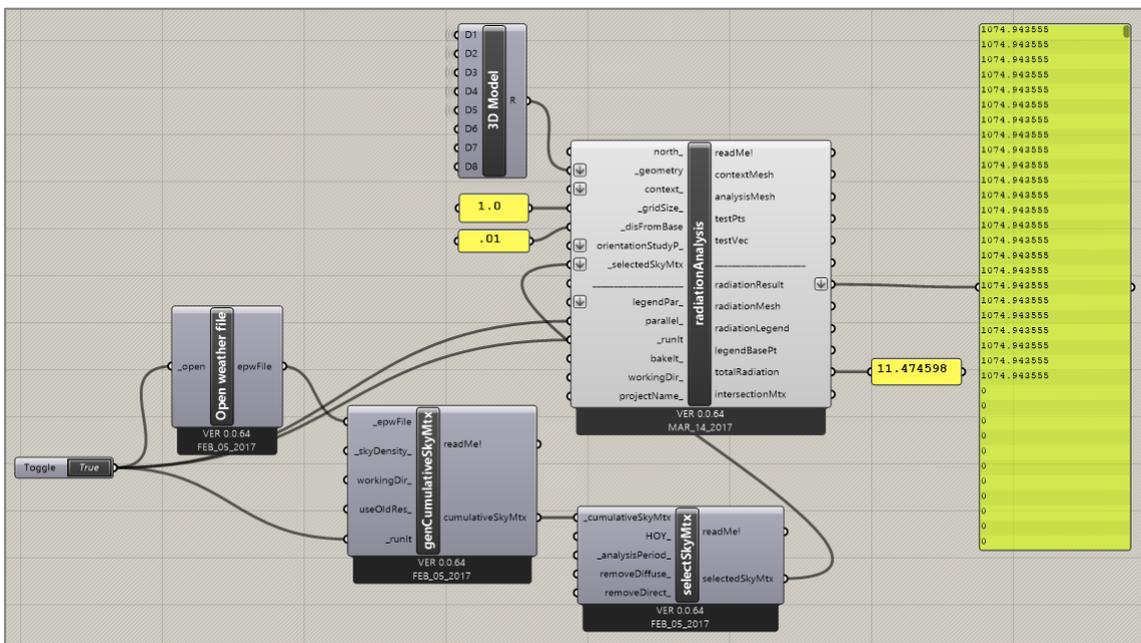


Figure 5.109: Grasshopper code for carrying out radiation analysis

The test calculates the total radiation (in KWh) that falls on the envelope of the building. To run it, a grid of cells that represents the envelope needs to be identified. The analysis is computed through mass addition of results at each of the test points (in KWh/m<sup>2</sup>), multiplied by the area of the face that the test points is representing. The weather data of Riyadh in Saudi Arabia, which has a hot-arid climate, was applied on all cases. Results from the analysis were compared with a solid mass that has the same geometric properties of the proposed designs. The following settings were identified for the analytical model (Table 5.23).

Table 5.23: Settings for running radiation analysis

| Aspects                     | Settings  |
|-----------------------------|---|
| Dimensions of the layout    | Width = 30 m<br>Length = 45 m<br>Height = 70 m (18 floors)  |
| Description of the building | - Base model: Solid building mass with no courtyards<br>- Proposed design: Includes public and private courtyards                 |
| Weather data                | Riyadh, KSA<br>(obtained from <a href="http://Energyplus.net/weather">http://Energyplus.net/weather</a> , accessed on 24.11.2017) |
| Time                        | 1 January 1:00 AM – 31 December 24:00 PM  |
| Size of grid cells          | 1 x 1 meters  |

Results of the analysis showed that the total amount of radiation for the proposed designs reduced (0.97%) in average when it is compared with a building mass that has no courtyards. Surface areas that receive low amount of radiation; ranged between 0.0 and 800.0 KWh/m<sup>2</sup>, increased three times approximately for the proposed designs than the base model. In contrast, surfaces that receive higher amount of radiation; ranged between 800.1 and 1500.0 KWh/m<sup>2</sup>, and between 1500.1 and 2215.6 KWh/m<sup>2</sup>, reduced (-406%) and (-554%), respectively (Table 5.24, and Figure 5.110). Such differences are due to the arrangement of courtyards on east, west, and south facades, which offers additional shaded surfaces for the building (Figures 5.111 and 5.112). Detailed results of radiation analysis for all cases are shown in (Volume 2 - Appendix (5-C-3)).

Table 5.24: A comparison between a solid mass with no courtyards, and the proposed design according to amount of radiation

| Cases  | % of Surface Area according to Amount of Radiation (KWh/m <sup>2</sup> ) |                                       |                                     | Total Radiation (KWh)              |  |
|--|--|---------------------------------------|-------------------------------------|------------------------------------|--|
|  | 0.0 to 800.0 KWh/m <sup>2</sup>  | 800.1 to 1500.0 KWh/m <sup>2</sup>    | 1500.1 to 2215.6 KWh/m <sup>2</sup> |                                    |  |
| <b>Base Model (A Building Mass with No Courtyards)</b> | <b>26.1 %</b>  | <b>58.0 %</b>                         | <b>15.9 %</b>                       | <b>11,736,821</b>                  |  |
| <b>Proposed Designs</b>                                | Case (# 1)   | 82.8 %<br>(Increased: + 315 %)        | 14.4 %<br>Reduced: (- 403 %)        | 2.8 %<br>Reduced: (- 568 %)        | 11,401,993                               |
|  | Case (# 2)   | 82.4 %<br>(Increased: + 315 %)        | 14.2 %<br>Reduced: (- 410 %)        | 3.4 %<br>Reduced: (- 470 %)        | 11,443,531                               |
|  | Case (# 3)   | 83.3 %<br>(Increased: + 320 %)        | 14.0 %<br>Reduced: (- 415 %)        | 2.7 %<br>Reduced: (- 590 %)        | 11,454,201                               |
|  | Case (# 4)   | 82.3 %<br>(Increased: + 315 %)        | 14.8 %<br>Reduced: (- 392 %)        | 2.9 %<br>Reduced: (- 550 %)        | 11,474,006                               |
|  | Case (# 5)   | 83.2 %<br>(Increased: + 320 %)        | 14.1 %<br>Reduced: (- 411 %)        | 2.7 %<br>Reduced: (- 590 %)        | 11,324,268                               |
|  | <i>Average</i>   | <b>82.8 %</b><br>(Increased: + 317 %) | <b>14.3 %</b><br>Reduced: (- 406 %) | <b>2.9 %</b><br>Reduced: (- 554 %) | <b>11,419,600</b><br>Reduced: (- 0.97 %) |

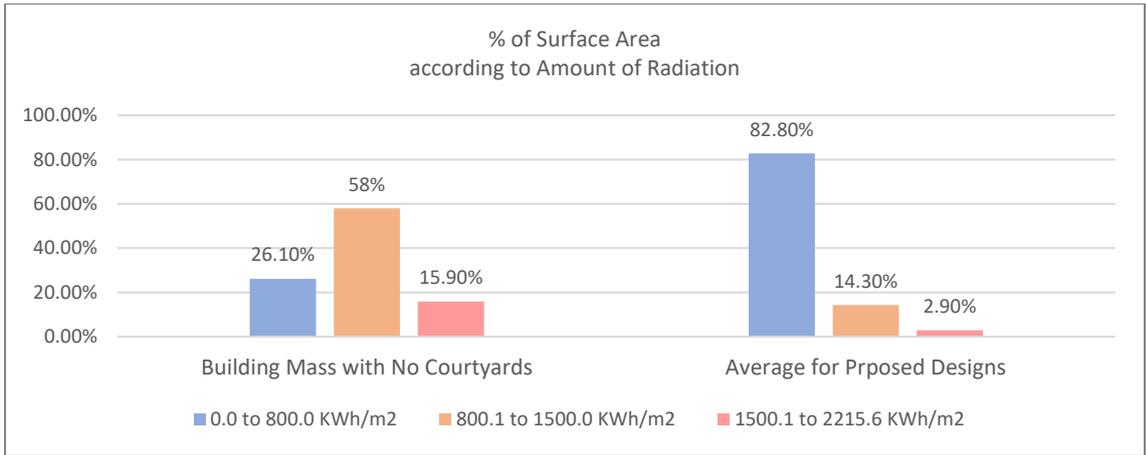


Figure 5.110: Differences between new solutions and a building mass that has no courtyards, according to amounts of radiation

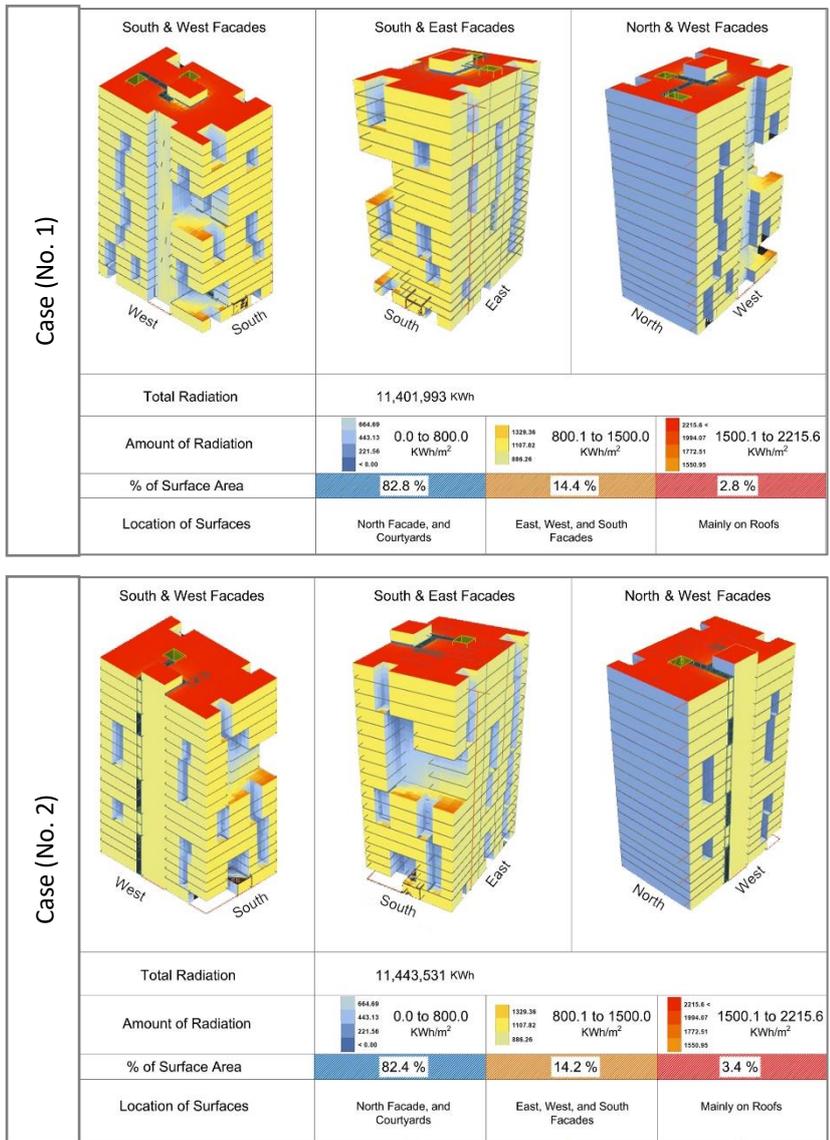


Figure 5.111: Radiation analysis for Case # 1, and Case # 2

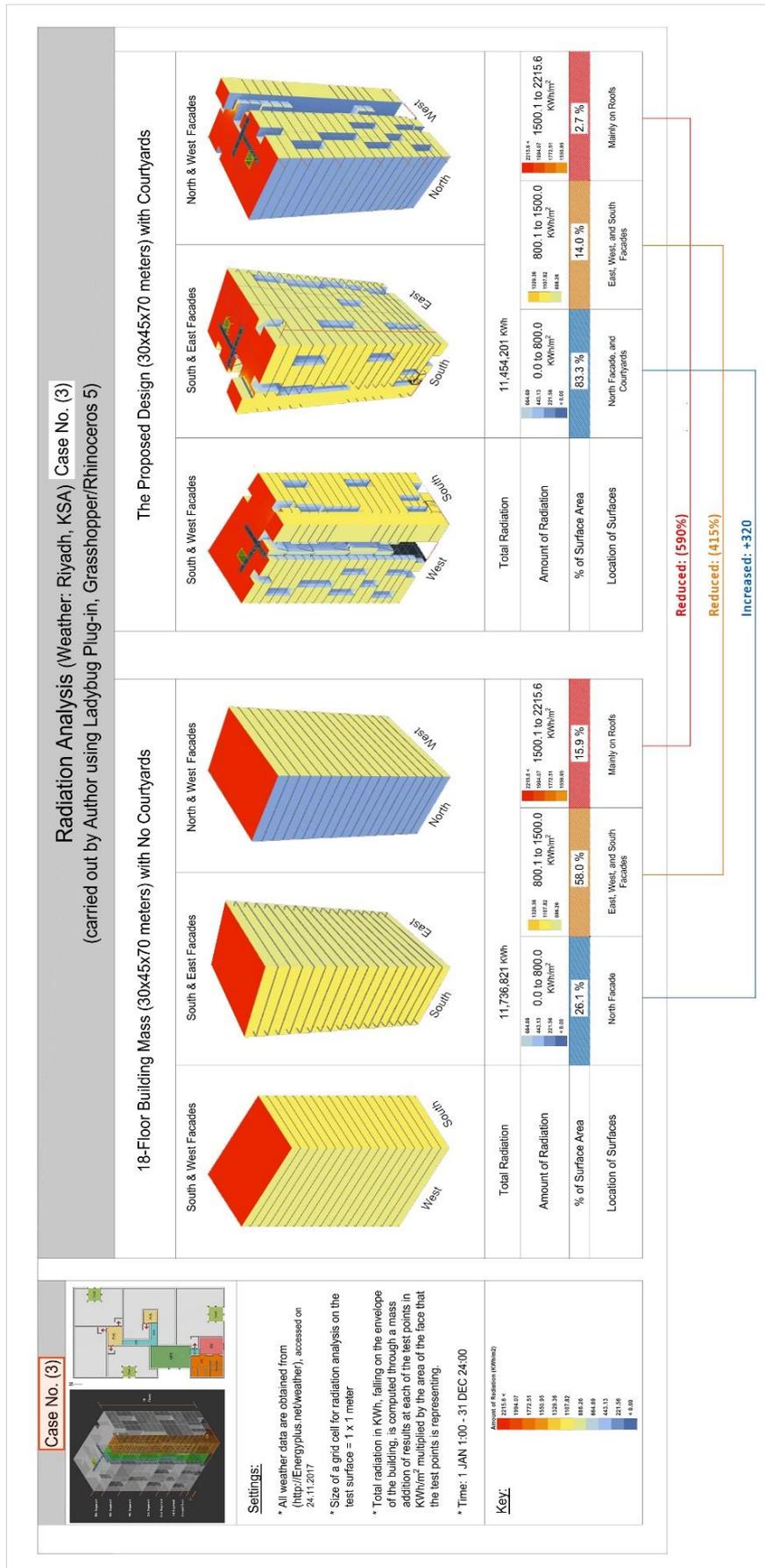


Figure 5.112: A comparative radiation analysis between the base model and Case # 3

### 5.12.3. Economic Qualities

One issue that is important for developers is the economic revenue of the building. Their target is to increase the area of residential units. Thus, offering public areas inside the building is not a concern. In contrast, residents and designers wish to include such spaces to enhance social interaction between neighbours, and to provide secure areas for children. Dealing with this contradiction, predefined constraints for the allowable area of common spaces were defined during the construction of the model. Results of the spatial analysis showed that percentages of designed spaces from the total allowable area are ranged between 92.7% and 97.7% (Table 5.25). Common spaces inside the building represent less than 18% of the total designed area (Figure 5.113). The area of all apartments represents more than 82% of the designed area. Such percentages, compared with number of units, add an economic advantage for the design. For instance, an 18-floor building, with a boundary area of 1350 m<sup>2</sup> for each floor, an average number of 95 units could be generated. Each apartment has an average area of 200 m<sup>2</sup>.

Table 5.25: Percentages of designed spaces from the total allowable area

| Case No. | Total Allowable Area (m <sup>2</sup> ) | Total Designed Spaces (m <sup>2</sup> ) | % of Designed Spaces | % of Common Spaces from Designed Areas | % of Residential Units from Designed Areas | No. of Units | Average Area of Each Unit (m <sup>2</sup> ) |
|----------|--|---|----------------------|--|--|--------------|---|
| Case #1  | 24300 m <sup>2</sup>                   | 22518 m <sup>2</sup>                    | 92.7 %               | 18.5 %                                 | 81.5 %                                     | 94           | 195.3 m <sup>2</sup>                        |
| Case #2  |  | 22923 m <sup>2</sup>                    | 94.3 %               | 18.7 %                                 | 81.3 %                                     | 94           | 198.2 m <sup>2</sup>                        |
| Case #3  |  | 23248 m <sup>2</sup>                    | 95.7 %               | 16.8 %                                 | 83.2 %                                     | 100          | 193.4 m <sup>2</sup>                        |
| Case #4  |  | 23733 m <sup>2</sup>                    | 97.7 %               | 18.0 %                                 | 82.0 %                                     | 92           | 211.6 m <sup>2</sup>                        |
| Case #5  |  | 22855 m <sup>2</sup>                    | 94.1 %               | 19.0 %                                 | 81.0 %                                     | 93           | 199.2 m <sup>2</sup>                        |
|          |  | <i>Average</i>                          |                      | <b>18.2 %</b>                          | <b>81.8 %</b>                              | <b>95</b>    | <b>200.0 m<sup>2</sup></b>                  |

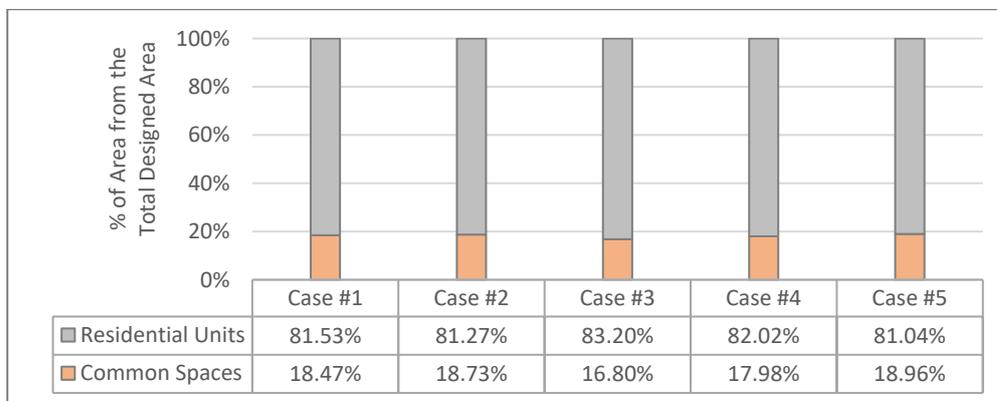


Figure 5.113: Percentages of common spaces and residential units from the total designed area

Main public spaces (MPS), and private courtyards inside apartments, constitute only 4.48% and 6.63%, respectively, from the area of the building (Figures 5.114 and 5.115). However, these features are part of the rentable area and aid the selling of apartments quickly. Thus, there is a revenue with no loss area. Furthermore, there is an omission of corridor spaces, which represent less than 5% of the total area. Finally, there is a reduction in number of fire doors, as courtyards and public spaces are part of the escape route, and they are open to well-ventilated access. A sample of detailed calculations carried out by the tool is presented in (Figure 5.116). Results for other cases are shown in (Volume 2 - Appendix 5-C-4).

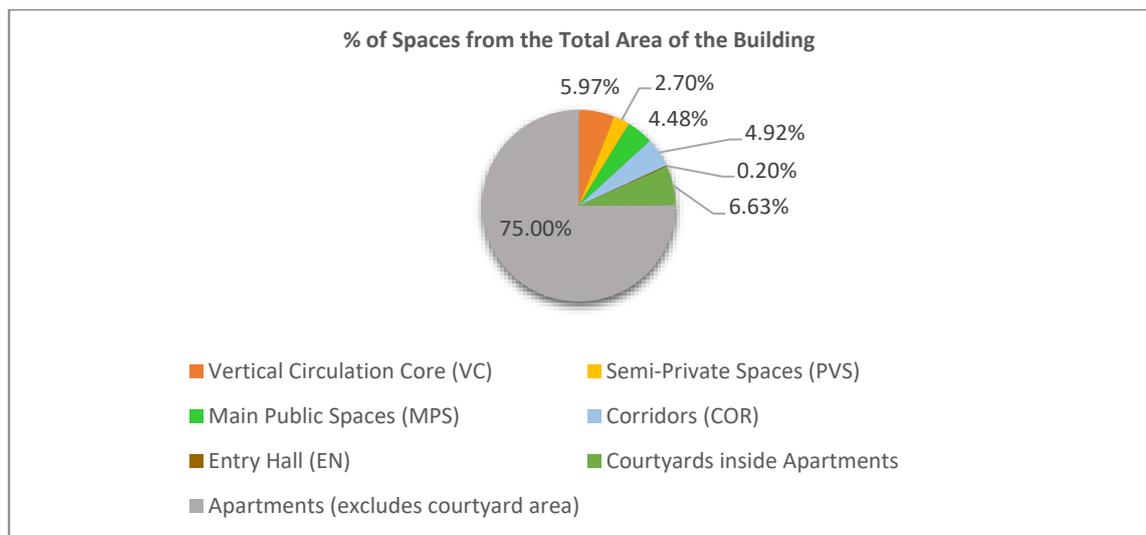


Figure 5.114: Average percentages of different spaces for all cases

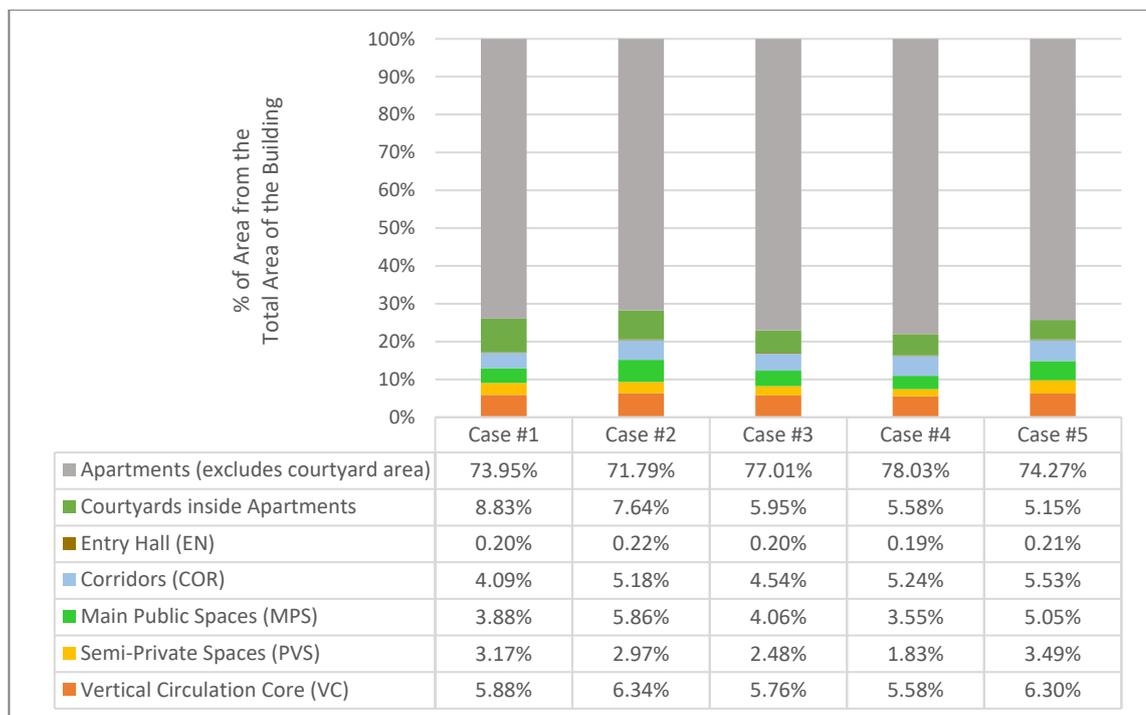


Figure 5.115: Percentages of different spaces from the total designed areas

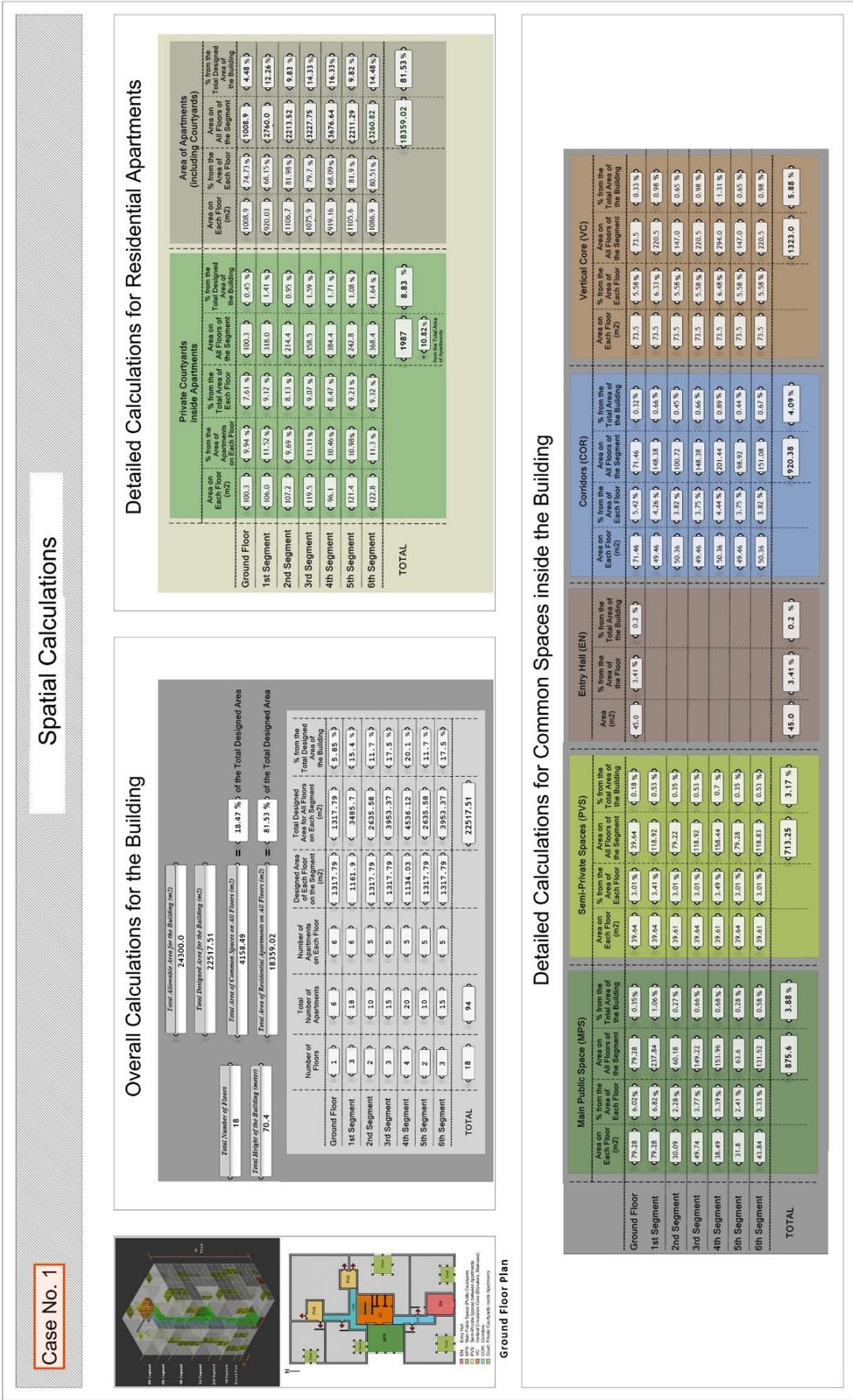


Figure 5.116: Detailed calculations for the different spaces for Case #1

#### 5.12.4. Summary of the Evaluation Process for the Five Alternatives

After analysing all dimensions of sustainability for the different alternatives, three proposed designs (Cases #2, #4, and #5) achieved higher values (more than 88% for each case) regarding the five social criteria: hierarchy of spaces, crowding, social interaction, visual privacy, and viewing the outside context. However, the other two cases (Cases #1, and #3) achieved 82%, and 75% respectively (Figures 5.117 and 5.118). The evaluation process depends on assigning 100% for the best case that achieved this quality. Percentages for other cases for the same aspect have been normalised according to the best solution.

1. Hierarchy of spaces: the percentage refers to the average of connectivity and integration values for spaces that are located on the ground floor, and how each case achieved a hierarchical system of movement from public to private zones.
2. Crowding: which is refer to the average number of units connected with common spaces. The highest percentage (100%) indicates that only one unit is attached to one common space, which means that the crowding will be decreased.
3. Social interaction: this percentage indicates the total area of main public and semi-private spaces on the ground floor. The highest percentage (100%) refers to the largest area of these spaces.
4. Visual privacy: which refers to the area of residential units that could be seen from common areas on the ground floor.
5. Views to the exterior: this percentage has been calculated based on the length of facades for private and public courtyards that are connected with the outside.
6. Environmental rewards: the percentage indicates how much the amount of radiation for each case has been reduced in comparison to the building mass with no courtyards.
7. Economic value: the percentage for each case refers to the area of residential units on the ground floor. The highest percentage (100%) means that the case achieved the largest area of apartments.

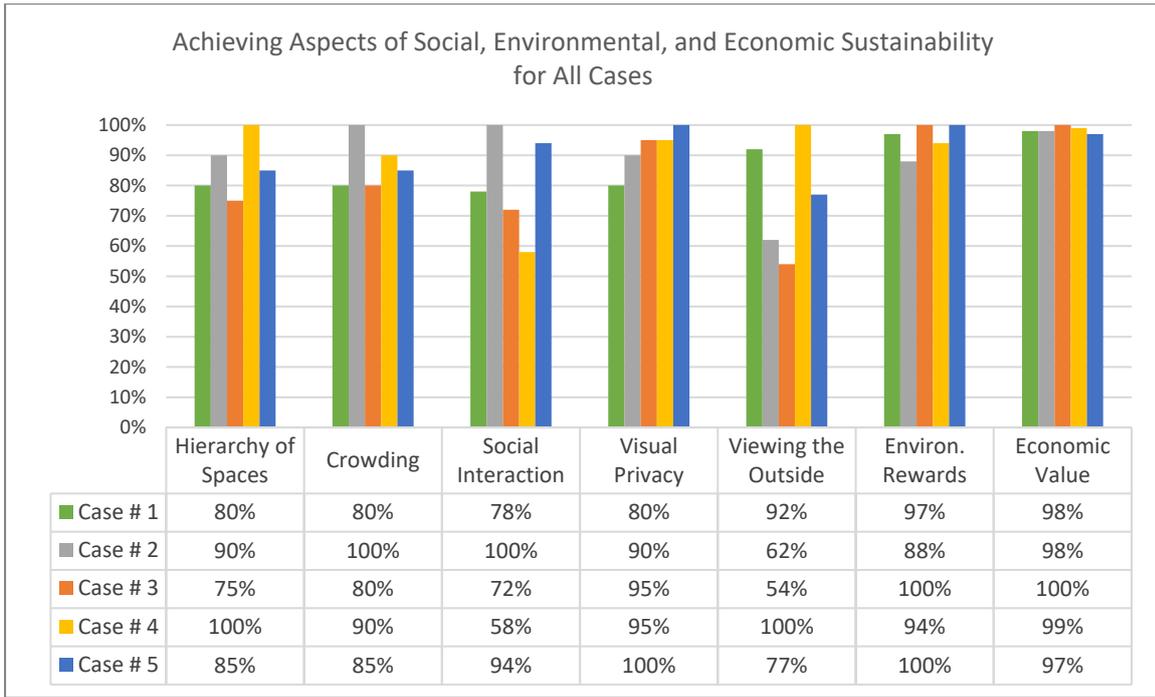


Figure 5.117: Achieving aspects of social, environmental, and economic sustainability for all cases

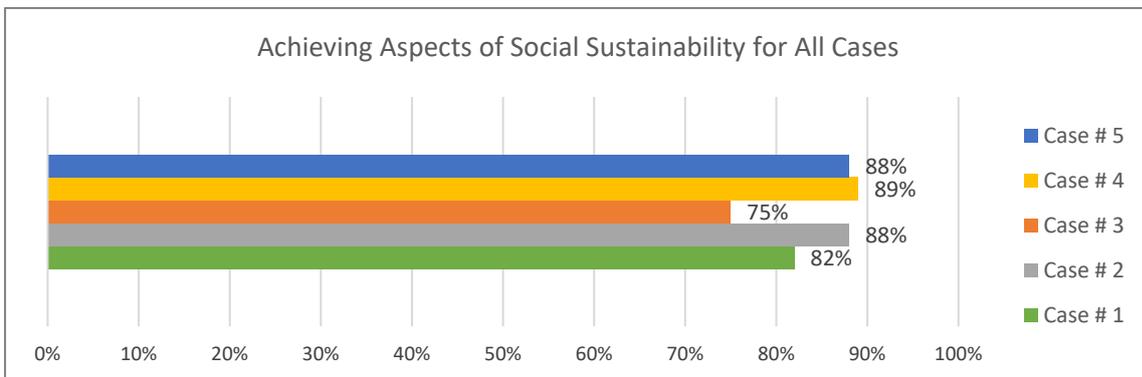


Figure 5.118: Achieving aspects of social sustainability for all cases

### 5.13. Usability Evaluation for the Developed Computational Tool: An Experimental Study

Usability of any tool lies in the clarity of the application (Kitchley and Srivathsan 2014). It could be measured by three issues: (a) effectiveness: to which extent the objectives of the tool are achieved; (b) efficiency: time and effort that have been expended to achieve the objectives; and (c) satisfaction: the acceptability of the tool by users (Park and Hwan 1999). Therefore, an experimental study that evaluates these issues for the developed tool was conducted at Welsh School of Architecture, Cardiff University. The study asked professionals, and 3<sup>rd</sup>-year architecture students, to use the tool for the design of a multi-story residential building. The target is to assess flexibility and creativity of the tool in the early stage of the design, and to compare results of users who are not experienced with the interface, with results produced by the researcher.

Moreover, it aims to evaluate usability and functionality levels of the interface. Participants completed a questionnaire to get concise feedback about aspects they particularly enjoyed or dislike during the implementation. Comments raised by participants were used to improve the quality of the script and the design process.

#### 5.13.1. Criteria for the Evaluation Process

For determining the acceptability of a computational tool, and if it is easy to learn and pleasant to use, a user-based assessment is needed. This evaluation could be implemented using an empirical method through testing the tool with real users to inspect the usability of the interface (Nielsen 1994). A set of usability criteria are preferred to be achieved in an acceptable interface (Park and Hwan 1999; Paryudi and Fenz 2013; Jeffries *et al.* 1991):

- Suitability for the task (appropriate functionality).
- User control (controllability).
- Flexibility (suitability for individualisation, adaptability).
- Error management (error prevention and correction).
- Compatibility (conformity with user expectations).
- Self-descriptiveness.
- Consistency (consistency in location, format, syntax, and naming).

For this study, three issues were adopted for the evaluation process:

- a. Effectiveness, which measures the suitability of the tool, productivity of users in the early stage of the design, and if it can be used effectively in professional practice.

Moreover, it measures accuracy and completeness that users achieved. The following aspects were assessed:

- The tool reflected the design process in practice.
  - Proportion of users who would prefer using the interface over other applications.
  - Average accuracy of completed tasks.
  - Percentage of users completed the task.
  - Number of errors facing a user (i.e. number of times the interface misleads a user).
- b. Efficiency, which relates to mental and physical resources, such as time and human efficiency. These include:
- Time to complete a task.
  - Learning time.
  - Time spent using help or documentation.
  - Number of questions asked by a user.
  - Descriptions were informative.
- c. Satisfaction, which quantifies the strength of user's reactions, opinions, and attitudes. This aspect evaluates the following issues:
- Number of times a user expressed clear frustration during the experiment.
  - Procedures were simple and required a minimum number of steps.
  - The interface and menus were clear and designed in a logical process.
  - Command names and options were clear and easy to remember.
  - Overall rating scale for user satisfaction.

A questionnaire<sup>1</sup> was designed to evaluate the developed tool according to the criteria mentioned above. A total number of 15 questions were categorised into two groups:

- a. The first group, which included 13 questions, focused on the level of satisfaction with the tool. Participants were asked to assess the following issues using a five-point scale ranging from (1) to (5), where (1) indicates 'strongly disagree', and (5) indicates 'strongly agree':
- The tool can be used effectively in professional practice
  - Suitable for early stages of design

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<sup>1</sup> See (Volume 2 – Appendix (5-C-5): Questionnaire Form for the Evaluation of the Tool)

- Final result matched your initial expectations
- Appropriate number of input data
- Performing tasks was easy to learn
- Needs the support of a person to use this tool
- You were able to complete the task in a reasonable amount of time
- You can become productive using the tool
- You could recover from mistakes easily
- Information provided with each stage was clear and effective
- The organisation of the interface was clear
- The interface and colours were pleasant
- The tool has all functions and capabilities you expect it to have

b. The second group asked the user about positive and negative aspects of the tool.

Moreover, the researcher recorded the following aspects during the implementation process:

- Number of questions asked by the user about commands, and about the design process,
- Number of errors faced the user,
- Number of times the user expressed frustration during the experiment.

As part of the research ethics, the work was carried out by the codes of ethics applied by the researching body. An ethical approval form appended with the research proposal and ethics statement were submitted to the Ethics Committee in Welsh School of Architecture, Cardiff University. The approval (No. EC1711-346) was obtained on 16/11/2017<sup>2</sup>.

Moreover, all participants were informed about the purpose of the study, how they were expected to take part in it, how much time the experiment expected to take, and the right of any participant not to answer any particular question, or to withdraw from the study at any time. The participation in the study was entirely voluntary.

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<sup>2</sup> See (Volume 2 – Appendix (5-C-5): Ethical Approval Form)

### 5.13.2. Choosing a Sample of Users

The main strategy adopted in this experiment is to compare efficiency and effectiveness of the computational tool on two groups of users: professional architects, and architecture students. However, participants do not need any previous experience in Grasshopper to use the design tool.

The study sample was composed of 11 participants: eight professionals (post-graduate researchers, who have previous experience in design in their countries), and three architecture students, who are in their third year of study. As the tool was designed to generate high-rise residential buildings in the Middle East and North Africa, all professional architects have been selected from countries that are part of the study area, so they have shared cultural values (Table 5.26). On the other hand, students have different backgrounds, and not all of them are from the study area. This adds a potential value to capture different cultural perspectives. To manage the experiment with the limited time and cost, and to control the implementation process by the researcher, the test was conducted in Welsh School of Architecture, Cardiff University, between 21.11.2017 and 5.12.2017. Each experiment was conducted individually in the same settings, and took approximately 45 minutes (Figure 5.119). A short tutorial was presented by the researcher at the start. At the end of the implementation, users completed an evaluation form about the tool.

Table 5.26: Sample of users who participated in the experimental study

| Number           | Background and Professional Experience     |           |                     |  | Previous Experience in Grasshopper |
|------------------|--|-----------|---------------------|--|------------------------------------|
|                  | 3 <sup>rd</sup> -Year Architecture Student | Architect | Years of Experience | Country (where the Architect practised the Profession) |                                    |
| Participant # 1  |  | X         | 9 years             | Egypt  | Yes                                |
| Participant # 2  |  | X         | 6 years             | Saudi Arabia   | Yes                                |
| Participant # 3  |  | X         | 6 years             | Jordan   | No                                 |
| Participant # 4  |  | X         | 5 years             | Jordan   | No                                 |
| Participant # 5  |  | X         | 2 years             | Iraq   | No                                 |
| Participant # 6  |  | X         | 1 year              | Jordan   | No                                 |
| Participant # 7  |  | X         | 1 year              | Libya  | No                                 |
| Participant # 8  |  | X         | 1 year              | Qatar  | Yes                                |
| Participant # 9  | X  |           | -                   | Syria  | No                                 |
| Participant # 10 | X  |           | -                   | China  | No                                 |
| Participant # 11 | X  |           | -                   | Malaysia   | Yes                                |



Figure 5.119: Samples from the implementation process of the experiment (21.11.2017 to 5.12.2017)

### 5.13.3. Solutions Produced by Participants

All participants were asked to design a residential building with the following requirements:

- The user can choose different dimensions for the layout.
- There are no restrictions on the height and number of floors.
- The main entrance is located on the southern edge of the building.
- The maximum number of apartments on each floor is 6.
- Area of each apartment could be ranged between 90 and 260 m<sup>2</sup>.

Such constraints give the user flexibility to produce different solutions, and at the same time, help the researcher to evaluate the practicality of the tool for generating alternatives. Four designs were selected randomly for the analysis; two by professional architects (Exp. #A and #B), and two by students (Exp. #C and #D) (Table 5.27, and Figure 5.120).

Table 5.27: Variations in parameters for the selected experiments

| Parameters                        | Experiment # A                | Experiment # B                | Experiment # C                | Experiment # D                |
|-----------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
|                                   | By Professionals              |                               | By architecture students      |                               |
| Dimensions of the layout          | Width = 40 m<br>Length = 25 m | Width = 30 m<br>Length = 45 m | Width = 35 m<br>Length = 30 m | Width = 30 m<br>Length = 50 m |
| Area of the ground floor          | 1000 m <sup>2</sup>           | 1350 m <sup>2</sup>           | 1050 m <sup>2</sup>           | 1500 m <sup>2</sup>           |
| Number of floors                  | 7 floors                      | 12 floors                     | 16 floors                     | 9 floors                      |
| Number of designed segments       | GF +<br>3 segments            | GF +<br>6 segments            | GF +<br>5 segments            | GF +<br>2 segments            |
| Location of the main public space | East                          | North                         | West                          | East                          |
| Location of the circulation core  | South                         | Centre                        | Centre                        | South                         |
| Total number of apartments        | 51<br>apartments              | 58<br>apartments              | 94<br>apartments              | 68<br>apartments              |

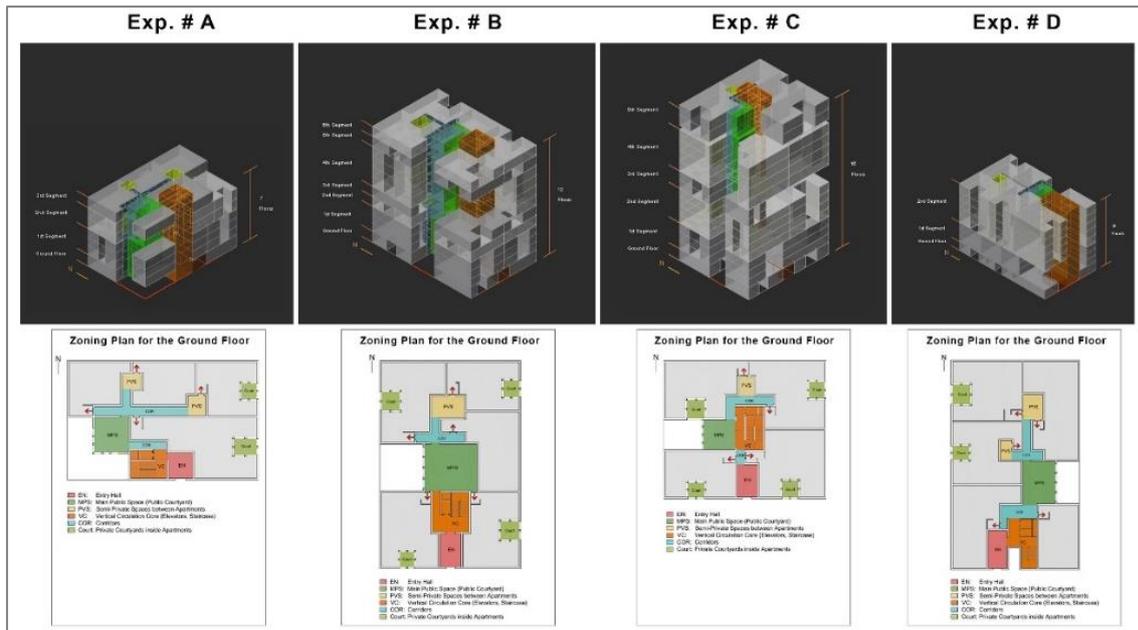


Figure 5.120: Solutions produced by participants: (A + B) by professionals, (C + D) by students

### a. Socio-Spatial Qualities

A detailed spatial-syntactical analysis was conducted for the four designs (Figures 5.121 and 5.122). The ground floor and one randomly-selected segment in each building were evaluated.

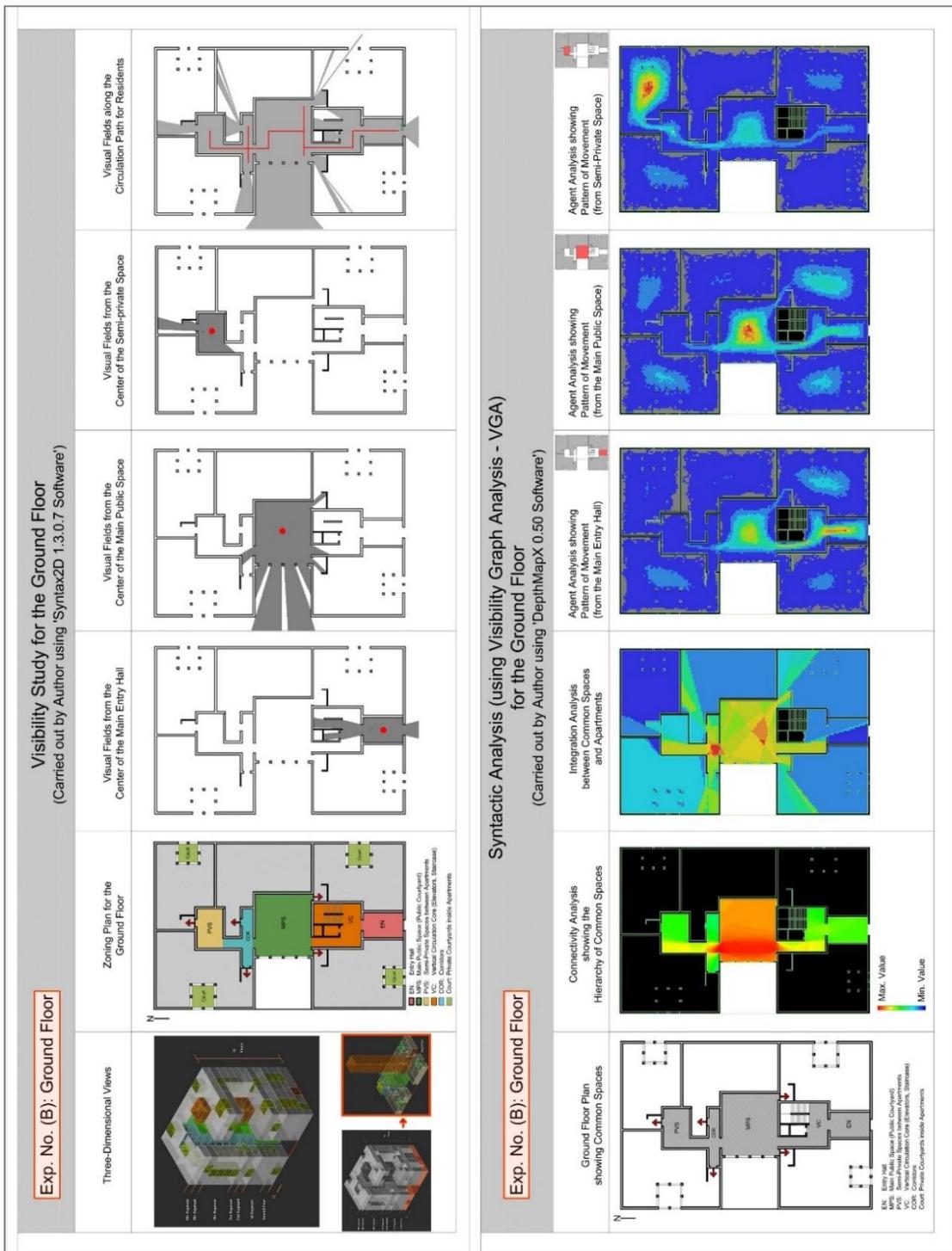


Figure 5.121: Visibility study and syntactic analysis for the ground floor - Experiment #B

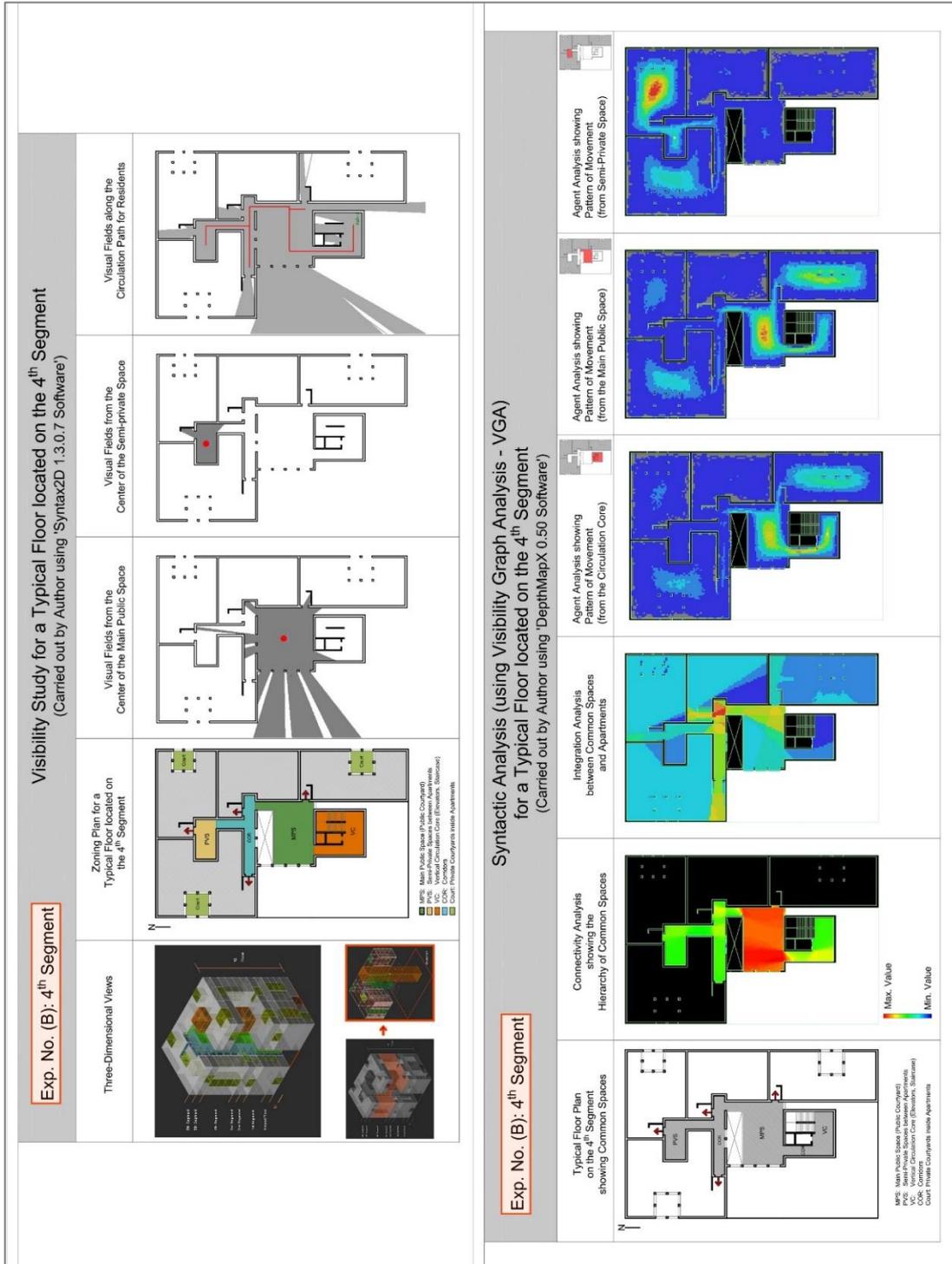


Figure 5.122: Visibility study and syntactic analysis for the 4<sup>th</sup> segment - Experiment #B

- *Social Indicator (1): Crowding*

Agent analysis from the centre of each common space showed that a maximum of two residential units are connected with each transitional area (Figures 5.123 and 5.124). However, the circulation core is connected with other public spaces rather than apartments. This topological arrangement decreases crowding inside the building, and increases the privacy of families.

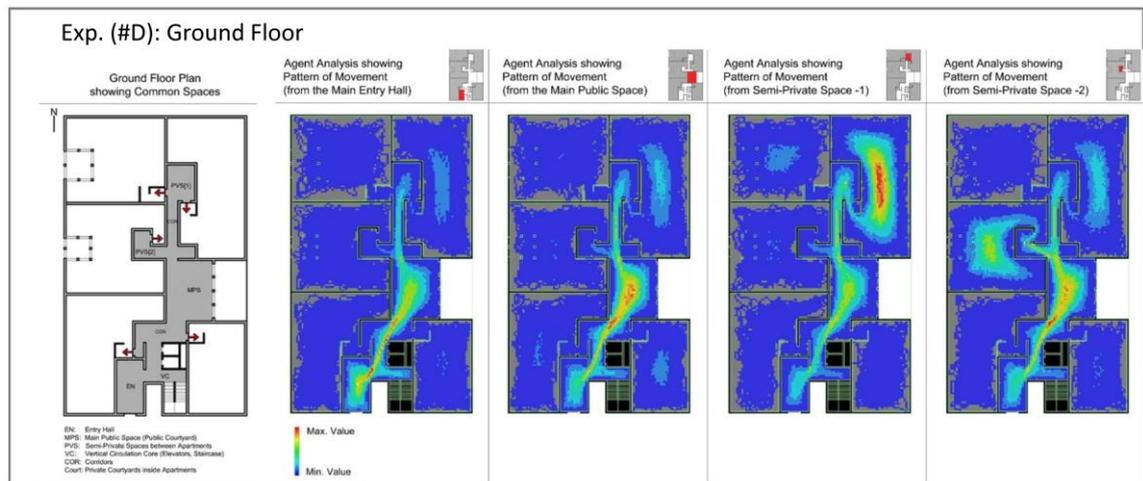


Figure 5.123: Agent analysis from the centre of each common space on the ground floor for Experiment #D

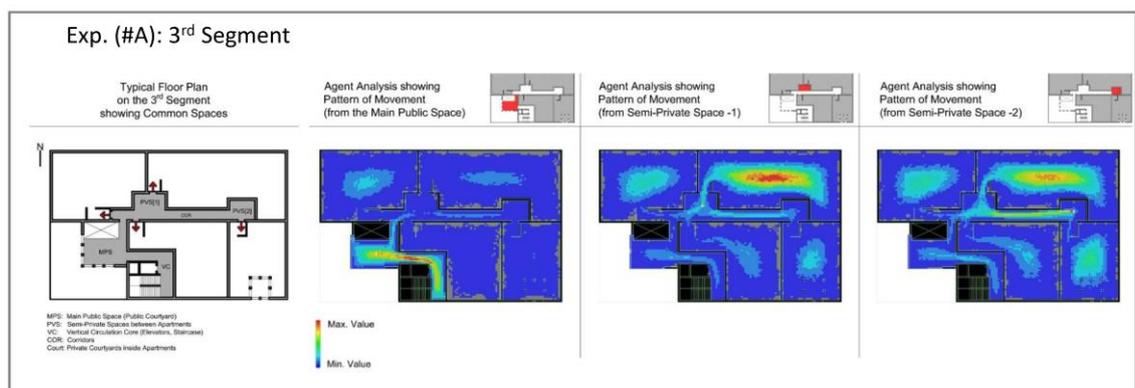


Figure 5.124: Agent analysis from the centre of each common space on the 3<sup>rd</sup> segment for Experiment #A

- *Social Indicator (2): Hierarchy of Spaces*

In most solutions, the syntactic analysis showed that the main public space (MPS) and the vertical circulation core (VC) have great connectivity values in comparison to the entry hall (EN), and semi-private areas (PVS) (Tables 5.28 and 5.29, and Figure 5.125). Corridors have intermediate values, which, therefore, a hierarchical system of movement from public to

semi-private areas could be achieved. These results are similar to the analysis of solutions produced by the researcher.

Table 5.28: Hierarchy of common spaces based on connectivity values

| Experiment No. | No. of Segment          | Hierarchy of Common Spaces based on Connectivity Values |
|----------------|-------------------------|---|
| Exp. # A       | Ground Floor            | MPS > PVS-2. > EN > PVS-1. > VC .                       |
|                | 3 <sup>rd</sup> Segment | MPS > PVS-2. > PVS-1. > VC .                            |
| Exp. # B       | Ground Floor            | MPS > VC > EN > PVS-1.                                  |
|                | 4 <sup>th</sup> Segment | MPS > VC > PVS-1.                                       |
| Exp. # C       | Ground Floor            | VC > MPS > EN > PVS-1.                                  |
|                | 4 <sup>th</sup> Segment | VC > MPS > PVS-2. > PVS-1.                              |
| Exp. # D       | Ground Floor            | MPS > VC > EN > PVS-1. > PVS-2.                         |
|                | 2 <sup>nd</sup> Segment | MPS > VC > PVS-1.                                       |

Key: MPS: Main Public Space, PVS-1: Semi-Private Space (#1), EN: Entry Hall  
 VC: Vertical Circulation Core, PVS-2: Semi-Private Space (#2)

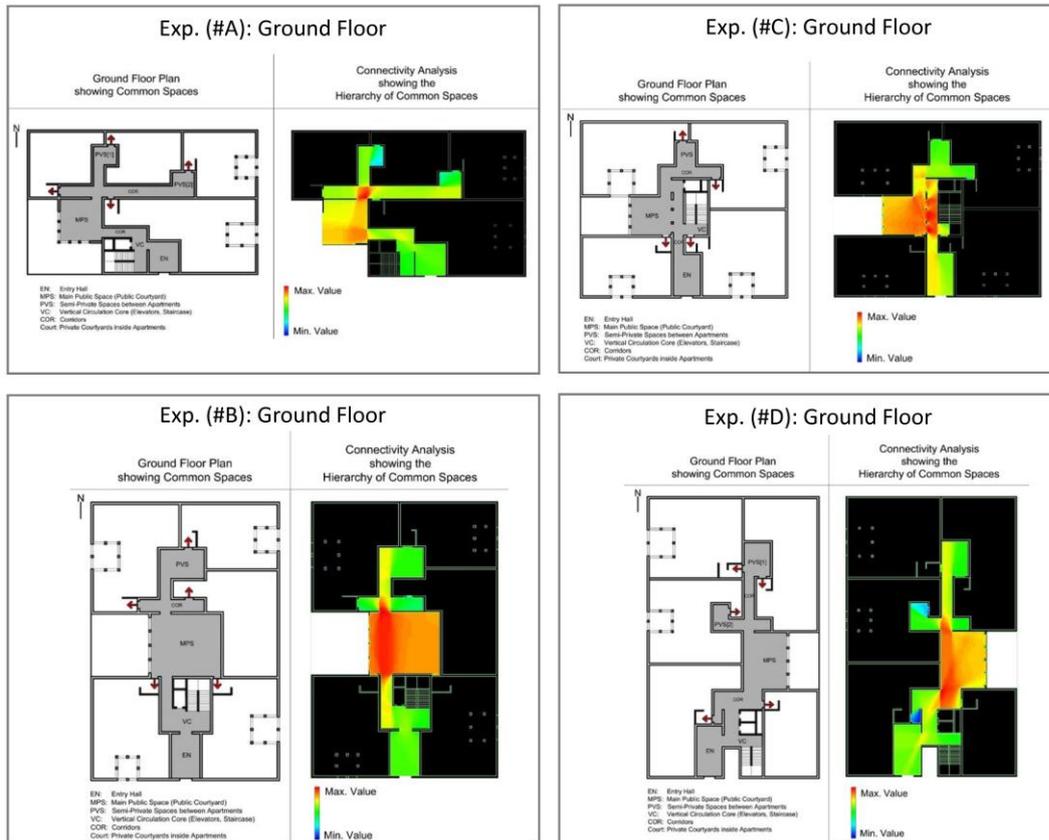


Figure 5.125: Hierarchy of common spaces according to connectivity values on the ground floor of the selected experiments

Table 5.29: Connectivity values for common spaces for solutions produced by participants

| Experiment No. | No. of Segment          | Connectivity Values for Common Spaces |                                |                 |                            |                            |
|----------------|-------------------------|---------------------------------------|--------------------------------|-----------------|----------------------------|----------------------------|
|                |                         | Main Public Space (MPS)               | Vertical Circulation Core (VC) | Entry Hall (EN) | Semi-Private Space (PVS-1) | Semi-Private Space (PVS-2) |
| Exp. # A       | Ground Floor            | 7.71                                  | 2.50                           | 3.92            | 3.34                       | 3.98                       |
|                | 3 <sup>rd</sup> Segment | 5.50                                  | 2.15                           | -               | 3.91                       | 5.20                       |
| Exp. # B       | Ground Floor            | 14.13                                 | 6.74                           | 5.73            | 4.12                       | -                          |
|                | 4 <sup>th</sup> Segment | 9.91                                  | 3.45                           | -               | 3.10                       | -                          |
| Exp. # C       | Ground Floor            | 7.86                                  | 8.75                           | 4.79            | 2.94                       | -                          |
|                | 4 <sup>th</sup> Segment | 6.73                                  | 7.30                           | -               | 1.43                       | 4.44                       |
| Exp. # D       | Ground Floor            | 12.60                                 | 8.10                           | 5.90            | 4.22                       | 4.01                       |
|                | 2 <sup>nd</sup> Segment | 4.72                                  | 4.10                           | -               | 2.67                       | -                          |

Key:  The highest connectivity value     The lowest connectivity value

Integration values for the designed areas on each floor showed that residential units in most cases have lower values (the blue colour in Figure 5.124) than common spaces, namely the main public courtyard and semi-private areas (Table 5.30). However, amounts of integration for the entry hall, and in some cases the vertical circulation core, are the lowest. Such results indicate that these spaces are isolated due to the location at the edge of the building.

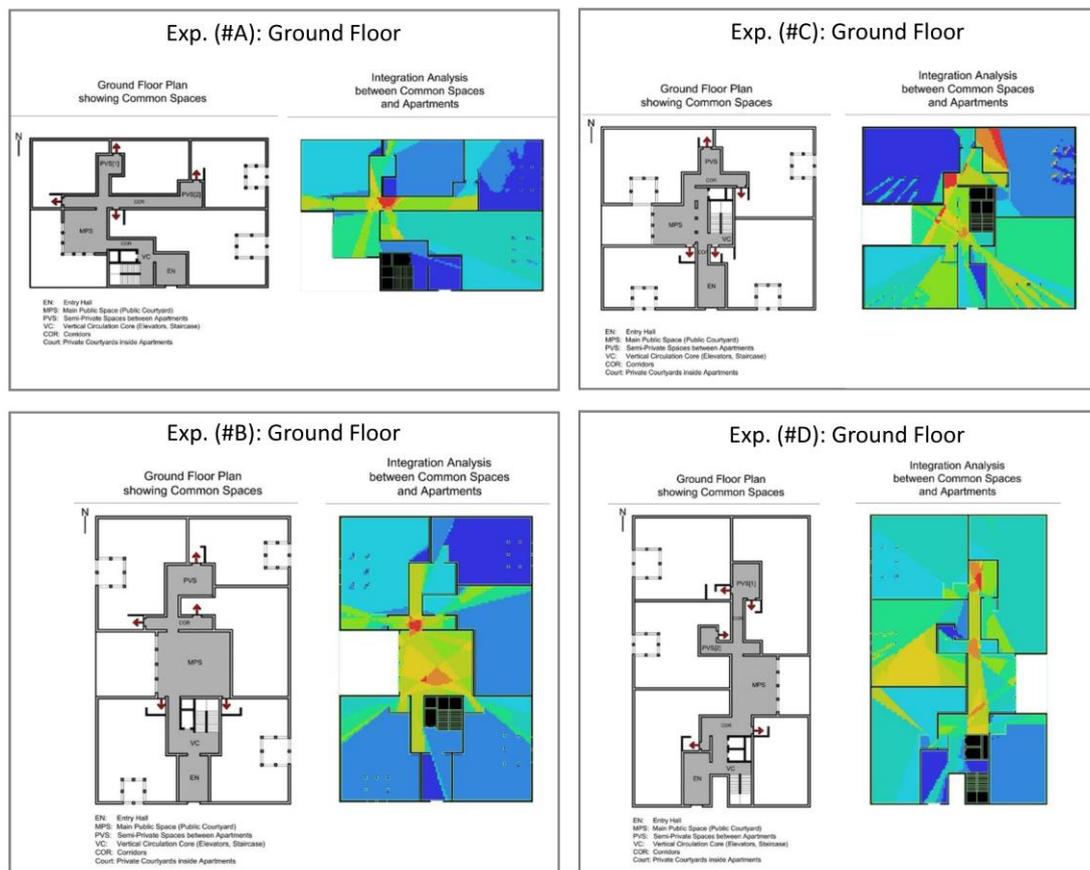


Figure 5.124: Integration analysis for the ground floor of the selected experiments

Table 5.30: Hierarchy of spaces based on integration values

| Cases    | No. of Segment | Hierarchy of Spaces based on Integration Values   |
|----------|----------------|---|
| Exp. # A | Ground Floor   | PVS-2 > PVS-1 > MPS > AP.1+2+3+4 > EN > VC .<br>6.22 5.77 5.60 4.36/4.12/3.70/3.60 3.30 3.28                  |
|          | 3rd Segment    | PVS-1 > PVS-2 > MPS > AP.1+2+3+4 > VC .<br>6.44 6.07 5.40 4.91/4.66/3.86/3.61 2.92                            |
| Exp. # B | Ground Floor   | MPS > PVS-1 > AP.1 > VC > AP.2+3+4+5 > EN .<br>8.14 4.84 4.57 4.38 4.29/4.28/4.22/3.80 3.58                   |
|          | 4th Segment    | AP.1+2 > MPS > AP.3 > PVS-1 > AP.4 > VC .<br>4.53/4.53 4.44 4.36 4.18 4.12 3.54                               |
| Exp. # C | Ground Floor   | MPS > PVS-1 > EN > AP.1 > VC > AP.2+3+4<br>5.31 5.04 5.02 4.89 4.72 4.70/3.89/3.75                            |
|          | 4th Segment    | MPS > VC > PVS-1 > PVS-2 > AP.1+2+3+4+5<br>6.49 5.69 4.55 4.51 4.26/4.24/4.22/4.02/3.48                       |
| Exp. # D | Ground Floor   | PVS-1 > AP.1 > PVS-2 > AP.2 > MPS > VC > AP.3+4+5 > EN .<br>5.36 5.02 4.64 4.44 4.42 4.41 4.35/4.29/3.79 3.49 |
|          | 2nd Segment    | PVS-1 > VC > AP.1 > MPS > AP.2+3+4+5+6<br>5.13 5.04 5.02 4.23 4.11/4.05/3.92/3.53/3.51                        |

Key: MPS: Main Public Space, PVS-1: Semi-Private Space (#1), EN: Entry Hall  
 VC: Vertical Circulation Core, PVS-2: Semi-Private Space (#2), AP: Apartments

- Social Indicator (6): Visual Privacy

The isovist analysis for the selected solutions showed that visual fields from centres of common spaces toward apartments are preserved (Figure 5.127). Same results were observed from the analysis of visual fields along the movement path between apartments.

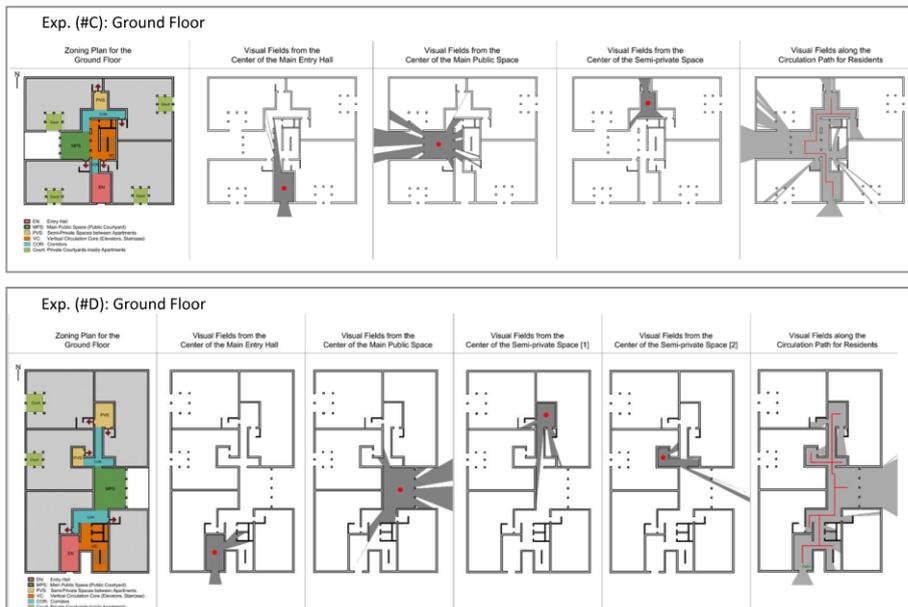


Figure 5.127: Isovist analysis from the centre of each common space on the ground floor Experiments #C and #D

### b. Economic Qualities

In contrast to the solutions generated by the researcher, results of the spatial analysis for alternatives designed by participants showed that percentages of designed spaces from the total allowable area are ranged between 84.1% and 87.5% (Table 5.31). Such reductions are due to intuitions of designers for generating creative forms rather than achieving an economic value for their designs. However, number of apartments that have been designed in comparison to the area of the building could compensate developers for the loss of area. The area of all apartments represents more than 81% of the designed area (Figure 5.128).

Table 5.31: Percentages of designed spaces from the total allowable area for the selected experiments

| Experiment No. | Total Allowable Area (m <sup>2</sup> ) | Total Area of Designed Spaces (m <sup>2</sup> ) | % of Designed Spaces | % of Common Spaces from Designed Areas | % of Residential Units from Designed Areas | No. of Residential Units | Average Area of Each Unit (m <sup>2</sup> ) |
|----------------|--|---|----------------------|--|--|--------------------------|---|
| Exp. #A        | 7000 m <sup>2</sup>                    | 6067 m <sup>2</sup>                             | 86.7 %               | 16.3 %                                 | 83.7 %                                     | 51                       | 100 m <sup>2</sup>                          |
| Exp. #B        | 16200 m <sup>2</sup>                   | 13620 m <sup>2</sup>                            | 84.1 %               | 21.7 %                                 | 78.3 %                                     | 58                       | 184 m <sup>2</sup>                          |
| Exp. #C        | 16800 m <sup>2</sup>                   | 14704 m <sup>2</sup>                            | 87.5 %               | 16.1 %                                 | 83.9 %                                     | 94                       | 131 m <sup>2</sup>                          |
| Exp. #D        | 13500 m <sup>2</sup>                   | 11605 m <sup>2</sup>                            | 86.0 %               | 20.0 %                                 | 80.0 %                                     | 68                       | 136 m <sup>2</sup>                          |
| <i>Average</i> |  |   |                      | <b>18.5 %</b>                          | <b>81.5 %</b>                              |                          |   |

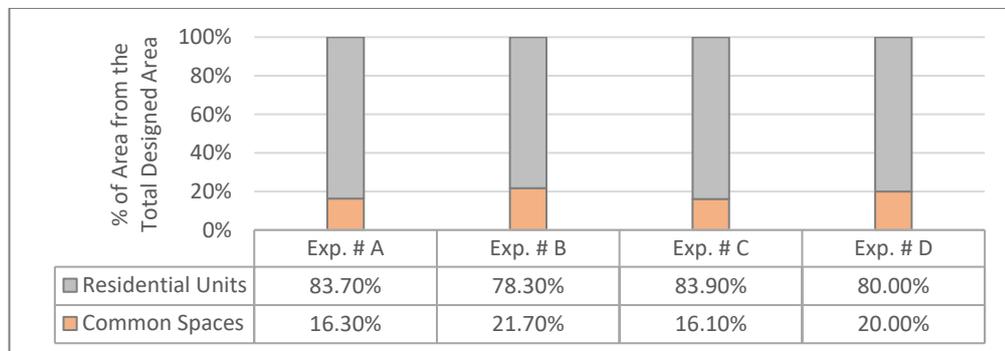


Figure 5.128: Percentages of common spaces and residential units from the total designed area

Main public spaces (MPS), and semi-private areas in front of apartments constitute only 5.11% and 2.80%, respectively, from the area of the building. The average percentage of courtyard area inside apartments is 5.36% (Figures 5.129 and 5.130). Furthermore, corridor spaces represent less than 5% of the total area. A sample of detailed calculations carried out by the tool is represented in (Figure 5.131). Results for other cases are shown in (Volume 2 - Appendix (5-C-8)).

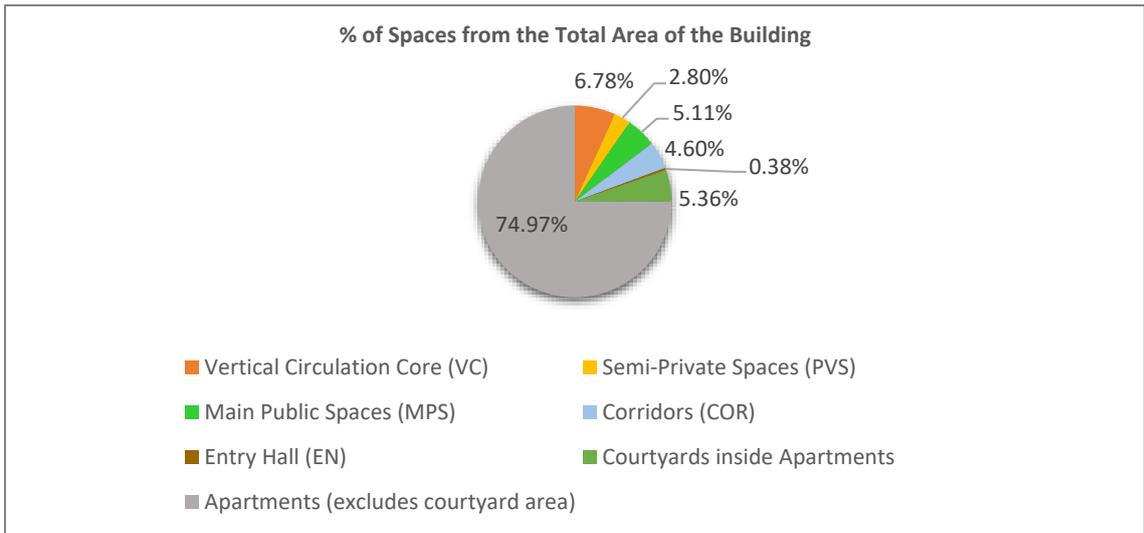


Figure 5.129: Average percentages of different spaces for the selected experiments

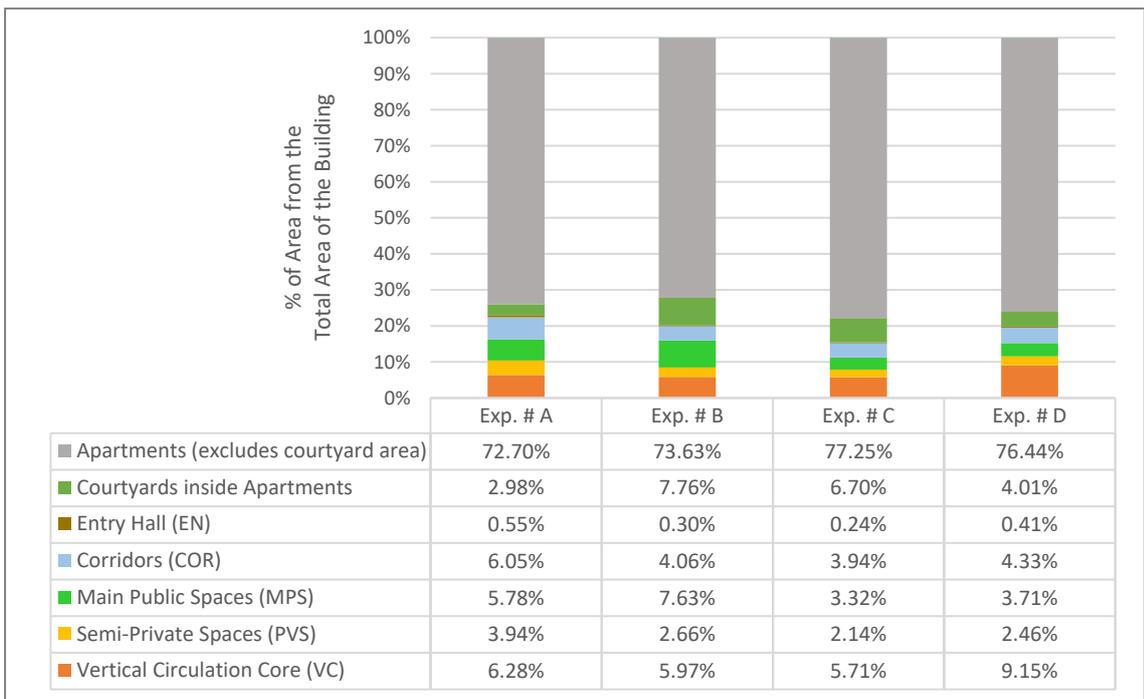


Figure 5.130: Percentages of different spaces from the total designed areas for the selected experiments

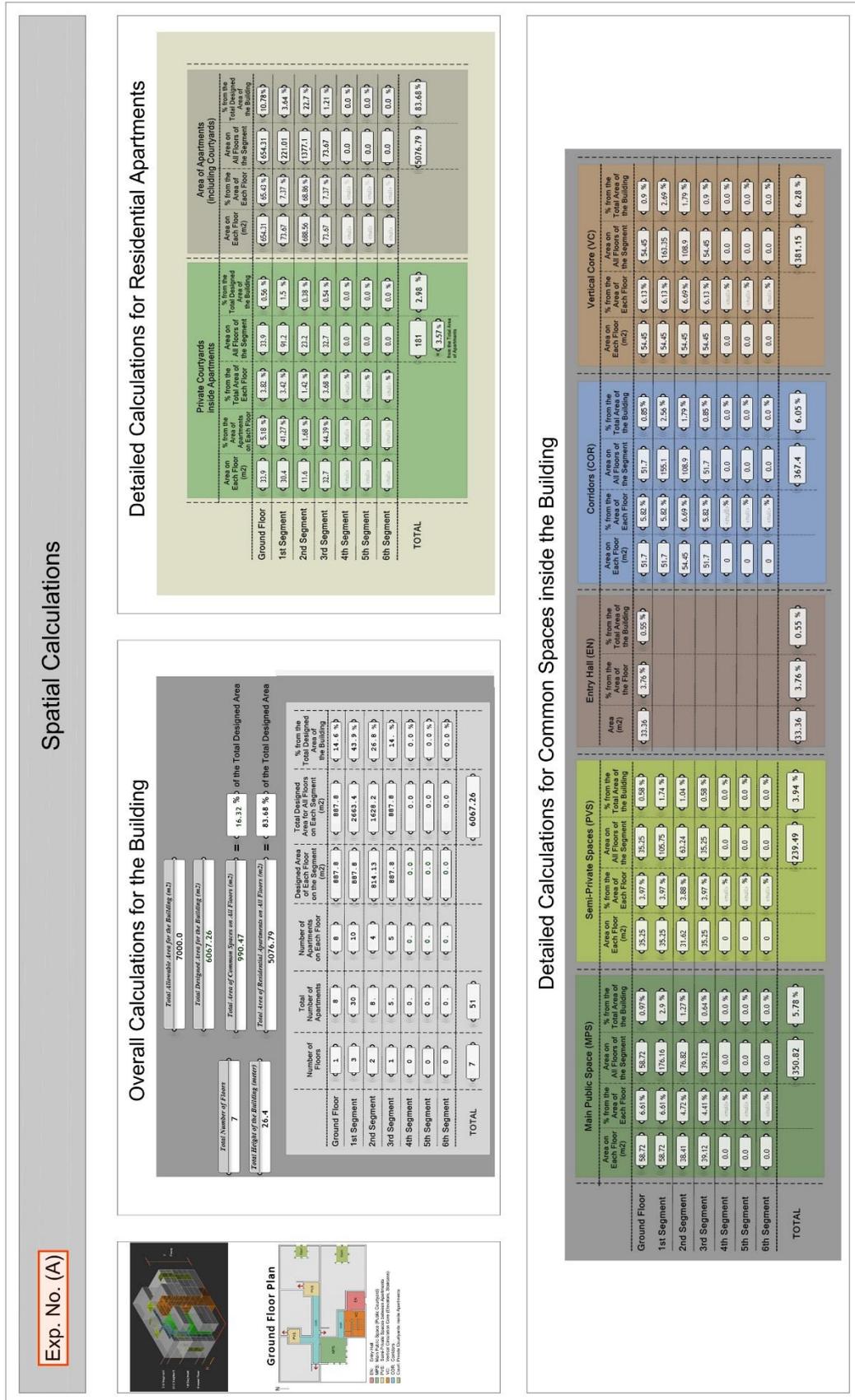


Figure 5.131: Detailed calculations for the different spaces for Experiment #A

### 5.13.4. Summary of the Evaluation Process for the Four Experiments

After analysing all dimensions of sustainability for the selected four alternatives produced by participants, the proposed design (#B) achieved the highest value (95%) regarding the five social criteria: hierarchy of spaces, crowding, social interaction, visual privacy, and viewing the outside context. However, the other three designs (Exp. #A, #C, and #D) achieved 85%, 79%, and 82%, respectively (Figures 5.132 and 5.133). The evaluation process depends on assigning 100% for the best case that achieved this quality. Percentages for other cases for the same aspect have been normalised according to the best solution.

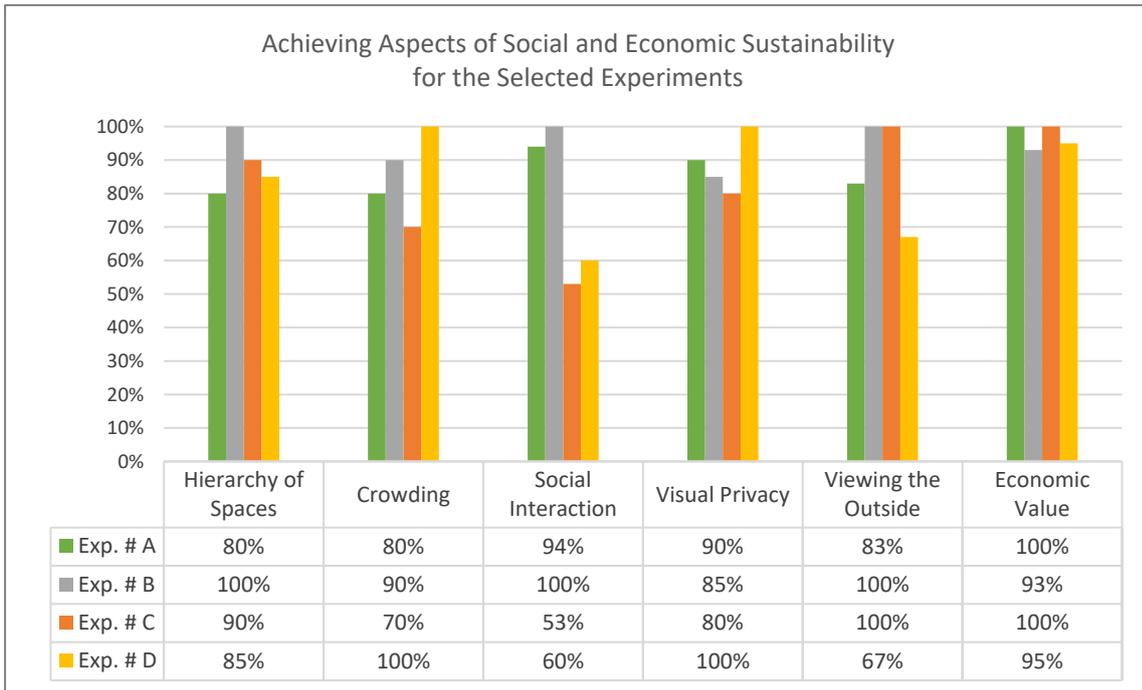


Figure 5.132: Achieving aspects of social and economic sustainability for the selected experiments

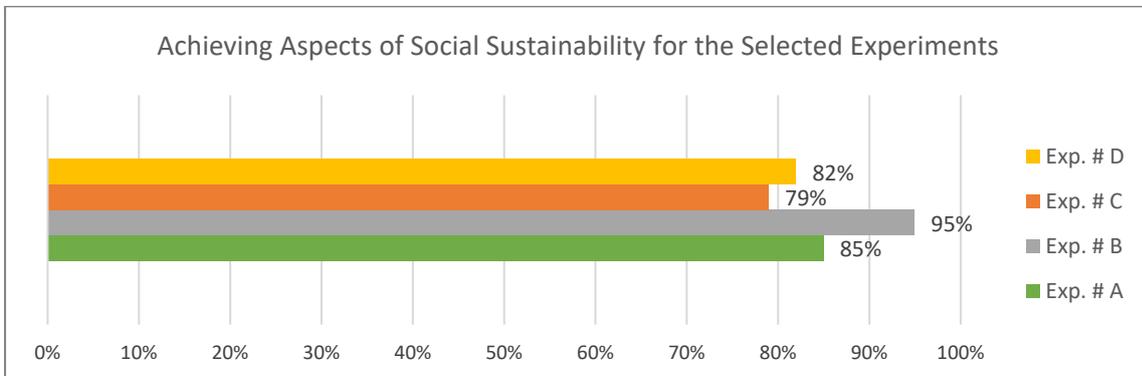


Figure 5.133: Achieving aspects of social sustainability for the selected experiments

### 5.13.5. Results from the Usability Evaluation

Results collected from answers on the questionnaire showed that most participants have positive feedback about the tool. Based on their replies to questions, and comments they raised during the implementation process, the following are the main findings of the evaluation:

#### a. Effectiveness of the Tool

- More than 45% of participants suggested that the tool can be used effectively in professional practice. 82% of the sample expressed their interests to use it in early stages of the design (Figure 5.134).
- It offers designers a flexible system with parameters that could be modified according to their ideas. However, more than 45% of users created designs that were not expected.

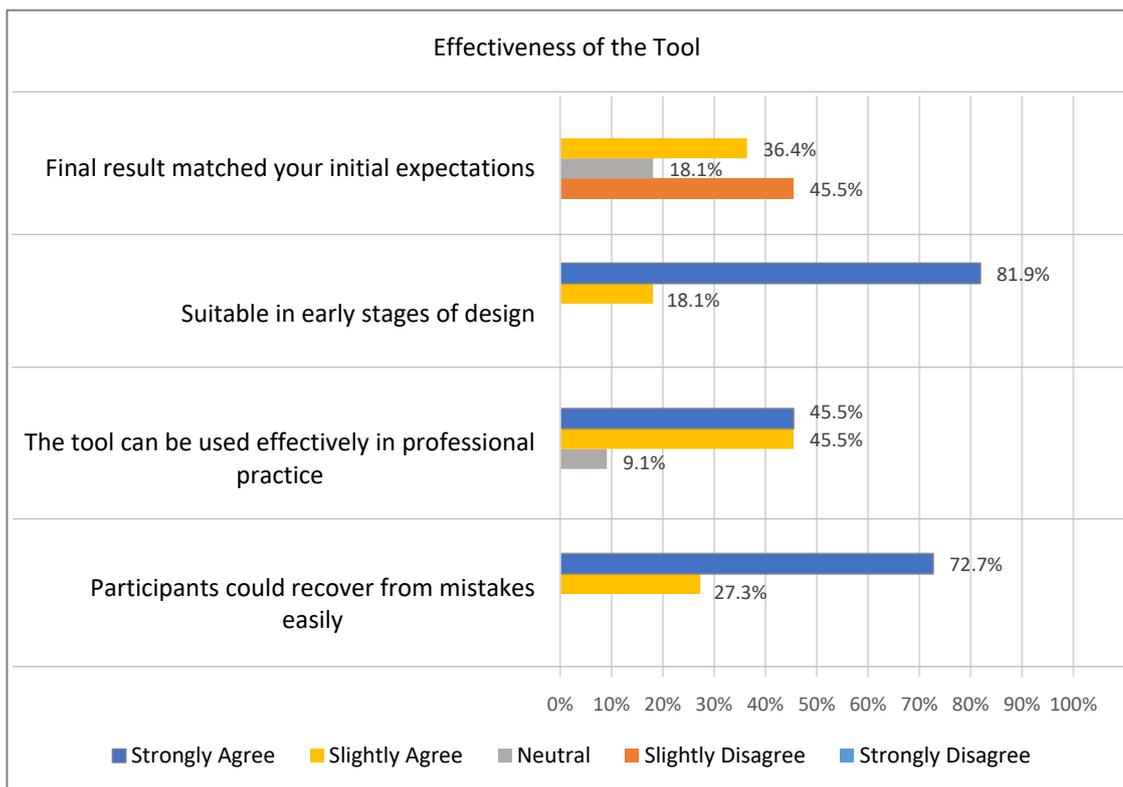


Figure 5.134: Results of the questionnaire regarding the effectiveness of the tool

- During the implementation, only 27% of users faced errors when they searched for suitable alternatives for some spaces, such as corridors (Figure 5.135). However, 73% of them recovered from mistakes easily.

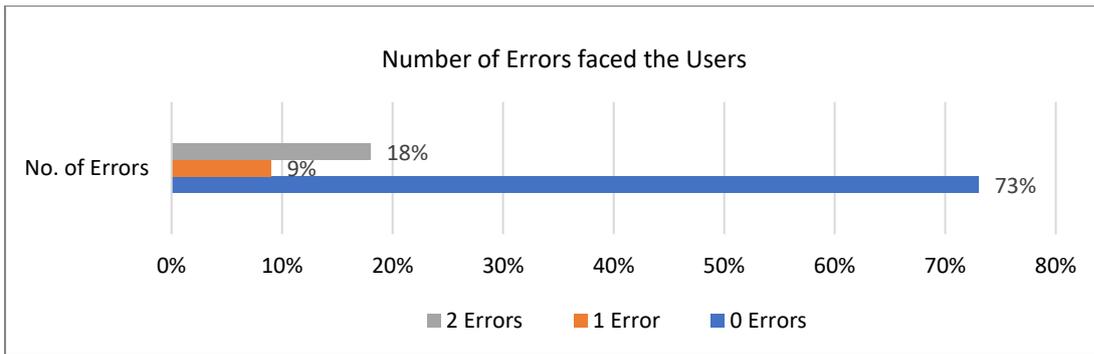


Figure 5.135: Number of errors faced the users during the implementation process

**b. Efficiency of the Tool**

- The tool offers architects and students the ability to finish the design in a short amount of time in comparison to other applications (Figure 5.136). This is due to the structured process that they need to follow, and the predefined parameters that control the generation process. Usually, a third-year student can finish the design for a building in 40 minutes using the tool, while he/she needs between 4 to 5 hours to complete a sketch manually or using other software.

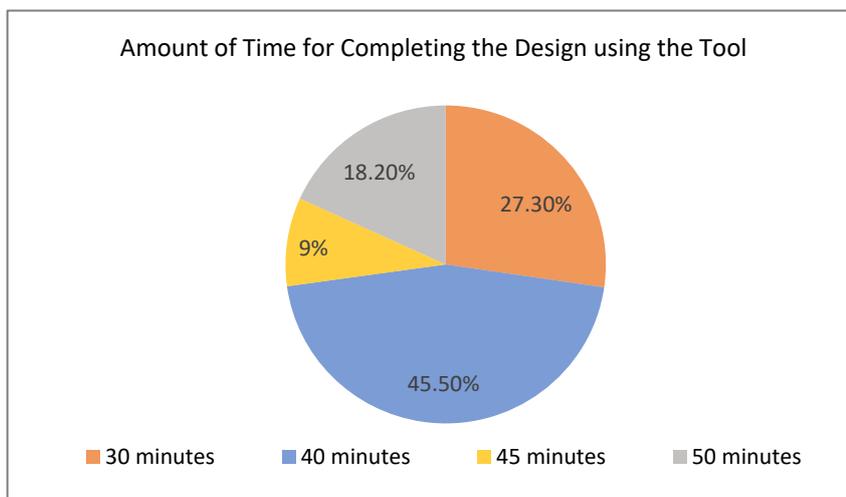


Figure 5.136: Amount of time for completing the task using the tool

- Most users (82% of the sample) indicated that performing tasks was easy to learn. More than 54% of participants found that information provided with each stage was clear and effective to complete the task (Figure 5.137). However, 27%, 18%, and 36% of participants asked 2, 3, or 4 questions, respectively, about commands, while only 18% asked questions about the design process (Figure 5.138). These queries were concentrated mainly on how to use commands in Grasshopper, and what are minimum and maximum values for number sliders. Such comments are useful for enhancing the

representation of the interface through adding more descriptions, or changing the type of a menu in a particular stage of design.

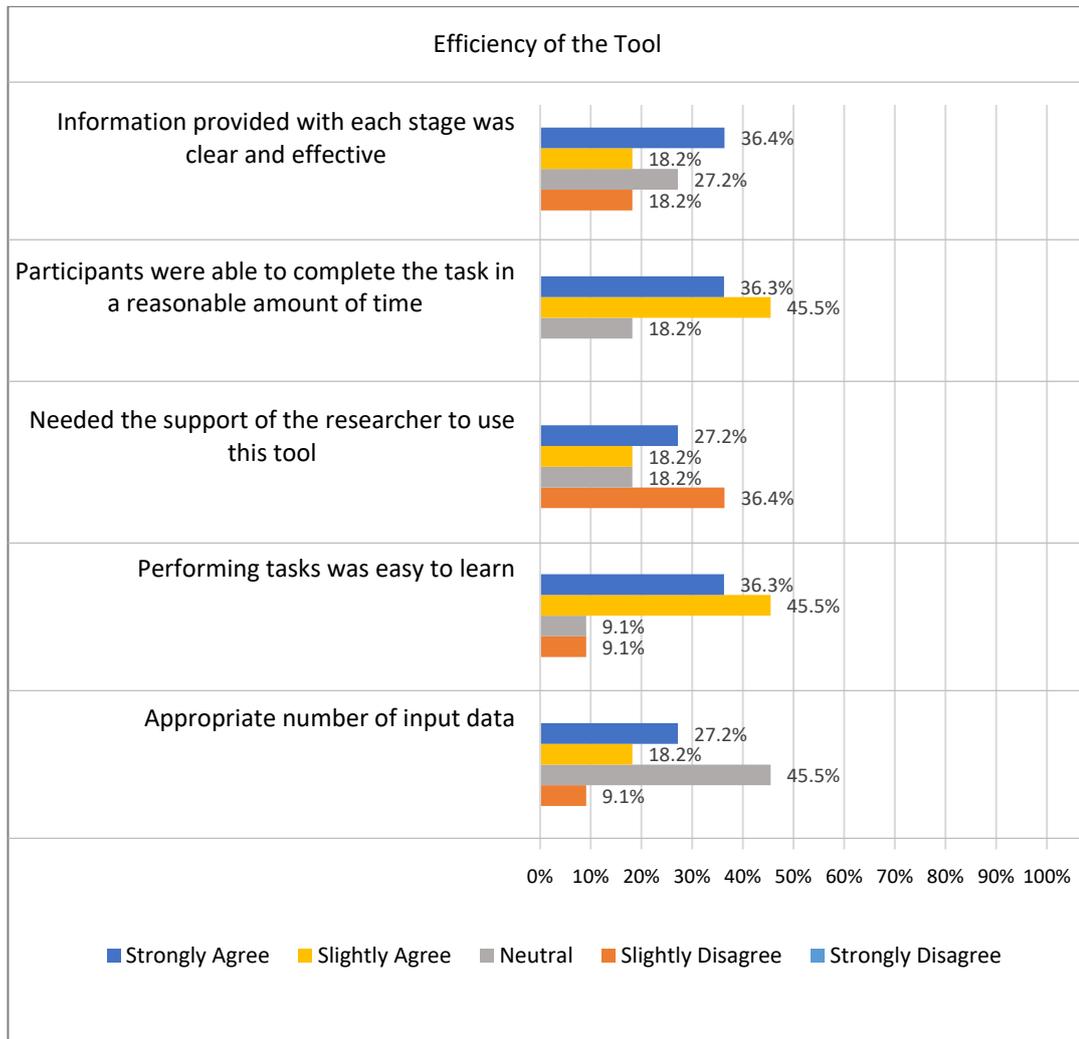


Figure 5.137: Results of the questionnaire regarding the efficiency of the tool

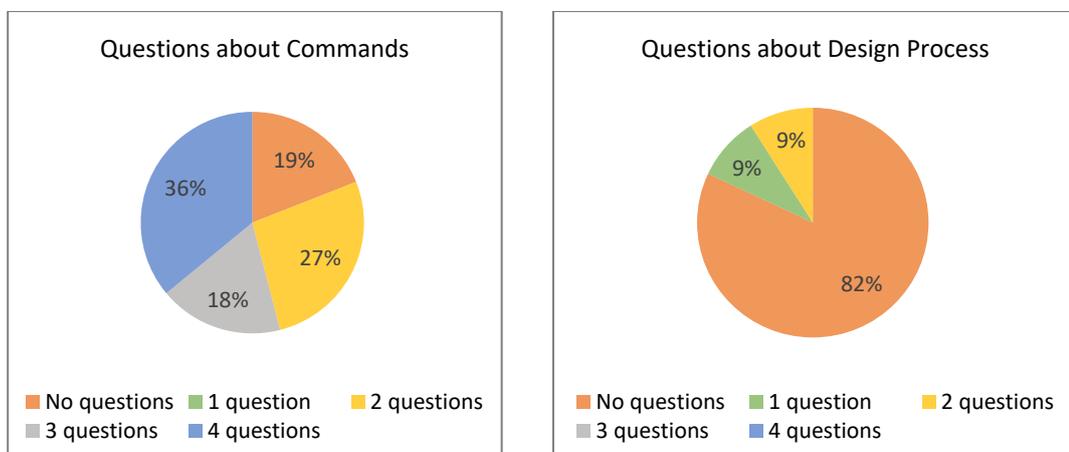


Figure 5.138: Number of questions by participants about commands and design process

### c. Satisfaction with the Tool

Most participants were satisfied with the tool as a design instrument for generating high-rise residential buildings. More than 63% of the sample indicated that they can become more productive using the tool (Figure 5.139). Moreover, 73% of participants found the organisation of the interface was clear. No user expressed clear frustration during the implementation process.

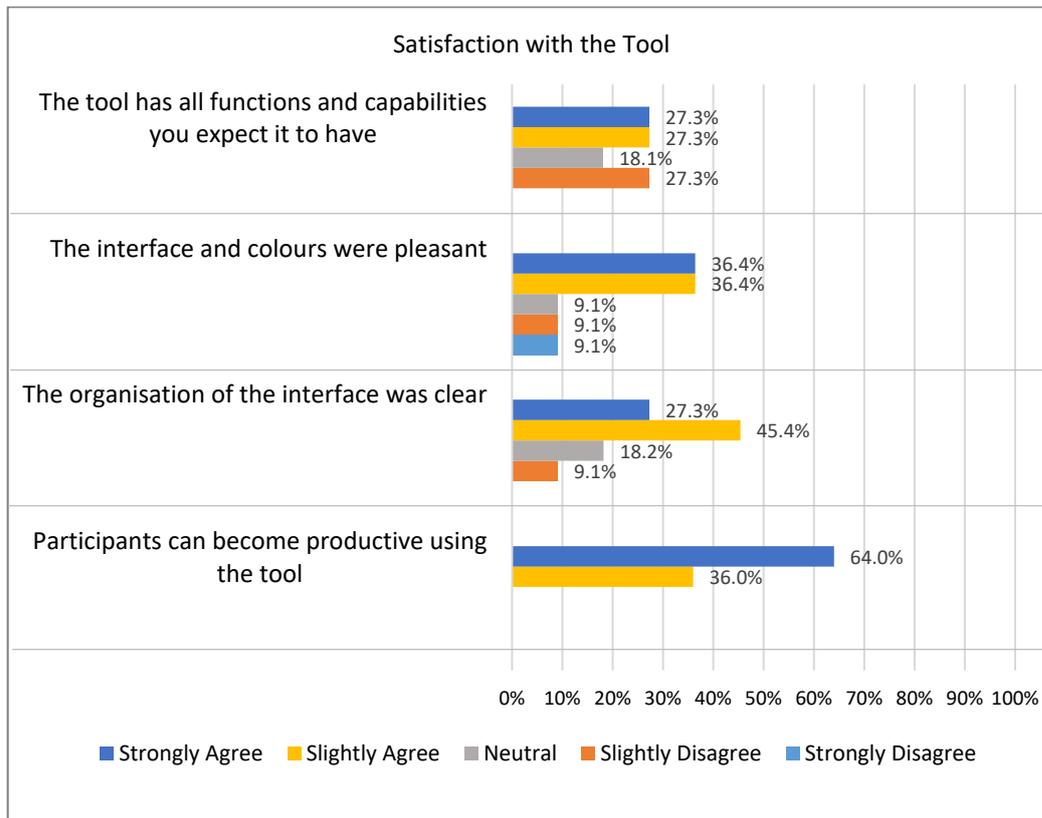


Figure 5.139: Results of the questionnaire regarding level of satisfaction with the tool

Participants raised the following issues as positive capabilities for the tool:

- Quick to show three-dimensional views and two-dimensional layouts for the different segments of the building,
- Easy to return to previous stages of the design,
- Using a distinctive colour for each zone makes the process much easier,
- The automated optimisation process for finding the best layout for apartments provides solutions that are not easy to achieve manually,
- Predefined relationships between spaces allow a quick process of design.

However, users suggested a list of issues to be considered for enhancing the interface:

- Add more alternatives for the location of the vertical circulation core, and the entry hall.
- Add more details for the design, such as windows, the shape of structural columns, structural calculations.
- Add the cost estimation as one of the factors for the optimisation process.
- Add more descriptions about minimum and maximum values for parameters.
- Allow designers to change orientation of spaces.

### **5.14. Conclusion**

The assessment process and the usability evaluation for the computational tool showed that the intended objective of the model for generating socially sustainable residential buildings had been achieved successfully. A class of satisfactory alternatives for mid-rise and high-rise buildings were constructed by changing parameters embedded in the model, with no need to build it from scratch. Moreover, the tool allows architects to think dynamically with multi-dimensional constraints rather than traditional methods that focus on a single design solution.

Although the tool is limited to orthogonal rectangular layouts, and falls short on generating other complex shapes, it gives the user flexibility to capture the relationship between public and private zones, and the integration of a series of public courtyards distributed on the different levels of the building, with the possibility of generating a private courtyard inside each apartment. These open spaces offer residents to enjoy the outside views, and achieve a thermal comfort inside the building.

Spatial and syntactical analyses for the different options showed that a set of predefined spatial parameters and topological relationships allows designers to arrange spaces in a hierarchical system of movement, from public areas to private zones. For instance, constraints that determine the location of the vertical circulation core and its relation with apartments add a social value to the design through preserving the privacy of each family. Moreover, the distribution of public courtyards on different floors offers a mechanism for decreasing crowding and enhancing social interaction between residents.

Another advantage of the tool is that common spaces could be arranged only in a non-linear pattern, which, therefore, breaks the visual fields inside the building and maintains the privacy of the family. Also, constraints on the maximum area of these spaces add an

economic value for the design. The tool offers developers to include public spaces and private courtyards that constitute only 11% of the area of the building. However, these features are part of the rentable area and aid the selling of the apartment quickly. Thus, there is a revenue with no loss area. Furthermore, there is an omission of corridor spaces, which represent less than 5% of the total area.

The usability evaluation indicated that most users were satisfied with the tool as a design instrument for generating high-rise residential buildings. Moreover, they expressed their interests to use the tool in the early stage of the design, as they can investigate alternatives that would be hidden. The tool offers architects and students the ability to finish the design in a short amount of time in comparison to other applications.

Chapter Six

**Research Conclusion**

## Chapter Six:

# Research Conclusion

### 6.1. Introduction

The Middle East and North Africa (MENA) region has one of the world's most rapidly expanding urban population. One of the dramatic impacts on the built environment is the emergence of high-rise residential buildings. Most recent developments in the study area are constructed as iconic buildings that ignore the specifics of the cultural context, lifestyle, living patterns, local traditions, and climate. Although there is a focus on utilising technology and creating environmentally sustainable solutions, most designs have ignored the potential of incorporating social needs and cultural values. Therefore, a balance between social sustainability and other economic and environmental dimensions is one of the requirements that designers may need to achieve.

Outcomes from the survey, which was conducted by the researcher in MENA region, and focused on the spatial design of new apartment buildings and its effects on the social life of residents, showed that most families have lower levels of satisfaction in terms of: (1) security and safety, (2) human comfort, (3) social relations with neighbours, (4) availability of open spaces and living areas, (5) visual privacy; and (6) accessibility. The survey indicated that the current situation of apartment buildings do not afford secure spaces for children, as parents keep them inside apartments due to safety concerns and difficulties of supervision at a distance. Moreover, residents have a problem with social interaction with neighbours, due to the lack of gathering areas inside buildings or in front of their apartments. Thus, lack of social support and sense of community and familiarity with neighbours are significant negative impacts on residents. Most residential units are crowded due to the small area of family zones and outdoor spaces, such as terraces and balconies. As a result, residents changed the original layouts of their houses to accommodate their needs. Finally, the excessive use of glazed facades, and the location of entrances opposite to each other, destruct the privacy of the family. Most of the residents would prefer to have outdoor terraces and courtyards inside their houses and buildings, as they feel that these features allow a high degree of social interaction with neighbours, and increase the interaction with

the environment, as it gives access to the natural light and ventilation. Although there is a trend of inserting a central atrium in residential buildings, it is not exposed to the daily life, so it seems to be lifeless.

In contrast, many studies revealed that the vernacular model of houses and neighbourhoods in the study area offer a successful example of socially cohesive and healthy environment. Most of these dwellings consider the cultural, social, and local living patterns of residents, through a hierarchical configuration of public spaces and private courtyards that allow for a high degree of social interaction between families, and at the same time maintain their privacy. Results of spatial and syntactical analyses for traditional houses and neighbourhoods largely confirmed these findings. Historically, courtyard houses were the most spread types of residential buildings in the hot-arid regions of the Middle East and North Africa. The courtyard is the most significant space in the house and the most accessible and connected function. Other functions are controlled and accessed through the courtyard and follow its geometric pattern. Moreover, the deep location of private areas and intimate spaces related to the courtyard provides a protected and comfortable atmosphere for the family members.

Learning from previous experiences, and investigating the current needs of the society, were adopted as a strategy for generating sustainable vertical buildings that could enhance the social life and the well-being qualities, such as privacy and security. However, research projects that explicitly address the application of vernacular strategies, such as courtyards and public spaces, in contemporary high-rise developments are rare. Most studies are history-oriented and describing how this kind of architecture worked in the past. Moreover, spatial features that promote social sustainability were neither fully explored nor widely recognised.

This research aimed to extract topological relationships that reflect the culture and social values of the society. The study adopted different computational methods for analysing historical cases based on spatial reasoning approach. Computational models are widely used for processing the design in its various stages - including analysis, simulation, and generation - efficiently and accurately. However, the current focus of computational models, such as shape grammar, is primarily limited to formal/geometrical aspects. Non-geometrical components, such as psychological requirements and social/cultural constraints, are also critical aspects, as they offer a comprehensive understanding of the design problem, and harmonise the output with its context and the needs of its users.

Therefore, the study contributed to this growing area of research, by providing a mechanism for measuring, coding, and representing social realities in computational models. Results of this analytical process were used to construct a set of socio-spatial rules for developing a flexible computational design tool for architects that guides the emergence of sustainable high-rise residential buildings. The tool allows the ability to reveal logical spatial topologies based on social-environmental restrictions, and produce prototype solutions that offer a balance between rationality and creativity. The hot-arid region of the Middle East and North Africa (MENA) region was selected for the implementation of the model.

The following are important areas where the study made an original contribution:

- The development of a mechanism for measuring and coding the different indicators of social sustainability.
- The development of a structured analytical system that traces the social life inside residential buildings.
- The construction of a socio-spatial parametric grammar, extracted from vernacular houses and neighbourhoods, for the design of contemporary high-rise residential buildings.
- The development of a flexible computational design tool for architects that guides the emergence of sustainable high-rise residential buildings, with the ability to reveal logical spatial topologies based on social-environmental restrictions.

The following sections discuss these contributions to the architectural design process, the main benefits and implications of the study. Finally, recommendations and directions for future studies are illustrated.

## **6.2. Design Process as a Balance between Rationality and Creativity**

In the field of architecture, designers aim to create artefacts and organise spaces to accommodate activities that satisfy human needs. They use their knowledge, experience, and creative skills to transform their ideas into forms. In professional practice, different approaches could be adopted. The first is a rational approach, where architects focus on a systematic process and perceive the design from a social point of view (Williams *et al.* 2011). This leads to designs that consider the program and the different needs of users. The second is more artistic, and concentrates on aesthetic values and the overall image of the form. However, a holistic design process needs a dynamic balance between both perspectives, in

addition to other technical, economic, and environmental requirements. In this way, creative, practical, and appropriate solutions could be achieved.

The present study adopted this holistic perspective that views the design as a combination of rationality and creativity in the development of a parametric computational tool. The process started with defining the geometric properties of objects, and correlations between each other, as rules and relationships that are associated with parameters. These constraints were specified clearly according to specific indicators that reflect aspects of social sustainability in vernacular houses and neighbourhoods. Moreover, they revealed the current spatial needs of users, and the different requirements of high-rise buildings. This finite number of specific steps and generative rules reflects the rationalist model for addressing and solving a design problem.

However, the tool does not exclude creativity and innovation from the design process. The construction of the system was guided by a rational reasoning grammar. Shape grammar is a formal approach that provides a systematic review of existing designs that have specific typology or style. This knowledge can be categorised based on several criteria to construct a database that consists of design elements, conditions, parameters, and actions (rules) that define relationships between shapes, or transformations to be applied on shapes. Using this approach, which is an example of models in the field of computational creativity, designers can revise parameters, and control the application of rules, to modify their designs at any stage (Tching *et al.* 2017). Accordingly, the system allows the generation of a wide range of new solutions that are within the same stylistic language. Results emerged from applying these rules could enrich the design product with new vocabularies and unexpected compositions.

Another advantage of this system of form-finding is that it offers designers more productivity, as they can understand the problem, and develop solutions synchronously. The usability evaluation showed that the amount of time that the architect needs to finish a schematic design for a high-rise building reduced from 5 hours, using a manual process or other applications, to 40 minutes, using the developed tool.

### **6.3. Measuring Social Sustainability**

Social sustainability is about designing for impact, and therefore, improving the quality of life. This social function of architecture could be realised through spatial organisations. One

of the challenges for achieving this aspect is the difficulty of identifying suitable measures that represent the social needs of users. However, these metrics are different from statistical social data or environmental indicators.

The study contributed to this area of research through developing a system of analysis that allows architects the ability to integrate social parameters in the spatial design of buildings. A total of 13 social indicators, with different modes of representation, such as numbers, diagrams, and textual descriptions, were identified, and used to define parameters, rules, and constraints. These indicators are the following: (1) population density and crowding; (2) hierarchy of spaces; (3) social interaction and amount of living areas; (4) human comfort; (5) accessibility; (6) visual privacy; (7) acoustical privacy; (8) olfactory privacy; (9) spirituality; (10) security and safety; (11) views to the exterior; (12) availability of services; and (13) hygiene.

Each social indicator has different layers that could be measured at both scales: the residential unit, and the cluster. The study adopted two approaches for recording and encoding these social aspects. Firstly, a phenomenological survey has been conducted as a method to record residents' needs and concerns, and to clarify specific cultural and social values. An online questionnaire has been distributed to families from 17 countries within the study area, to collect information about (1) the house and the household structure; (2) spatial descriptions; (3) social merits; (4) environmental qualities; and (5) information about neighbours and the house context. Information gained from the survey were encoded and presented as spatial parameters and specifications.

Secondly, 'spatial reasoning' for selected precedents from the study area was adopted as a rigorous method for addressing features that have social or experiential significance. Moreover, it enables designers to obtain a better understanding of the layout complexity and the social logic of spaces. For instance, studying the location of spaces, and measuring distances between functions, are useful for analysing accessibility and movement. Defining relationships between spaces offers information about their hierarchy, and the degree of social interaction that takes place within them. Tracing visual fields from selected locations in a building allows a precise evaluation of spatial elements that affect the privacy of its occupants. Information extracted from these cases were categorised into classes and prototypes, and presented as abstracted diagrams, which are associated with descriptions and spatial parameters.

Two types of analyses were used to understand this complexity. The first approach is 'typological analysis', which involves categorising components of designs that have shared

characteristics according to predefined criteria (such as location, area, geometric properties, and patterns of arrangement). The second approach is 'syntactical analysis', which explores topological and social relations implicit in the architectural setting. These two approaches offer 'declarative knowledge' about the building, and 'procedural knowledge' about the design (Achten 1997).

Results extracted from the syntactical analysis, such as control and integration values, are useful for interpreting the social life and the overall configuration (e.g., high integration values indicate that spaces are busy, more accessible, and less private). Different computational tools were used for carrying out syntactical analyses. Firstly, *Syntax2D*, to execute isovist analysis that addresses the visual fields of a person at one location of the environment (e.g., the main entry point of the neighbourhood, and from the entry point(s) of each house in the cluster). Secondly, *DepthmapX*, which is a 'Visibility Graph Analysis (VGA)' tool to understand the spatial configuration of the environment. VGA includes (i) connectivity analysis that creates visibility connections between all spaces; and (ii) agent analysis, which indicates patterns of movement, and the frequent use of spaces released from selected locations. Thirdly, *AGraph*, which is a 'node-and-connection model' that produces syntactic calculations and justified graphs, which include: depth of spaces; and integration of functions.

The analyses mentioned above require from designers an extra effort to calculate spatial qualities, such as areas and proportions of spaces. Moreover, the use of *AGraph* software for extracting syntactic values requires drawing the 'node-and-connection' justified graph manually. Thus, errors could easily occur during this process. Another limitation of these graphs is that it does not generate accurate descriptions of the formal reality of the design. For instance, spaces could be connected in different alternatives, and have the same justified graph. Furthermore, functions located on different levels/floors need to be identified from other nodes in the system.

Therefore, the study suggested an automated model of syntactical analysis, embodied in Rhino/Grasshopper, which offers an alternative method for extracting spatial topologies and syntactic calculations. The developed model of analysis adds new aspects to the justified graph of Hiller and Hanson, as a representation of formal and social realities. These additional issues are the following: (a) hierarchy of spaces (public, semi-public, semi-private, private, and intimate); (b) orientation; (c) type of enclosure (covered, open, and semi-open); (d) shared surfaces between adjacent spaces; (e) on which floor a space is located, and (f) entry

point(s) between spaces. Moreover, it reveals geometric proportions for each space; percentage of space area from the overall area of the layout; and the dominant users for each space (male, female, or both). These issues are presented as visual diagrams, which include: (1) patterns of movement, and distances between spaces, to analyse accessibility and security inside houses; (2) the actual geometry of each space rather than symbolic nodes.

The model depends on generating the layout of buildings according to a 'space partitioning' mechanism, using non-manifold topology (NMT), to define topological relations between adjacent spaces without any void. This tool could be efficiently used to analyse floor layouts that have any size or geometry in a short time of execution, and with a high degree of accuracy that does not require the user to possess an advanced level of knowledge in syntactic analysis.

#### **6.4. Qualitative Representations in Computational Models**

Analysing social indicators creates a database that identifies spatial elements and specific relationships, which can be used by designers to improve the social qualities of future developments. Embedding these qualitative aspects in the decision-making process requires a system of representation.

The study examined one computational tool that is used for generating forms. Shape grammar is a ruled-based system that has a bottom-up approach. It starts with an initial shape, and then applying pre-defined rules recursively on forms. However, shape grammars do not clarify social, cultural, and environmental dimensions of designs, as they deal only with formal properties. Moreover, some design possibilities generated by shape grammar are geometric abstractions rather than meaningful designs.

Therefore, the study adopted 'discursive grammars' that add more information as textual descriptions associated with rules and objects. These explanations could define some properties of the design, such as height and number of doors, or explain conditional specifications, such as room capacity, the dominant users for each space, and adjacency relations between functional zones.

Moreover, spatial parameters, which reflect specific social meanings, were attached to the definition of rules. In this way, limitations found in traditional shape grammars, such as semiotic and semantic dimensions, have been addressed. Each parameter could be represented as a condition, or a numeric domain that includes minimum and maximum

values. The following parameters were defined: (a) area of each space relative to the total area of the building/house, (b) geometric properties of each space (length and width), (c) location of each space, (d) functions that are adjacent to the space, (e) patterns of openings, (f) orientation, and (g) thickness of walls. Changing values of parameters could affect aspects of social sustainability. For instance, increasing width of living spaces could enhance social interaction and decrease crowding. Changing the orientation of a courtyard could affect the thermal comfort of residents, and their ability to view the outside. Using this approach, the efficiency, adaptability, and flexibility of the design could be increased.

Based on the socio-spatial catalogue extracted from the analytical process for historical cases, two groups of grammars were constructed. The first group illustrates the language of vernacular houses in MENA region. Seventeen sets of rules, with a total number of 185 parametric rules, were defined. Each set addresses the spatial configuration of a particular vocabulary/function. Labels that describe the function of each space, its corners, and its centre are associated with shapes and points. These labels were used to control shapes and application of rules. A rule could be applied if the left side of the rule matches topological relationships between that element and other spaces, regardless the geometric properties of the space. As the courtyard is the main feature in traditional houses, topological relations for other functions depend on the location of the courtyard. The grammar allows architects the ability to arrange spaces on one floor or two floors.

The second group defines the language of traditional neighbourhoods in the study area. It includes 73 parametric rules, which were categorised into seven groups. Mathematical expressions, which address geometric aspects such as area, width, length, and orientation, were attached to these rules to reflect the different dimensions of social sustainability.

Findings revealed from the validation process for the constructed grammars showed its potential for implementing strategies of social sustainability. For example, the *Isovist* analysis and the Visual Graph Analysis (VGA) for a new alternative for a courtyard house indicated that the privacy of the household is protected from public and semi-public spaces (the entry hall and the guest room). This protection is due to the description of spatial rules that strictly limits the visual access to the courtyard by using different mechanisms, such as the bent entrance, the use of partitions in front of the main entrance, size, and location of windows for guest rooms. Another successful dimension that has been achieved is the hierarchical arrangement of zones from public to private. Such a requirement needs to define certain topological relationships between spaces. In this specific case, values that represent the

distance between the main entrance (a public space) and the guest room (a semi-public zone), need to be lower than the distance between the entry hall and the bedroom (an intimate area). Thus, a protected atmosphere for the family members could be achieved.

### **6.5. A Transition from Standard Mass Buildings to ‘Contemporary-Vernacular’ Sustainable Developments**

Most of the contemporary high-rise developments in the study area are characterised by a mass building that might not be differentiated from one city to another. The field survey and the spatial investigation of different apartment buildings showed that developers require architects to focus on meeting their financial and functional needs through adopting the concept of standardisation. In most cases, there is a lack of gathering areas and open spaces inside the building. Although there is a central atrium in some buildings as a controlled area, yet, this space seems to be lifeless as its exposure to the environment is limited. Moreover, there is a sudden transition from public zones to apartments to increase the area of residential units. Another observation is that residents depend dominantly on mechanical systems for heating, cooling and ventilation due to the excessive use of glazed facades. As a result, several impacts on residents, such as lower levels of interaction, and the destruction of their privacy, could be noticed.

On the other hand, there are successful contemporary developments that promote ‘green’ concepts, by using passive design elements to increase the link with the environment. These features include, for example, skycourts, terraces and roof gardens. Such an approach has its roots in vernacular architecture, especially in the Middle East and North Africa. As the courtyard represents the concept of a space that relates the interior to the exterior, designers in developing economies have appropriated this feature and built on its advantages (Samizay 2010; Goethert 2010). The courtyard has been adopted at different scales: the housing unit, and the cluster. Each scale maintains the concept of the courtyard as many social and cultural advantages to families could be achieved, in addition to economic and environmental benefits to the city could be added.

This ‘synthesis view’, which addresses the process of creating a balance between traditional values of living, in parallel with progress and development, refers to the concept of ‘regionalism’. Ken Yeang, for example, bases his works on the adaptation of ‘regionalism’, through understanding traditional values, as well as the importance of progress, without the direct use of traditional forms and materials (Pomeroy 2014). This approach offers a respect

for the cultural identity of the place, and consideration of the latest issues of technological developments.

As previous findings of this research contribute evidence that vernacular houses and neighbourhoods considered a socially sustainable model of residential buildings, the study adopted the concept of 'regionalism' for generating a 'contemporary-vernacular' high-rise building. This way of thinking, which leads designs to respond to specific context, is a balance between two views: the 'traditional' perspective, where designers see the loss of traditional ways and values, and the 'modern' perspective, where designers declare the inevitability of change in the age of globalisation (Ragette 2003).

Accordingly, spatial rules that have specific social meanings extracted from the traditional model were combined with requirements of high-rise buildings, to construct a socio-spatial grammar for vertical developments. The aim is to create a sustainable way of living, and a sense of local identity, without ignoring aesthetics and economic values.

The grammar built on the benefits of the horizontal arrangement of residential quarters in MENA region, through dividing the high-rise building into vertical segments, as a representation of neighbourhoods in a traditional fabric. This solution could highly promote the concept of hierarchy and clustering that creates a mutual responsibility for common spaces in each segment for encouraging interaction between neighbours. The grammar allows for the generation of a hierarchical system of public and semi-public spaces (public courtyards) on each segment of the building. Moreover, a private courtyard, surrounded by rooms on three sides at least, could be generated inside each apartment.

These rules, associated with spatial parameters, were translated into a computational tool embodied in Rhino/Grasshopper. The target is to offer designers an alternative method for implementing strategies of social sustainability in the early stage of the design, and at the same time add flexibility and creativity to the generation process. The interface provides designers with a catalogue of main spaces that are needed in high-rise residential buildings. Moreover, it allows designers to create different alternatives by modifying geometric properties and location of design elements. Finally; it offers a search for better solutions according to predefined criteria.

The tool suggests a list of 10 procedural tasks that guide the user through an interactive interface. Each task aims to generate a space or group of spaces that have the same function. The design strategy adopted in the tool is to split the building into vertical segments. The

maximum number of segments is six, and each segment could be reached up to five floors. The total number of floors that could be generated is 30 floors.

The tool offers architects the ability to evaluate their designs through different outputs: (a) two-dimensional layouts, and three-dimensional views; (b) analytical diagrams for each segment; and (c) design metrics that show detailed calculations for the different zones in the building. The assessment process and the usability evaluation for the computational tool showed that the intended objective of the model for generating socially sustainable residential buildings had been achieved successfully. A class of satisfactory alternatives for mid-rise and high-rise buildings were constructed by changing parameters embedded in the model, with no need to build it from scratch.

Different benefits could be achieved using the developed interface. Regarding social awards, the hierarchical system of movement, from public areas to private zones, and the different sizes of public and private courtyards offer a mechanism for decreasing crowding, enhancing social interaction between residents, and enjoying the outside views. Another advantage is that common spaces could be arranged only in a non-linear pattern, which, therefore, breaks the visual fields inside the building and maintains the privacy of the family.

Constraints on the maximum area of common areas add an economic value to the design. The tool offers developers the ability to include public spaces and private courtyards that constitute only 11% of the area of the building. However, these features are part of the rentable area and aid the selling of the apartment quickly. Thus, there is a revenue with no loss area. Furthermore, there is an omission of corridor spaces, which represent less than 5% of the total area.

Regarding environmental rewards, results of radiation analysis for the suggested designs showed that surfaces, which receive high amount of radiation, reduced more than 500% when it was compared with a building mass that has no courtyards. Moreover, the increased area of external facades, by integrating courtyards, allows for an access to the natural light and air to penetrate the building.

As a result, the developed parametric model that integrates spatial and social constraints, with specific topological relationships between spaces, provides an alternative approach to the construction of high-rise buildings that respect the cultural context, climate, and people. Moreover, it facilitates the production of socially sustainable solutions that have the same identity.

## 6.6. Research Limitations

Although the results of this research have been very encouraging, there are some limitations. Regarding the phenomenological study, which asked people about the current situation of their apartments, floor plans and architectural drawings of their houses were not recorded. This lack of information is due to the online distribution of the survey, where residents could not upload these drawings. However, linking responses with spatial layouts could provide a holistic understanding of the different problems.

Although the study addressed 13 major indicators for social sustainability in residential buildings, there are other factors that have direct effects on level of satisfaction. For instance, quality of finishes and materials, quality of services, annual energy cost, and the context are important issues that need to be incorporated in a larger approach. This process could be managed using Building Information Modelling (BIM) to create a digital description of every aspect of the built environment. However, such a model needs collaboration between different experts to update information at key stages of a project.

In the constructed grammar for traditional houses and neighbourhoods, all vocabularies were represented by polygons, and abstracted into squares and rectangles instead of their geometric complexity. However, the aim is to make generalisations about the vernacular model of residential buildings in the Middle East and North Africa rather than addressing specific geometries.

The same issue is for the developed computational model. The generation process is limited to orthogonal rectangular layouts and controlled by rules extracted from traditional houses and neighbourhoods. However, it falls short on generating other complex shapes as these geometries are not commonly used in historical cases.

Moreover, the different regulatory codes, such as setbacks, building heights, and building forms, for residential developments were not addressed during the construction of the grammar. This issue is due to the variety of these regulations between the different countries in the study area.

Finally, the tool suggested that the main elevation of the building is located on the South. Moreover, changing the angle of each space is not supported in the system. Yet, considering other orientations and angles require extra time for defining spatial parameters for other

spaces, as there are specific topological relations between the different areas that need to be achieved.

### **6.7. Recommendations and Directions for Future Works**

The study showed that the computational tool is an efficient and effective instrument to be adopted by architecture students and professional architects in the early stage of the design for constructing sustainable high-rise buildings. After the implementation and the evaluation process, the following are recommendations for future studies that require further investigations.

- This study outlined a systematic and structured approach for the analysis of a particular building typology in the hot-arid regions of the Middle East and North Africa. Future work could be directed to investigate other typologies, and other climate zones using the same method.
- Another area of research is to develop the interface to include extra details, such as windows, the shape of structural columns, and structural calculations, to be used effectively in the detailed process of the design. Moreover, adding rendered materials to surfaces can provide a realistic image of the design.
- A fertile area for future research is to add the cost estimation as one of the factors for the optimisation process. In this way, designers can attract the attention of real-estate developers to integrate public gathering spaces and private courtyards in the design of the building.
- The tool can be improved by integrating a machine-learning algorithm, to allow an automated optimisation process, and supplement the manual process of evaluation using other computational models. This process can lead to other best solutions that are unpredictable.
- Future development that can increase the relationship between the context and the grammar is to consider building regulations and codes of high-rise residential building, as each country has different regulatory data.
- The primary focus in the architectural design is to achieve an aesthetic value. Although beauty is a subjective issue, future research is to develop a computational method that encodes and evaluates this qualitative aspect of the design.

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**Towards a Socio-Spatial Parametric Grammar for  
Sustainable Tall Residential Buildings in  
Hot-Arid Regions**

Learning from the Vernacular Model of the  
Middle East and North Africa

**VOLUME TWO**  
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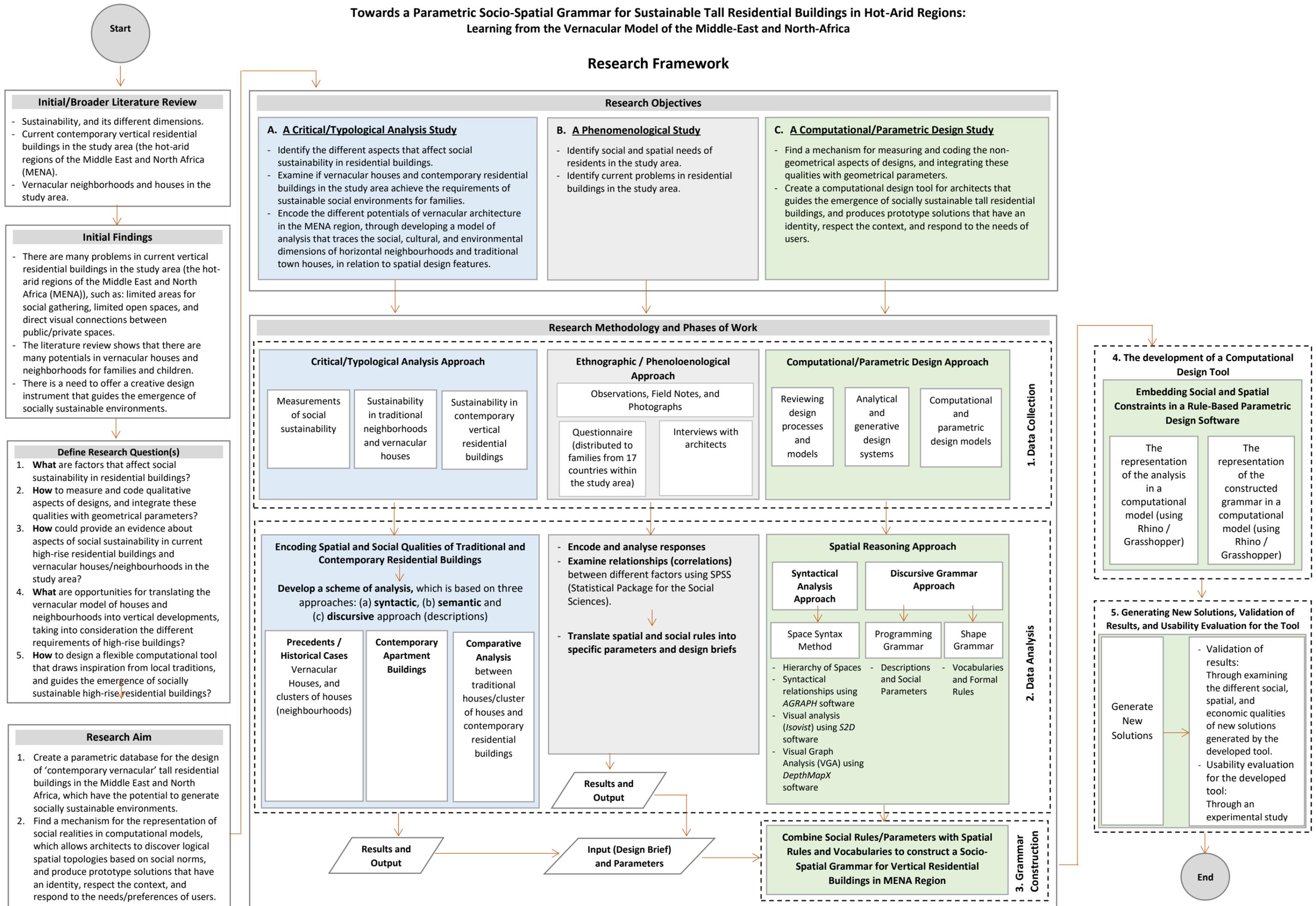
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Appendix (1 - 1)

**Research Framework**

# Towards a Parametric Socio-Spatial Grammar for Sustainable Tall Residential Buildings in Hot-Arid Regions: Learning from the Vernacular Model of the Middle-East and North-Africa

## Research Framework



Appendix (4-A-1)

**The Interview Guide with Architects**

## Interview Guide with Architects



### Investigating the Design Process and Design Features of Vernacular/Contemporary Residential Buildings in The Middle-East and North-Africa

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---

The following is a guide that outlines the main structure of the interview with architects and professionals. It is part of study undertaken for obtaining a PhD degree about generating sustainable high-rise residential buildings in the Middle East and North Africa, which trace the vernacular houses and the social and cultural values of the society.

The researcher would like to ask you some questions about traditional and contemporary housing environment. Your answers are appreciated, as the information you provide will be very helpful for understanding the different design philosophies for achieving the spatial, social and environmental needs of users and developers.

The interview will take about 30 minutes. Please do not feel obliged to answer a question if you do not wish to. Your response will be strictly confidential and used only for this academic research.

Please do not hesitate to ask any question and feel free to add your comments. Thank you for your time and feedback.

Researcher: Amer Al-Jokhadar

A handwritten signature in blue ink, appearing to read 'Amer Al-Jokhadar'.

Supervisors: Dr. Wassim Jabi - Dr. Oriel Prizeman

A handwritten signature in blue ink, appearing to read 'W. Jabi'.

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### 3. Your Design Philosophy

3.1. What do you think the most appropriate house type for this region? Why?



a. Courtyard house

b. Single house within a garden

.....  
.....  
.....

3.2. In your opinion, is it possible to include a courtyard in each apartment in the design of a high-rise building?

.....  
.....  
.....  
.....  
.....

3.3. When you design an apartment building, what are the general requirements and design features that the client usually ask for?

.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....

3.4. Which of the following factors do you aspire to have significant in your design? How?

a. The culture .....

.....  
.....  
.....  
.....

b. The context and the identity of the place .....

c. Modernity .....

d. Environmental requirements .....

e. Functional requirements .....

f. Other .....

**3.5. What are the different treatments for achieving the following qualities in the design of apartment buildings?**

a. Hierarchy of spaces (from public to private zones) .....

b. Public spaces inside the building when you have a small footprint .....

c. Visual privacy .....

d. Controlling sounds .....

e. Controlling smells .....

f. Playgrounds for children .....

g. Accessibility .....

- h. Social interaction .....
- i. Separation between male and female zones .....
- j. Security and safety .....
- k. Natural lighting .....
- l. Natural ventilation .....
- m. Reducing energy consumption for heating and cooling .....
- n. Landscape and greenery .....

**3.6. Do you think that vernacular elements should be used in contemporary designs? How?**

.....

.....

.....

.....

.....

.....

**3.7. Do you insert vernacular elements in your design? If yes, what are these features?**

.....

.....

.....

.....

.....

.....



Appendix (4-A-2)

**The Questionnaire Form  
(In both languages: Arabic and English)**

## Questionnaire Form



### Investigating Social and Spatial Needs in Residential Buildings in The Middle-East and North-Africa

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This questionnaire is part of study undertaken for obtaining a PhD degree about generating sustainable high-rise residential buildings in the Middle East and North Africa, which trace the social and cultural values of the society and satisfy their spatial needs.

The researcher would like to ask you some questions about your current housing environment. Your answers are appreciated, as the information you provide will be very helpful for outlining guidelines for designers in order to enhance the social and spatial residential environment.

The questionnaire will take about 20 minutes to complete. Please do not feel obliged to answer a question if you do not wish to. Your response will be strictly confidential and used only for this academic research.

Please do not hesitate to ask any question and feel free to add your comments. Thank you for your time and feedback.

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Supervisors: Dr. Wassim Jabi - Dr. Oriel Prizeman

For correspondence:

Email: Al-JokhadarA@cardiff.ac.uk  
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Tel (Jordan) 00962-79 597 27 14

| Ref. No. | Region |                     |   |       |   |                      |
|----------|--------|---------------------|---|-------|---|----------------------|
|          | 1      | Gulf Region & Yemen | 3 | Egypt | 5 | <i>Bilad Al-Sham</i> |
|          | 2      | <i>Al-Maghreb</i>   | 4 | Iraq  | 6 | Turkey               |

**1. Information about Your House and the Household Structure**

**1.1. In which country do you live today?**

- |                                       |                                  |  |
|---------------------------------------|----------------------------------|--|
| <input type="checkbox"/> Saudi Arabia | <input type="checkbox"/> Kuwait  | <input type="checkbox"/> United Arab Emirate |
| <input type="checkbox"/> Bahrain      | <input type="checkbox"/> Qatar   | <input type="checkbox"/> Oman                |
| <input type="checkbox"/> Jordan       | <input type="checkbox"/> Syria   | <input type="checkbox"/> Lebanon             |
| <input type="checkbox"/> Palestine    | <input type="checkbox"/> Egypt   | <input type="checkbox"/> Iraq                |
| <input type="checkbox"/> Turkey       | <input type="checkbox"/> Morocco | <input type="checkbox"/> Tunis               |
| <input type="checkbox"/> Algeria      | <input type="checkbox"/> Yemen   |  |

**1.2. Type of your house:**

- Detached house/villa       Attached house       Apartment in a building

**1.3. Tenure type:**

- Owned       Rental

**1.4. How long have you been living in this house?**

- Under 1 year       1 year and under 5 years       5 years and under 10 years  
 10 years and above

**1.5. Approximate date of construction:** .....

**1.6. Household structure:**

- |   |  |   |
|---|--|---|
| <input type="checkbox"/> Single               | <input type="checkbox"/> Couple          | <input type="checkbox"/> Couple with children         |
| <input type="checkbox"/> Single with children | <input type="checkbox"/> Extended family | <input type="checkbox"/> Other (please specify) ..... |

**1.7. Number of people living in the house including yourself:** .....

**1.8. Number of dependent children (under 18 years old) living in the house:** .....

**2. Spatial Description of Your House**

**2.1. Total area of your house:**

- |   |   |   |
|---|---|---|
| <input type="checkbox"/> Less than 100 m <sup>2</sup> | <input type="checkbox"/> 100 – 140 m <sup>2</sup>     | <input type="checkbox"/> 141 – 180 m <sup>2</sup> |
| <input type="checkbox"/> 181 – 250 m <sup>2</sup>     | <input type="checkbox"/> More than 250 m <sup>2</sup> |   |

**2.2. How many levels/floors is your house?**

- One floor       Two Floors       Three Floors

**2.3. How many rooms and indoor spaces in each level in your house?**

| Type of rooms and indoor spaces            | Number of rooms in the First level | Number of rooms in the Second level | Number of rooms in the Third level |
|--|------------------------------------|-------------------------------------|------------------------------------|
| a. Entry hall                              |                                    |                                     |                                    |
| b. Guest room (only for male guests)       |                                    |                                     |                                    |
| c. Guest room (only for female guests)     |                                    |                                     |                                    |
| d. Guest room (for both male and female)   |                                    |                                     |                                    |
| e. Dining room                             |                                    |                                     |                                    |
| f. Family living room                      |                                    |                                     |                                    |
| g. Multi-purpose hall                      |                                    |                                     |                                    |
| h. Office / Study area                     |                                    |                                     |                                    |
| i. Master bedroom (with in suite bathroom) |                                    |                                     |                                    |
| j. Bedroom (for kids)                      |                                    |                                     |                                    |
| k. Guest bedroom                           |                                    |                                     |                                    |
| l. Guest toilet                            |                                    |                                     |                                    |
| m. Bathroom                                |                                    |                                     |                                    |
| n. Kitchen                                 |                                    |                                     |                                    |
| o. Breakfast area                          |                                    |                                     |                                    |
| p. Storage                                 |                                    |                                     |                                    |
| q. Other .....                             |                                    |                                     |                                    |

**2.4. How many outdoor spaces in each level in your house?**

| Type of outdoor spaces         | Number of outdoor spaces in the First level | Number of outdoor spaces in the Second level | Number of outdoor spaces in the Third level |
|--------------------------------|---|--|---|
| a. Balcony                     |   |  |   |
| b. Courtyard                   |   |  |   |
| c. Garden surrounded the house |   |  |   |
| d. Roof terrace                |   |  |   |
| e. Other .....                 |   |  |   |

**2.5. What is the approximate area of the outdoor spaces in your house?** ..... m<sup>2</sup>

**2.6. Did you make any changes for the original interior layout of your house to accommodate your needs?**

Yes       No

If your answer is (yes), please write what are these changes:

.....

.....

.....

### 3. Spatial and Social Qualities of Your House

3.1. If you need additional spaces in your house, what would these spaces be?

.....

3.2. How would you describe your level of satisfaction with the interior layout of your house, using a scale of 1 to 5, where (1) indicates 'strongly dissatisfied' and (5) indicates 'strongly satisfied'?

| Strongly Dissatisfied | Slightly Dissatisfied | Neutral | Fairly Satisfied | Strongly Satisfied |
|-----------------------|-----------------------|---------|------------------|--------------------|
| 1                     | 2                     | 3       | 4                | 5                  |

3.3. How would you describe your level of satisfaction with the size of your house in comparison with the size of your family, using a scale of 1 to 5, where (1) indicates 'strongly dissatisfied' and (5) indicates 'strongly satisfied'?

| Strongly Dissatisfied | Slightly Dissatisfied | Neutral | Fairly Satisfied | Strongly Satisfied |
|-----------------------|-----------------------|---------|------------------|--------------------|
| 1                     | 2                     | 3       | 4                | 5                  |

3.4. Name one thing you like most in the arrangement of rooms in your house.

.....

3.5. Name one thing you like least in the arrangement of rooms in your house.

.....

3.6. Do you agree or disagree with the following statements, using a scale of 1 to 5, where (1) indicates 'strongly disagree' and (5) indicates 'strongly agree'?

|   | Strongly Disagree | Slightly Disagree | Neutral | Fairly Agree | Strongly Agree |
|---|-------------------|-------------------|---------|--------------|----------------|
| a. Family living spaces in my house are crowded.  | 1                 | 2                 | 3       | 4            | 5              |
| b. Guest rooms are too large in comparison with the size of family living spaces in my house.   | 1                 | 2                 | 3       | 4            | 5              |
| c. There is no visual separation between spaces for guests (guest and dining rooms) and family spaces (living room) inside the house.   | 1                 | 2                 | 3       | 4            | 5              |
| d. There is a direct visual connection between the entrance and the living room in my house.  | 1                 | 2                 | 3       | 4            | 5              |
| e. There are many paths and circulation spaces between rooms in my house.   | 1                 | 2                 | 3       | 4            | 5              |
| f. I can move easily between spaces without barriers (such as walls, steps) in my house.  | 1                 | 2                 | 3       | 4            | 5              |
| g. Bedrooms in my house are calm zones and isolated from living spaces.   | 1                 | 2                 | 3       | 4            | 5              |
| h. There are no private outdoor areas for children inside my house.   | 1                 | 2                 | 3       | 4            | 5              |
| i. I cannot see the outside views from the inside of my house.  | 1                 | 2                 | 3       | 4            | 5              |
| j. The location and orientation of the kitchen in my house prevent the cooking smells to be entered to other spaces. (Please specify on which side the window of the kitchen is located). | 1                 | 2                 | 3       | 4            | 5              |

**3.7. Is there any change in levels between different spaces inside your house?**

Yes  No

If your answer is (yes), please answer the following questions:

a. What are the two spaces/rooms that are separated by steps (for example: living room / kitchen)?

.....

b. How many steps between these two spaces? .....

c. Are these steps practical?  Yes  No

**3.8. Is there any change in levels between the outside and the main entrance of your house?**

Yes  No

If your answer is (yes), please answer the following questions:

a. How many steps between the entrance and the outside? .....

b. Are these steps practical?  Yes  No

**3.9. If you had the chance to buy an apartment in a multi-story (or high-rise) residential building, to what extent would you be interested to include the following spaces in your apartment and in the building, using a scale of 1 to 5, where (1) indicates 'not at all interested' and (5) indicates 'very interested'?**

|  | Not at all interested | Not very interested | Neutral | Somewhat interested | Very interested |
|--|-----------------------|---------------------|---------|---------------------|-----------------|
| a. I would prefer to have outdoor terraces and balconies in my apartment.  | 1                     | 2                   | 3       | 4                   | 5               |
| b. I would prefer to have commercial facilities in the ground floor of the building.   | 1                     | 2                   | 3       | 4                   | 5               |
| c. I would prefer to have common gathering spaces (such as plaza, courtyard, interior garden) inside the building.                         | 1                     | 2                   | 3       | 4                   | 5               |
| d. I would prefer to have two-level apartment; the first level is for guest rooms and living spaces, and the second level is for bedrooms. | 1                     | 2                   | 3       | 4                   | 5               |



|   | Not at all interested | Not very interested | Neutral | Somewhat interested | Very interested |
|---|-----------------------|---------------------|---------|---------------------|-----------------|
| <p>e. I would prefer to have a courtyard inside my apartment.</p>    | 1                     | 2                   | 3       | 4                   | 5               |
| <p>f. I would prefer to have an 'iwan' (a sheltered living space with one open-side connected directly with the courtyard) inside my apartment.</p>  | 1                     | 2                   | 3       | 4                   | 5               |
| <p>g. I would prefer to have a 'gallery' (a sheltered space with columns around the courtyard) inside my apartment.</p>                            | 1                     | 2                   | 3       | 4                   | 5               |

**3.10. If you had the chance to buy an apartment in a multi-story (or high-rise) residential building, what are the key features that you would like to be in the apartment and in the building?**

- a. Features in the apartment: .....
- .....
- .....
- b. Features in the building: .....
- .....
- .....
- .....

**4. Environmental Qualities of Your House**

4.1. Do you have specific spaces in your house used only in summer?

- Yes  No

If your answer is (yes), please specify these spaces .....

4.2. Do you have specific spaces in your house used only in winter?

- Yes  No

If your answer is (yes), please specify these spaces .....

4.3. If you move to another house, would you prefer to have two living spaces in your house, one used in summer and the other in winter?

- Yes  No

4.4. What is the height from the floor to the ceiling in your house? .....

4.5. What is the most appropriate height of ceiling would you prefer if you move to another house?

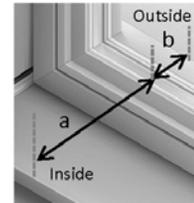
- 280 cm  between 290 cm and 350 cm  above 350 cm

4.6. What is the thickness of the exterior wall in your house? (From any window in your house, you can measure or estimate the distance from the glass to the inside edge of the wall (a), and add it to the distance from the glass to the outside edge of the wall (b)).

Distance (a) from the glass to the inside edge of wall = ..... cm

Distance (b) from the glass to the outside edge of wall = ..... cm

Overall thickness of wall = a + b = ..... cm



4.7. Do you have any of the following problems in your house? (Please tick all relevant issues).

- Poor natural ventilation  Poor natural lighting  
 Too hot and/or too cold  Poor sound insulation  
 Bad orientation  Lack of green areas and water features

4.8. How would you describe the following indoor conditions in your house in SUMMER season (without any use of mechanical equipments)?

a. Temperature:

|           |               |            |               |          |
|-----------|---------------|------------|---------------|----------|
| Very cold | Slightly cool | Acceptable | Slightly warm | Very hot |
| 1         | 2             | 3          | 4             | 5        |

b. Humidity:

|          |              |            |                |            |
|----------|--------------|------------|----------------|------------|
| Very dry | Slightly dry | Acceptable | Slightly humid | Very humid |
| 1        | 2            | 3          | 4              | 5          |

c. Air Movement and Natural Ventilation:

|            |                |            |                   |               |
|------------|----------------|------------|-------------------|---------------|
| Very still | Slightly still | Acceptable | Slightly draughty | Very draughty |
| 1          | 2              | 3          | 4                 | 5             |

**5. Housing Context and Neighbours**

5.1. How many neighbours do you know? .....

5.2. Do you have any of the following problems where you live? (Please tick all relevant issues).

- |   |  |
|---|--|
| <input type="checkbox"/> Noise from neighbours                        | <input type="checkbox"/> Lack of privacy due to the huge number of windows                       |
| <input type="checkbox"/> Lack of common gathering spaces              | <input type="checkbox"/> Lack of security and safety issues for children                         |
| <input type="checkbox"/> Lack of social interaction between neighbors | <input type="checkbox"/> I cannot use the outdoor terraces as my neighbours can see these spaces |

5.3. What are the different treatments in your house that protect your privacy from your neighbours? (Please tick all relevant issues).

- |  |   |
|--|---|
| <input type="checkbox"/> High walls between neighbours | <input type="checkbox"/> No openings overlooking my neighbours                  |
| <input type="checkbox"/> High roof parapet             | <input type="checkbox"/> The use of screens ( <i>mashrabiyyah</i> ) and louvers |
| <input type="checkbox"/> Curtains                      | <input type="checkbox"/> Other (please specify) .....                           |

5.4. What are the different external elements that give your house/apartment a special characteristic from your neighbors? (for example: the color of outside walls, decorations, shelters, pergolas, plants, etc...)

.....

Are these elements part of the traditional architectural features in your region?  Yes  No

5.5. If you are currently living in an apartment building, please answer the following questions:

a. What is the total number of floors in your apartment building? .....

b. On which floor are you living? .....

c. How many apartments are at your floor? .....

d. Do you believe there are too many apartments on your floor?  Yes  No

e. How many times you are chatting with your neighbours in your building per week? .....

f. Where are you chatting with your neighbours? (Please tick all relevant issues).

- |  |   |
|--|---|
| <input type="checkbox"/> At the entrance of the building       | <input type="checkbox"/> At the entrance of your apartment    |
| <input type="checkbox"/> At the outside garden of the building | <input type="checkbox"/> At the courtyard inside the building |

g. Name one thing you like most in the overall design of your building.

.....

h. Name one thing you like least in the overall design of your building.

.....

Finally, if you have any comments, clarifications or opinions that you would like to share with us, please do not hesitate to write these down.

.....  
.....  
.....  
.....

End of the Questionnaire  
Thank you for your time and kind effort  
Page 7 of 7

## نموذج استبيان



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### دراسة الاحتياجات الاجتماعية والتصميمية للمباني السكنية في منطقة الشرق الأوسط وشمال افريقيا

يمثل هذا الاستبيان جزءاً من دراسة أكاديمية، يقوم بإعدادها المهندس عامر الجوخدار للحصول على درجة الدكتوراه في هندسة العمارة من جامعة كارديف في المملكة المتحدة (بريطانيا)، حول المباني السكنية في منطقة الشرق الأوسط وشمال افريقيا ليكون تصميمها مستداماً يأخذ بعين الاعتبار القيم الاجتماعية والثقافية للمجتمع ويلبي الاحتياجات الفراغية والمكانية والبيئية.

من خلال هذا الاستبيان نود طرح مجموعة من الأسئلة حول السكن الحالي الذي تعيشون فيه، نستطلع فيها آراءكم الشخصية التي ستكون بمثابة قاعدة بيانات تحدد المبادئ التوجيهية للمصممين من أجل تحسين البيئة الاجتماعية والتصميمية للمباني السكنية.

تستغرق تعبئة الاستبيان حوالي 20 دقيقة، وللمشارك الكريم الحق في عدم إجابة أي سؤال لا يرغب في الإجابة عنه. ويؤكد الباحث على أن جميع الإجابات سيتم التعامل معها بخصوصية تامة ولن تستخدم إلا لأغراض البحث العلمي. يرجى عدم التردد في الرجوع إلى الباحث للإستفسار عن أي سؤال غير واضح أو إضافة أي تعليق أو رأي ترونه مفيداً.

شاكرين لكم وقتكم ومشارككم

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| المنطقة |            |   |        | الرقم المرجعي |                      |
|---------|------------|---|--------|---------------|----------------------|
| 5       | بلاد الشام | 3 | مصر    | 1             | الخليج العربي واليمن |
| 6       | تركيا      | 4 | العراق | 2             | المغرب العربي        |

## 1. معلومات حول السكن والأسرة

1.1. في أي بلد تعيش حالياً ؟

- |   |                                 |   |
|---|---------------------------------|---|
| <input type="checkbox"/> المملكة العربية السعودية | <input type="checkbox"/> الكويت | <input type="checkbox"/> الإمارات العربية المتحدة |
| <input type="checkbox"/> البحرين                  | <input type="checkbox"/> قطر    | <input type="checkbox"/> سلطنة عمان               |
| <input type="checkbox"/> الأردن                   | <input type="checkbox"/> سوريا  | <input type="checkbox"/> لبنان                    |
| <input type="checkbox"/> فلسطين                   | <input type="checkbox"/> مصر    | <input type="checkbox"/> العراق                   |
| <input type="checkbox"/> تركيا                    | <input type="checkbox"/> المغرب | <input type="checkbox"/> تونس                     |
| <input type="checkbox"/> الجزائر                  | <input type="checkbox"/> اليمن  |   |

2.1. ما هو نوع السكن الحالي ؟

- منزل مستقل / فيلا  سكن متلاصق  شقة في عمارة سكنية

3.1. ما هو نوع حيازة السكن ؟

- ملكية خاصة  مستأجر

4.1. منذ متى وأنت تسكن في هذا المسكن ؟

- أقل من سنة  سنة وأقل من 5 سنوات  5 سنوات وأقل من 10 سنوات  10 سنوات فأكثر

5.1. ما هو تاريخ البناء التقريبي للمنزل/المبنى الذي تسكن فيه ؟

6.1. تركيبة الأسرة:

- فرد واحد  زوج وزوجة فقط  زوج وزوجة مع أبناء  فرد مع أبناء  عائلة ممتدة  أخرى (يرجى ذكرها)

7.1. عدد الأشخاص الذين يعيشون في المنزل (بما في ذلك نفسك):

8.1. عدد الأطفال المعالين (أقل من عمر 18 سنة) الذين يعيشون في المنزل:

## 2. مواصفات المنزل

1.2. المساحة الإجمالية لمنزلك:

- أقل من 100 م<sup>2</sup>  100 - 140 م<sup>2</sup>  141 - 180 م<sup>2</sup>  أكبر من 250 م<sup>2</sup>  181 - 250 م<sup>2</sup>

2.2. ما هو عدد طوابق منزلك ؟

- طابق واحد  طابقين  ثلاثة طوابق

3.2. ما هو عدد الغرف في كل طابق من منزلك ؟

| نوع الغرف والمساحات الداخلية           | عدد الغرف في الطابق الأول | عدد الغرف في الطابق الثاني | عدد الغرف في الطابق الثالث |
|--|---------------------------|----------------------------|----------------------------|
| أ. المدخل                              |                           |                            |                            |
| ب. غرفة الصيوف (تستخدم فقط للرجال)     |                           |                            |                            |
| ج. غرفة الصيوف (تستخدم فقط للنساء)     |                           |                            |                            |
| د. غرفة الصيوف (تستخدم للرجال والنساء) |                           |                            |                            |
| هـ. غرفة الطعام                        |                           |                            |                            |
| و. غرفة المعيشة                        |                           |                            |                            |
| ز. قاعة متعددة الاستخدامات             |                           |                            |                            |
| ح. غرفة مكتب / غرفة دراسة              |                           |                            |                            |
| ط. غرفة نوم رئيسية (مع حمام)           |                           |                            |                            |
| ي. غرفة نوم للأطفال                    |                           |                            |                            |
| ك. غرفة نوم للضيوف                     |                           |                            |                            |
| ل. حمام للضيوف                         |                           |                            |                            |
| م. حمام                                |                           |                            |                            |
| ن. مطبخ                                |                           |                            |                            |
| س. ركن للإفطار                         |                           |                            |                            |
| ع. مخزن                                |                           |                            |                            |
| ف. غرف أخرى                            |                           |                            |                            |

4.2. ما هو عدد المساحات الخارجية في كل طابق من منزلك ؟

| نوع المساحات الخارجية    | عدد المساحات الخارجية في الطابق الأول | عدد المساحات الخارجية في الطابق الثاني | عدد المساحات الخارجية في الطابق الثالث |
|--------------------------|---------------------------------------|--|--|
| أ. فناء (حوش / أرض ديار) |                                       |  |  |
| ب. بلكونة / برندة        |                                       |  |  |
| ج. حديقة حول المنزل      |                                       |  |  |
| د. تراس على سطح المنزل   |                                       |  |  |
| هـ. مساحات أخرى          |                                       |  |  |

5.2. ما هي المساحة التقريبية للفراغات الخارجية في منزلك ؟

6.2. هل قمت بعمل أية تعديلات على التصميم الداخلي الأصلي للمنزل وذلك لتلبية احتياجاتك ؟  نعم  لا  
إذا كانت إجابتك (نعم)، يرجى ذكر هذه التعديلات.

### 3. تقييم المواصفات التصميمية والحياة الاجتماعية داخل المنزل

1.3. إذا كنت بحاجة إلى مساحات إضافية في منزلك، ما هي هذه المساحات ؟

3.2. كيف تصف مستوى رضاك عن توزيع الغرف والتصميم الداخلي لمنزلك، وذلك باستخدام مقياس (من 1 إلى 5) حيث يشير الرقم (1) إلى (عدم الرضا بشدة)، والرقم (5) إلى (الرضا التام) ؟ (ضع دائرة حول رقم الإجابة التي تراها مناسبة)

| غير راضي بشدة | غير راضي قليلاً | محايد (غير مستاء وغير راضي) | راضي إلى حد ما | راضي بشدة |
|---------------|-----------------|-----------------------------|----------------|-----------|
| 1             | 2               | 3                           | 4              | 5         |

3.3. كيف تصف مستوى رضاك عن مساحة منزلك بالمقارنة مع عدد أفراد أسرتك، وذلك باستخدام مقياس (من 1 إلى 5) حيث يشير الرقم (1) إلى (عدم الرضا بشدة)، والرقم (5) إلى (الرضا التام) ؟ (ضع دائرة حول رقم الإجابة التي تراها مناسبة)

| غير راضي بشدة | غير راضي قليلاً | محايد (غير مستاء وغير راضي) | راضي إلى حد ما | راضي بشدة |
|---------------|-----------------|-----------------------------|----------------|-----------|
| 1             | 2               | 3                           | 4              | 5         |

4.3. أذكر اسم شيء واحد يعجبك أكثر ما يمكن في توزيع الغرف في منزلك.

5.3. أذكر اسم شيء واحد لا يعجبك في توزيع الغرف في منزلك.

6.3. إلى أي مدى توافق أو لا توافق على العبارات التالية، وذلك باستخدام مقياس (من 1 إلى 5) حيث يشير الرقم (1) إلى (غير موافق بشدة)، والرقم (5) إلى (أوافق بشدة) ؟ (ضع دائرة حول رقم الإجابة التي تراها مناسبة)

| موافق بشدة | موافق إلى حد ما | محايد | غير موافق إلى حد ما | غير موافق بشدة |  |
|------------|-----------------|-------|---------------------|----------------|--|
| 5          | 4               | 3     | 2                   | 1              | أ. فراغات المعيشة العائلية في منزلي صغيرة ولا تلبى احتياجات الأسرة.  |
| 5          | 4               | 3     | 2                   | 1              | ب. مساحة غرفة الضيوف كبيرة جداً مقارنة بمساحة غرف المعيشة الخاصة بالأسرة في منزلي.                                       |
| 5          | 4               | 3     | 2                   | 1              | ج. لا يوجد هناك اتصال بصري بين (غرف الضيوف والطعام) وبين (الغرف الخاصة بالعائلة مثل غرفة المعيشة) في منزلي.              |
| 5          | 4               | 3     | 2                   | 1              | د. يوجد اتصال بصري مباشر بين (المدخل الرئيسي) وبين (غرفة المعيشة) في منزلي.  |
| 5          | 4               | 3     | 2                   | 1              | هـ. عدد الممرات والموزع بين الغرف كثيرة في منزلي.  |
| 5          | 4               | 3     | 2                   | 1              | و. أستطيع التنقل بسهولة بين الغرف دون أية عوائق (مثل الأدراج) في منزلي.  |
| 5          | 4               | 3     | 2                   | 1              | ز. غرف النوم في منزلي هادئة ومعزولة عن غرف المعيشة.  |
| 5          | 4               | 3     | 2                   | 1              | ح. لا يوجد مساحات خارجية خاصة للعب الأطفال داخل منزلي.   |
| 5          | 4               | 3     | 2                   | 1              | ط. لا أستطيع رؤية المناظر الخارجية من داخل منزلي.  |
| 5          | 4               | 3     | 2                   | 1              | ي. موقع وتوجيه المطبخ في منزلي يمنع روائح الطبخ من انتقالها إلى الغرف الأخرى. (يرجى ذكر الجهة التي يقع فيها شباك المطبخ) |

7.3. هل يوجد في منزلك عتبات (درجات) تفصل بين الغرف داخل المنزل ؟

نعم  لا

إذا كانت إجابتك (نعم)، الرجاء الإجابة على الأسئلة التالية:

أ. أذكر أسماء الغرفتين اللتين يفصل بينهما درجات (مثلاً: المطبخ / غرفة المعيشة).

ب. كم عدد الدرجات بين هاتين الغرفتين ؟

ج. هل وجود الدرجات بين هاتين الغرفتين أمر مريح وعملي ؟  نعم  لا

8.3. هل يوجد في منزلك عتبات (درجات) تفصل بين مدخل المنزل وخارج المنزل ؟

نعم  لا

إذا كانت إجابتك (نعم)، الرجاء الإجابة على الأسئلة التالية:

أ. كم عدد الدرجات بين مدخل المنزل وخارج المنزل ؟

ب. هل وجود الدرجات بين مدخل المنزل وخارج المنزل أمر مريح وعملي ؟  نعم  لا

9.3. إذا كانت لديك فرصة لشراء شقة في مبنى سكني متعدد الطوابق (أو مبنى سكني عالي)، إلى أي مدى أنت مهتم بوجود الفراغات التالية في هذه الشقة أو المبنى، وذلك باستخدام مقياس (من 1 إلى 5) حيث يشير الرقم (1) إلى (غير مهتم أبداً)، والرقم (5) إلى (مهتم جداً)؟ (ضع دائرة حول رقم الإجابة التي تراها مناسبة)

| غير مهتم أبداً | غير مهتم إلى حد ما | محايد | مهتم إلى حد ما | مهتم جداً |  |
|----------------|--------------------|-------|----------------|-----------|--|
| 1              | 2                  | 3     | 4              | 5         | أ. أفضل وجود تراسات خارجية وبرندات في الشقة.   |
| 1              | 2                  | 3     | 4              | 5         | ب. أفضل وجود محلات تجارية في الطابق الأرضي من المبنى.  |
| 1              | 2                  | 3     | 4              | 5         | ج. أفضل وجود مساحات لتجمع الجيران (مثل فناء/أرض ديار في منتصف المبنى، حدائق داخلية) داخل المبنى. |
| 1              | 2                  | 3     | 4              | 5         | د. أفضل أن تكون الشقة من طابقين: الطابق الأول لغرف الضيوف والمعيشة، والطابق الثاني لغرف النوم.   |
| 1              | 2                  | 3     | 4              | 5         | هـ. أفضل وجود فناء (أرض ديار / حوش) داخل الشقة.  |



|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 5 | 4 | 3 | 2 | 1 | <p>و. أفضل وجود إيوان (غرفة معيشة مسقوفة ومكتشوفة من جهة واحدة على الفناء (الحوش)) داخل الشقة.</p>  |
| 5 | 4 | 3 | 2 | 1 | <p>ز. أفضل وجود رواق (فراغ خارجي مسقوف ومحيط بأعمدة) حول الفناء (الحوش) داخل الشقة.</p>             |

10.3. إذا كانت لديك فرصة لشراء شقة في مبنى سكني متعدد الطوابق (أو مبنى سكني عالي)، ما هي المواصفات الرئيسية التي تفضل وجودها في الشقة وفي المبنى؟

- أ. مواصفات خاصة في الشقة: .....
- ب. مواصفات خاصة في المبنى: .....

#### 4. تقييم المواصفات البنائية داخل المنزل

1.4. هل يوجد في منزلك غرف أو مساحات محددة تستخدم فقط في فصل الصيف؟  
 نعم  لا

إذا كانت إجابتك (نعم)، ما هي هذا الغرف / المساحات؟ .....

2.4. هل يوجد في منزلك غرف أو مساحات محددة تستخدم فقط في فصل الشتاء؟  
 نعم  لا

إذا كانت إجابتك (نعم)، ما هي هذا الغرف / المساحات؟ .....

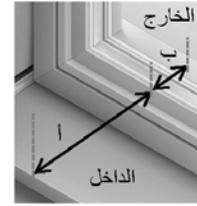
3.4. إذا سمحت لك الفرصة بالانتقال للسكن في منزل آخر، هل تفضل وجود غرفتين للمعيشة داخل منزلك، واحدة تستخدم في فصل الصيف والأخرى في فصل الشتاء؟  
 نعم  لا

4.4. ما هو ارتفاع السقف داخل منزلك؟ .....

5.4. إذا سمحت لك الفرصة بالانتقال للسكن في منزل آخر، ما هو الارتفاع المناسب للسقف؟  
 280 سم  290 - 350 سم  أكثر من 350 سم

6.4. ما هي سماكة الجدران الخارجية في منزلك؟ (يمكنك قياس السماكة من خلال قياس المسافة بين زجاج الشباك والحافة الداخلية للجدار (حسب الرمز أ) المشار إليه في الصورة المرفقة)، وقياس المسافة بين زجاج الشباك والحافة الخارجية للجدار (حسب الرمز ب) المشار إليه في الصورة المرفقة).

المسافة (أ) = المسافة بين زجاج الشباك والحافة الداخلية للجدار = ..... سم  
المسافة (ب) = المسافة بين زجاج الشباك والحافة الخارجية للجدار = ..... سم  
السماكة الكلية للجدار الخارجي = أ + ب = ..... سم



7.4. هل تعاني من أي من المشاكل التالية في منزلك؟ (يرجى وضع علامة أمام جميع المشاكل الموجودة).

تهوية طبيعية سيئة  إضاءة طبيعية سيئة  
 عزل صوتي سيء  توجيه الغرف باتجاه الشمس/الرياح سيء  
 البيت بارد جداً و/أو حار جداً  قلة المساحات الخضراء أو عناصر المياه

8.4. كيف تصف الأجواء الداخلية التالية في منزلك في فصل الصيف (دون استخدام أية أجهزة ميكانيكية أو كهربائية للتكييف أو ترطيب الهواء أو التهوية)؟ (ضع دائرة حول رقم الإجابة التي تراها مناسبة).

أ. درجة الحرارة الداخلية:

|           |             |              |             |          |
|-----------|-------------|--------------|-------------|----------|
| بارد جداً | بارد قليلاً | معتدل ومقبول | دافئ قليلاً | حار جداً |
| 1         | 2           | 3            | 4           | 5        |

ب. الرطوبة الداخلية:

|          |            |              |            |          |
|----------|------------|--------------|------------|----------|
| جاف جداً | جاف قليلاً | معتدل ومقبول | رطب قليلاً | رطب جداً |
| 1        | 2          | 3            | 4          | 5        |

ج. حركة الهواء والتهوية الطبيعية:

|                  |                       |              |                   |                        |
|------------------|-----------------------|--------------|-------------------|------------------------|
| الهواء ساكن جداً | الهواء ساكن إلى حد ما | معتدل ومقبول | حركة الهواء قليلة | حركة الهواء كثيرة جداً |
| 1                | 2                     | 3            | 4                 | 5                      |

## 5. العلاقة مع المنازل المحيطة والجيران

1.5. كم عدد الجيران الذين تعرفهم ؟ .....

2.5. هل تعاني من أي من المشاكل التالية في المنزل الذي تعيش فيه ؟ (يرجى وضع علامة أمام جميع المشاكل الموجودة).

- |   |  |
|---|--|
| <input type="checkbox"/> الإزعاج من الجيران               | <input type="checkbox"/> قلة الخصوصية بسبب كثرة الشبابيك                                       |
| <input type="checkbox"/> قلة أماكن التجمع مع الجيران      | <input type="checkbox"/> قلة الشعور بالأمان والأمن الخاصة بسلامة الأطفال                       |
| <input type="checkbox"/> قلة التواصل الاجتماعي مع الجيران | <input type="checkbox"/> لا أستطيع استعمال المساحات الخارجية والتراسات لأنها مكتوفة من الجيران |

3.5. ما هي المعالجات المختلفة في منزلك والتي تساعد في توفير الخصوصية لك ولعائلتك ؟ (يرجى وضع علامة أمام جميع ما ينطبق).

- |  |   |
|--|---|
| <input type="checkbox"/> أسوار عالية بين الجيران             | <input type="checkbox"/> عدم وجود شبابيك تطل مباشرة على الجيران                                   |
| <input type="checkbox"/> استخدام تصويتة عالية على سطح المنزل | <input type="checkbox"/> استخدام عناصر خشبية/معدنية على الشبابيك تمنع الجيران من رؤية داخل المنزل |
| <input type="checkbox"/> استخدام الستائر                     | <input type="checkbox"/> معالجات أخرى (اذكرها) .....  |

4.5. ما هي العناصر المستخدمة في منزلك/شقتك من الخارج والتي تميزه عن باقي المنازل والشقق المحيطة بك ؟ (مثل استخدام لون مختلف للجدران الخارجية، ديكورات خارجية، مظلات، معرشات، نباتات...).

هل استخدام هذه العناصر يعتبر جزء من التراث المعماري للمدينة التي تعيش بها ؟  نعم  لا

5.5. إذا كنت تسكن حالياً في شقة ضمن عمارة سكنية، يرجى الإجابة على الأسئلة التالية:

- أ. كم عدد الطوابق التي تتكون منها العمارة السكنية ؟ .....
- ب. في أي طابق تقع شقتك ؟ .....
- ج. كم عدد الشقق في الطابق الذي تعيش فيه ؟ .....
- د. برأيك هل عدد الشقق في الطابق الواحد كبير ومزدحم ؟  نعم  لا
- هـ. كم عدد المرات التي تتحدث فيها مع جيرانك في نفس العمارة في الأسبوع ؟ .....
- و. ما هو المكان الذي تجتمع وتتواصل فيه مع جيرانك ؟ (يرجى وضع إشارة أمام جميع الإجابات التي تنطبق)
- |   |   |
|---|---|
| <input type="checkbox"/> عند مدخل العمارة           | <input type="checkbox"/> في الممرات الداخلية عند مدخل الشقة |
| <input type="checkbox"/> في الحديقة الخارجية للمبنى | <input type="checkbox"/> في الفناء الداخلي (حوش) للعمارة    |
- ز. أذكر اسم شيء واحد تحبه أكثر ما يمكن في تصميم العمارة السكنية التي تعيش فيها.

ح. أذكر اسم شيء واحد لا تحبه في تصميم العمارة السكنية التي تعيش فيها.

أخيراً، إذا كانت لديك أية ملاحظات أو تعليقات أو مقترحات يرجى كتابتها في الأسفل.

.....

.....

.....

.....

.....

نهاية الاستبيان

نشكر لكم مساهمتكم ووقتكم

صفحة 7 من 7

Appendix (4-A-3)

**List of Variables and Questions for the  
Questionnaire**

**Table showing the Different Variables and Questions for the Questionnaire with Residents**

| Variable No. | Questions  |                                       |
|--------------|--|---------------------------------------|
| 1            | 1.1. In which country do you live today                                    |                                       |
| 2            | 1.2. Type of your house  |                                       |
| 3            | 1.3. Tenure type   |                                       |
| 4            | 1.4. How long have you been living in this house                           |                                       |
| 5            | 1.5. Approximate date of construction                                      |                                       |
| 6            | 1.6. Household structure   |                                       |
| 6-A          | Other (please specify)   |                                       |
| 7            | 1.7. Number of people living in the house including yourself               |                                       |
| 8            | 1.8. Number of dependent children (under 18 years old) living in the house |                                       |
| 9            | 2.1. Total area of your house  |                                       |
| 10           | 2.2. How many levels/floors is your house                                  |                                       |
| 11           | 2.3.a<br>Rooms<br>for guests   | Entry hall                            |
| 11-A         |  | Guest room (for both male and female) |
| 11-B         |  | Guest room (only for male guests)     |
| 11-C         |  | Guest room (only for female guests)   |
| 11-D         |  | Dining room                           |
| 11-E         |  | Guest toilet                          |
| 11-F         |  | Other (please specify)                |
| 12           | 2.3.b.<br>Family<br>spaces   | Family living room                    |
| 12-A         |  | Multi-purpose hall                    |
| 12-B         |  | Office / Study area                   |
| 12-C         |  | Other (please specify)                |
| 13           | 2.3.c.<br>Bedrooms   | Master bedroom # 1                    |
| 13-A         |  | Master bedroom # 2                    |
| 13-B         |  | Master bedroom # 3                    |
| 13-C         |  | Master bedroom # 4                    |
| 13-D         |  | Bedroom # 1 (for kids)                |
| 13-E         |  | Bedroom # 2 (for kids)                |
| 13-F         |  | Bedroom # 3 (for kids)                |
| 13-G         |  | Bedroom # 4 (for kids)                |
| 13-H         |  | Guest bedroom                         |
| 13-I         |  | Other (please specify)                |
| 14           | 2.3.d.<br>Services   | Bathroom # 1                          |
| 14-A         |  | Bathroom # 2                          |
| 14-B         |  | Bathroom # 3                          |
| 14-C         |  | Kitchen                               |
| 14-D         |  | Breakfast area                        |
| 14-E         |  | Storage                               |
| 14-F         |  | Other (please specify)                |
| 15           | 2.4.<br>Outdoor<br>spaces  | Courtyard                             |
| 15-A         |  | Garden surrounded the house           |
| 15-B         |  | Roof terrace                          |
| 15-C         |  | Balcony # 1                           |
| 15-D         |  | Balcony # 2                           |
| 15-E         |  | Balcony # 3                           |

|      |  |  |
|------|--|--|
| 15-F |  | Other (please specify)   |
| 16   | 2.5. What is the approximate area (in m <sup>2</sup> ) of the outdoor spaces in your house             |  |
| 17   | 2.6. Did you make any changes for the original interior layout of your house to accommodate your needs |  |
| 17-A | If your answer is (yes), please write what are these changes   |  |
| 18   | 3.1. If you need additional spaces in your house, what would these spaces be                           |  |
| 19   | 3.2. Level of satisfaction with the interior layout  |  |
| 20   | 3.3. Level of satisfaction with the size of your house   |  |
| 21   | 3.4. Name one thing you like most in the arrangement of rooms in your house.                           |  |
| 22   | 3.5. Name one thing you like least in the arrangement of rooms in your house.                          |  |
| 23   | 3.6. Do you agree or disagree with the following statements?   | Family living spaces in my house are crowded.  |
| 23-A |  | Guest rooms are too large in comparison with the size of family living spaces in my house.   |
| 23-B |  | There is no visual separation between spaces for guests (guest and dining rooms) and family spaces (living room) inside the house. |
| 23-C |  | There is a direct visual connection between the entrance and the living room in my house.  |
| 23-D |  | There are many paths and circulation spaces between rooms in my house.   |
| 23-E |  | I can move easily between spaces without barriers (such as partitions, steps) in my house.   |
| 23-F |  | Bedrooms in my house are calm zones and isolated from living spaces.   |
| 23-G |  | There are no private outdoor areas for children inside my house.   |
| 23-H |  | I cannot see the outside views from the inside of my house.  |
| 23-I |  | The location and orientation of the kitchen in my house prevent the cooking smells to be entered to other spaces.                  |
| 23-J |  | Please specify on which side the window of the kitchen is located.   |
| 24   | 3.7. Is there any change in levels between different spaces inside your house?                         |  |
| 25   | a. What are the two spaces/rooms that are separated by steps (for example: living room / kitchen)?     |  |
| 25-A | b. How many steps between these two spaces?  |  |
| 25-B | c. Are these steps practical? (Please answer: Yes or No)   |  |
| 26   | 3.8. Is there any change in levels between the outside and the main entrance of your house?            |  |
| 27   | a. How many steps between the entrance and the outside?  |  |
| 27-A | b. Are these steps practical? (Please answer: Yes or No)   |  |
| 28   | 3.9. Features if people buy an   | I would prefer to have outdoor terraces and balconies in my apartment.   |
| 28-A |  | I would prefer to have commercial facilities in the ground floor of the building.  |

|      |  |   |
|------|--|---|
| 28-B | apartment in a building:   | I would prefer to have common gathering spaces (such as plaza, courtyard, interior garden) inside the building.   |
| 28-C |  | I would prefer to have two-level apartment; the first level is for guest rooms and living spaces, and the second level is for bedrooms (as shown in the following image). |
| 29   |  | -----   |
| 30   |  | I would prefer to have a courtyard inside my apartment.   |
| 31   |  | -----   |
| 32   |  | I would prefer to have an 'iwan' (a sheltered living space with one open-side connected directly with the courtyard) inside my apartment.                                 |
| 33   |  | Any Comments  |
| 34   |  | I would prefer to have a 'gallery' (a sheltered space with columns around the courtyard) inside my apartment.   |
| 35   |  | Any Comments  |
| 36   |  | 3.10.   |
| 36-A |  | b. Features in the building   |
| 37   | 4.1. Do you have specific spaces in your house used only in summer?  |   |
| 37-A | If your answer is (yes), please specify these spaces   |   |
| 38   | 4.2. Do you have specific spaces in your house used only in winter?  |   |
| 38-A | If your answer is (yes), please specify these spaces   |   |
| 39   | 4.3. If you move to another house, would you prefer to have two living spaces in your house, one used in summer and the other in winter? |   |
| 40   | 4.4. What is the height (in cm) from the floor to the ceiling in your house?   |   |
| 41   | 4.5. What is the most appropriate height of ceiling would you prefer if you move to another house?                                       |   |
| 42   | 4.6. What is the overall thickness (in cm) of the exterior wall in your house?   |   |
| 43   | Any Comments   |   |
| 44   | 4.7. Problems in the house   | Poor natural ventilation  |
| 44-A |  | Poor natural lighting   |
| 44-B |  | Too hot and/or too cold   |
| 44-C |  | Poor sound insulation   |
| 44-D |  | Bad orientation   |
| 44-E |  | Lack of green areas and water features  |
| 45   | 4.8. Temperature   |   |
| 46   | 4.9. Humidity  |   |
| 47   | 4.10. Natural Ventilation  |   |
| 48   | 5.1. How many neighbours do you know?  |   |
| 49   | 5.2. Problems  | Noise from neighbours   |
| 49-A |  | Lack of privacy due to the huge number of windows   |
| 49-B |  | Lack of common gathering spaces   |
| 49-C |  | Lack of security and safety issues for children   |
| 49-D |  | Lack of social interaction between neighbors  |
| 49-E |  | I cannot use the outdoor terraces as my neighbours can see these spaces   |
| 50   | 5.3. Treatment for privacy   | Curtains  |
| 50-A |  | No openings overlooking my neighbours   |
| 50-B |  | The use of screens (mashrabiyyah) and louvers   |
| 50-C |  | High walls between neighbours   |

|      |   |   |  |  |
|------|---|---|--|--|
| 50-D |   | High roof parapet   |  |  |
| 50-E |   | Other (please specify)  |  |  |
| 51   | 5.4. External elements that give a special characteristics for the house          |   |  |  |
| 52   | Are these elements part of the traditional architectural features in your region? |   |  |  |
| 53   | 5.5.<br>Information<br>about the<br>building                                      | a. No. of Floors  |  |  |
| 54   |   | b. On which floor are you living  |  |  |
| 55   |   | c. How many apartments are at your floor  |  |  |
| 56   |   | d. Do you believe there are too many apartments on your floor?                    |  |  |
| 57   |   | e. How many times you are chatting with your neighbours in your building per week |  |  |
| 58   |   | f. chatting with neighbours   | Chatting at the entrance of the building       |  |
| 58-A |   |   | Chatting at the entrance of the apartment      |  |
| 58-B |   |   | Chatting at the outside garden of the building |  |
| 58-C |   |   | Chatting at the courtyard inside the building  |  |
| 59   |   | g. Name one thing you like most in the overall design of your building.           |  |  |
| 60   | h. Name one thing you like least in the overall design of your building.          |   |  |  |
| 61   | General Comments  |   |  |  |

Appendix (4-A-4)

**Ethical Approval Forms**

EC1606. 266

**WELSH SCHOOL OF ARCHITECTURE**  
**ETHICS APPROVAL FORM FOR STAFF AND PHD/MPHIL PROJECTS**

WS

|                                 |  |   |
|---------------------------------|--|---|
| Tick one box:                   | <input type="checkbox"/> STAFF   | <input checked="" type="checkbox"/> PHD/MPHIL |
| Title of project:               | Towards a Socio-Spatial Grammar for Sustainable Tall Residential Buildings in Hot-Arid Regions (Learning from the Vernacular Model in the Middle-East and North-Africa). |   |
| Name of researcher(s):          | Amer Al-Jokhadar   |   |
| Name of principal investigator: | Dr Wassim Jabi   |   |
| Contact e-mail address:         | Al-JokhadarA@cardiff.ac.uk   |   |
| Date:                           | 14 <sup>th</sup> June 2016   |   |

| Participants  | YES | NO | N/A |
|---|-----|----|-----|
| Does the research involve participants from any of the following groups?  |     |    |     |
| • Children (under 16 years of age)  |     | x  |     |
| • People with learning difficulties   |     | x  |     |
| • Patients (NHS approval is required)   |     | x  |     |
| • People in custody   |     | x  |     |
| • People engaged in illegal activities  |     | x  |     |
| • Vulnerable elderly people   |     | x  |     |
| • Any other vulnerable group not listed here  |     | x  |     |
| • When working with children: I have read the Interim Guidance for Researchers Working with Children and Young People ( <a href="http://www.cardiff.ac.uk/archi/ethics_committee.php">http://www.cardiff.ac.uk/archi/ethics_committee.php</a> ) |     |    | x   |

| Consent Procedure   | YES | NO | N/A |
|---|-----|----|-----|
| • Will you describe the research process to participants in advance, so that they are informed about what to expect?  | x   |    |     |
| • Will you tell participants that their participation is voluntary?   | x   |    |     |
| • Will you tell participants that they may withdraw from the research at any time and for any reason?   | x   |    |     |
| • Will you obtain valid consent from participants? (specify how consent will be obtained in Box A) <sup>1</sup>   | x   |    |     |
| • Will you give participants the option of omitting questions they do not want to answer?   | x   |    |     |
| • If the research is observational, will you ask participants for their consent to being observed?  | x   |    |     |
| • If the research involves photography or other audio-visual recording, will you ask participants for their consent to being photographed / recorded and for its use/publication? | x   |    |     |

| Possible Harm to Participants   | YES | NO | N/A |
|---|-----|----|-----|
| • Is there any realistic risk of any participants experiencing either physical or psychological distress or discomfort?   |     | x  |     |
| • Is there any realistic risk of any participants experience a detriment to their interests as a result of participation? |     | x  |     |

| Data Protection  | YES  | NO | N/A |
|--|--|----|-----|
| • Will any non-anonymous and/or personalised data be generated or stored?    |  | x  |     |
| • If the research involves non-anonymous and/or personalised data, will you: | • gain written consent from the participants   |    | x   |
|  | • allow the participants the option of anonymity for all or part of the information they provide | x  |     |

| Health and Safety   | YES | NO | N/A |
|---|-----|----|-----|
| Does the research meet the requirements of the University's Health & Safety policies? ( <a href="http://www.cf.ac.uk/osheu/index.html">http://www.cf.ac.uk/osheu/index.html</a> ) | x   |    |     |

| Research Governance   | YES | NO | N/A |
|---|-----|----|-----|
| Does your study include the use of a drug?<br>You need to contact Research Governance before submission ( <a href="mailto:resgov@cf.ac.uk">resgov@cf.ac.uk</a> )                    |     | x  |     |
| Does the study involve the collection or use of human tissue?<br>You need to contact the Human Tissue Act team before submission ( <a href="mailto:hta@cf.ac.uk">hta@cf.ac.uk</a> ) |     | x  |     |

<sup>1</sup> If any non-anonymous and/or personalised data be generated or stored, *written consent* is required.

If any of the shaded boxes have been ticked, you must explain clearly how the ethical issues are addressed. The list of ethical issues on this form is not exhaustive; if you are aware of any other ethical issues you need to make the SREC aware of them.

**Box A The Project** (provide all the information listed below in a separate attachment)

1. Title of Project
2. Purpose of the project and its academic rationale
3. Brief description of methods and measurements
4. Participants: recruitment methods, number, age, gender, exclusion/inclusion criteria
5. Consent and participation information arrangements - please attached consent forms if they are to be used
6. A clear and concise statement of the ethical considerations raised by the project and how is dealt with them
7. Estimated start date and duration of project

All information must be submitted along with this form to the School Research Ethics Committee for consideration

**Researcher's declaration** (tick as appropriate)

- |  |   |
|--|---|
| • I consider this project to have <b>negligible ethical implications</b> (can only be used if none of the grey areas of the checklist have been ticked). | x |
| • I consider this project research to have <b>some ethical implications</b> .  |   |
| • I consider this project to have <b>significant ethical implications</b>  |   |

**PhD student:**

| Signature   | Name             | Date       |
|---|------------------|------------|
|  | Amer Al-Jokhadar | 14.06.2016 |

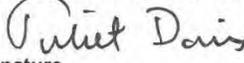
**Supervisor:**

| Signature   | Name        | Date       |
|---|-------------|------------|
|  | Wassim Jabi | 14.06.2016 |

**Advice from the School Research Ethics Committee**

**STATEMENT OF ETHICAL APPROVAL**

This project had been considered using agreed Departmental procedures and is now approved

|   |                   |          |
|---|-------------------|----------|
|  | Name Juliet DAVIS | 28.06.16 |
| Signature   | Name              | Date     |

Chair, School Research Ethics Committee



**Welsh School of Architecture**  
**Ysgol Bensaerniaeth Cymru**  
Head of School, Pennaeth yr Ysgol  
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10<sup>th</sup> June 2016

To whom it may concern,

**Re: Amer Al-Jokhadar**

I write to confirm that Amer Al-Jokhadar is a full-time PhD student at the Welsh School of Architecture, Cardiff University.

As part of his PhD research he will be travelling to Jordan between the dates of 26/7/2016 and 2/9/2016 to conduct field work, consisting of interviews and distributing questionnaires. We would be grateful for your assistance in enabling him to do this.

If you require further details, please contact me.

Yours faithfully,

Katrina Lewis  
Research Executive Officer

Email: [lewisk2@ccf.ac.uk](mailto:lewisk2@ccf.ac.uk)  
Direct line: +44 (0)2920 876251



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Appendix (4-A-5)

**Responses from the  
Interviews with Architects**

## Interview # 1 - Architect Khaled Jadallah

Date of Interview: 02/08/2016 (13:00 pm – 14:30 pm)

### 1. Traditional Houses in the Middle-East and North-Africa

- One of the most disguised features in traditional houses in the region is the hierarchy of spaces (from public to semi-public to private). This reflects the local culture. For example, there is a path (called *majaz* or *zuqak*) between the main entrance and the courtyard. This provides a privacy for all family members, as guests do not need to enter the courtyard. The guest room (*madafa*) is located near the entrance.

### 2. Contemporary Houses and High-rise Residential Developments in the Middle-East and North-Africa

- Balconies and terraces in apartment buildings do not offer the privacy for the family as the courtyard. These elements are oriented to the outside and connected only with one space, while the courtyard can connect more than one space together.
- Developers need each meter square in the apartment, so they do not prefer to insert courtyards. In contrast, people prefer to have balconies, terraces, gardens and courtyards in their apartments.
- The problem of setbacks between buildings limits the opportunity for inserting a courtyard inside the apartment or the house, as users want to benefit from the area that they allowed to build it.
- One of the problems that faces the new generation in the region is that there is no stability, which affected negatively on the relationships between neighbours. In contrast, expanded families who are living in the same house have strong relations with neighbours.

### 3. Your Design Philosophy

- Common spaces in neighbourhoods, between buildings and inside apartment buildings (especially in the lower floors) encourage the social interaction between neighbours.
- As we do not know the end-users of apartment buildings, architects need to be neutral in the design of facades. This means that they need to use contemporary materials (such as glass and louvers) and understand the meaning of each element instead of inserting traditional elements (such as arches, *mashrabiyyah*, and small windows).
- One of the best layouts for the house is to locate the terrace and the courtyard on the corner of the apartment, with the use of glazed facades as the weather is so harsh.
- Instead of using shutters, architects can use louvers, which provide privacy, natural lighting, and natural ventilation.
- Appropriate numbers and areas for apartments are:
  - o 180 – 240 m<sup>2</sup> (three bedrooms): two apartments in each floor.
  - o 60 – 80 m<sup>2</sup>: four apartments in each floor.
- The current regulations in Jordan specify that the maximum number of apartments in each flat is five. As a result, developers solve the small area of each apartment through converting it to duplex (two floors).
- Separation between male and female guests is still a priority in the spatial layout of the apartment, as it is part from the local culture.

## **Interview # 2 - Architect Mohammad Abbas**

**Date of Interview:** 07/08/2016 (10:00 am – 12:00 pm)

### **1. Traditional Houses in the Middle-East and North-Africa**

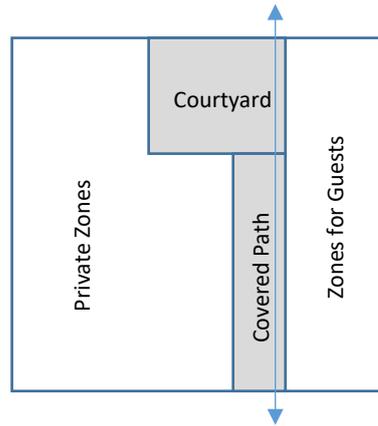
- One of the most important characteristics of traditional houses in the region is that the outside walls of the house are located on the boundary of plot, and opened to the inside through using courtyards. Gardens are inside the house and not on the sides of the house.
- The use of *mashrabiyyah* in front of the staircase to provide privacy and comfortable conditions.
- Roofs are used as terraces especially in the Gulf area and KSA.
- One example for the use of courtyards in old apartment buildings is Al-Ghuri building in Cairo, Egypt. There is a courtyard for each apartment on upper floor, with stores and stables located on the ground floor.
- The expansion of houses is a vertical pattern as an apartment building.
- The main bedroom in traditional houses is located on the upper floor, to have privacy and allow the wind to enter the space.
- In most traditional houses, there are two courtyards: one for residents and the other is for animals. This concept is adopted in contemporary houses or apartment buildings using the side area of the house as parking.
- In Lebanon and Syria (such as Aleppo), there are summer and winter zones.
- Proportion of each space is the most important feature that gives the residents the feel of comfort inside the house.

### **2. Contemporary Houses and High-rise Residential Developments in the Middle-East and North-Africa**

- Many people, especially the young generation, in the Gulf area, preferred duplex apartments.
- The most suitable area for the apartment is 150 m<sup>2</sup>.
- The current building regulations are not flexible, especially in terms of heights, setbacks, and areas. This affected the design of apartment buildings, such as inserting courtyards, or designing an apartment with two floors.

### **3. Your Design Philosophy**

- The most suitable form for courtyard houses or apartments in residential buildings is the U-shape.
- People prefer the open plan for their apartments with some partitions to have privacy for the family members.
- One solution for a residential building that have a courtyard inside the house is to divide the spatial layout into two zones, public and private, through inserting an outdoor covered path (opened from the two ends) that connected from one end with a courtyard. The design of this path depends on connecting the inside with the outside, inserting vegetation, and distinguishing the tiles of the outside from the outside.



Ala' Al-Masri Villa, Amman (Conceptual phase)

- Projects and Case Studies (designed by Architect Mohammad Abbas, Omraniyoun Consultants, Jordan and KSA):
  - o Modon Project, Dubai, UAE
  - o Apartment Buildings, Senegal
  - o Apartment Buildings, Mecca, KSA
  - o Wadi Abu Jamil, Beirut, Lebanon
  - o Al-Masri Villa, Amman, Jordan



BUILDING TYPE -3



DAR AL-OMRAN  
Planners - Architects - Engineers

SIGNATURE APARTMENT BUILDINGS  
SECTOR - C  
STAGE II - CONCEPT DESIGN

mace

DUBAI PROPERTIES  
دبي

BUILDING TYPE -3



DAR AL-OMRAN  
Planners - Architects - Engineers

SIGNATURE APARTMENT BUILDINGS  
SECTOR - C  
STAGE II - CONCEPT DESIGN

mace

DUBAI PROPERTIES  
دبي

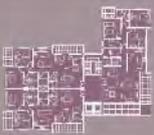
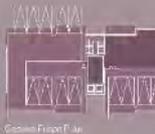
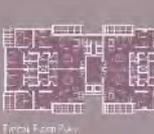
## RESIDENTIAL - BUILDING APARTMENTS



### BUILDING APARTMENTS

155 Apartment buildings are distributed in the site in 23 groups  
Each group of buildings gathered around a green garden and children playing area

## APARTMENT BUILDINGS

| BUILDING QUANT. |    |  | BUILDING QUANT.   |    |   |
|-----------------|----|--|---|----|---|
| B1              | 23 | <br>Ground Floor Plan | <br>Typical Floor Plan | B2 | 70  |
| B3              | 8  | <br>Ground Floor Plan | <br>Typical Floor Plan | B4 | 29  |
| B5              | 21 | <br>Ground Floor Plan | <br>Typical Floor Plan | B5 | 4   |
|                 |    |  |   |    | <br>Ground Floor Plan   |
|                 |    |  |   |    | <br>Typical Floor Plan |

### APARTMENT BUILDINGS

Main lobby, car parking and building utility at ground floor level  
Upper 4 floors for apartments, the fifth and sixth floors for apartments and duplexes with roof garden

### TYPE A

THREE BEDROOMS  
GROSS AREA = 156 m<sup>2</sup>  
TERRACE = 40 m<sup>2</sup>  
No. = 92



### TYPE B

TWO BEDROOMS  
GROSS AREA = 114 m<sup>2</sup>  
TERRACE = 18.5 m<sup>2</sup>  
No. = 720



### TYPE C

THREE BEDROOMS - DUPLEX  
GROSS AREA = 185 m<sup>2</sup>  
TERRACE = 94 m<sup>2</sup>  
No. = 23





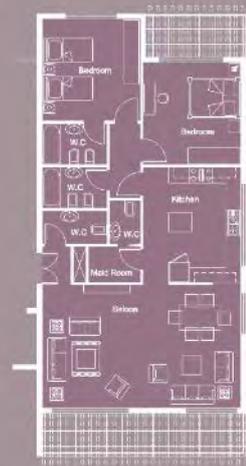
### TYPE D

THREE BEDROOMS  
 GROSS AREA = 158 m<sup>2</sup>  
 TERRACE = 70 m<sup>2</sup>  
 No. = 142



### TYPE E

TWO BEDROOMS  
 GROSS AREA = 120 m<sup>2</sup>  
 TERRACE = 20 m<sup>2</sup>  
 No. = 280



### TYPE F

THREE BEDROOMS - DUPLEX  
 GROSS AREA = 168 m<sup>2</sup>  
 TERRACE = 58 m<sup>2</sup>  
 No. = 70



UPPER FLOOR PLAN



LOWER FLOOR PLAN



### TYPE G

THREE BEDROOMS  
GROSS AREA = 134.5 m<sup>2</sup>  
TERRACE = 16.8 m<sup>2</sup>  
No. = 700



### TYPE H

THREE BEDROOMS  
GROSS AREA = 152 m<sup>2</sup>  
TERRACE = 34 m<sup>2</sup>  
No. = 116



### TYPE I

THREE BEDROOMS - DUPLEX  
GROSS AREA = 198 m<sup>2</sup>  
TERRACE = 130 m<sup>2</sup>  
No. = 29



UPPER FLOOR PLAN



LOWER FLOOR PLAN

### TYPE J

TWO BEDROOMS  
GROSS AREA = 112 m<sup>2</sup>  
TERRACE = 15 m<sup>2</sup>  
No. = 168



### TYPE L

THREE BEDROOMS - DUPLEX

GROSS AREA = 149 m<sup>2</sup>

TERRACE = 48 m<sup>2</sup>

No. = 42

UPPER FLOOR PLAN      LOWER FLOOR PLAN

### TYPE K

TWO BEDROOMS

GROSS AREA = 112 m<sup>2</sup>

TERRACE = 12 m<sup>2</sup>

No. = 84

### TYPE M

THREE BEDROOMS - DUPLEX

GROSS AREA = 170 m<sup>2</sup>

TERRACE = 53 m<sup>2</sup>

No. = 21

LOWER FLOOR PLAN      UPPER FLOOR PLAN

### TYPE N

TWO BEDROOMS

GROSS AREA = 122 m<sup>2</sup>

TERRACE = 34 m<sup>2</sup>

No. = 16



End of Interview

### **Interview # 3 - Architect Nael Juneidi**

**Date of Interview:** 14/08/2016 (17:00 pm – 18:00 pm)

#### **1. Traditional Houses in the Middle-East and North-Africa**

- In the current time, old houses are not suitable to live in it. Architects need to understand the meaning of each element (such as *mashrabiyyah*), and then reuse it in a new and contemporary way and material.
- The power of traditional houses is in the geometry of each space.
- Main features are centrality, axis, hierarchy, and orientation (toward the *qibla*).

#### **2. Contemporary Houses and High-rise Residential Developments in the Middle-East and North-Africa**

- Many people prefer the apartment to be duplex (two floors).
- To have a successful apartment building, developers should think with the issue of facility management, as many problems between residents are due to responsibilities of cleaning common spaces.

#### **3. Your Design Philosophy**

- The philosophy of the company (ICON) is to deconstruct the elements of Islamic architecture, then reframe and reconstruct these elements using new technologies.
- The target of the company (ICON) is to design and construct the project at the same time. This gives the architect the influence to execute his ideas.
- Apartments that have more than one entrance, and separated from other apartments in the building, are more desired for the residents.
- The power of any design is to allow children to feel free when they play, and at the same time provide security and safety.
- Our target is to build a compound with a public common space that offers social interaction between families. One example as a case study is a project for Zaha Hadid in New Mexico with an open urban space.

End of Interview

## Interview # 4 - Architect Raof Abu Laban

Date of Interview: 18/08/2016 (11:00 am – 13:00 pm)

### 1. Traditional Houses in the Middle-East and North-Africa

#### Needs for Sustainability:

- Initiatives for sustainability in the Islamic World have been started before USA or Europe as it is connected with environment, local materials and local traditions. In MENA region, the harsh arid climate and the lack of green areas compel people to adapt their buildings with the context and the environment in order to provide them with healthy and comfortable environment.
- The marketing of sustainability in USA (such as LEED) and Europe is more advanced than the Islamic World.

#### Traditional Cities and Neighborhoods:

- Each area benefits from what is available in the context, taking into consideration the local climate.
- People depend on the concept of 'trial and error' when they design their buildings.
- One of the most important books about the organization of Islamic cities is "Building Regulations" by Ibn Al-Rami "الإعلان بأحكام البنين". In his book, Ibn Al-Rami described the planning of cities are based on the needs of people more than specific rules. For instance, the width of alleys is equal to 7 arms (= 0.75 m x 7 = 5.25 m), which is suitable for two animals to walk in both directions.
- The height of any building should be the same of opposite one in order to offer shade between them for pedestrians.
- The orientation of alleys is East-West.
- Markets are planned in a linear pattern, and not around a plaza or square.
- Hassan Fathy failed in his project (Al-Gourna) in Egypt when he designed new houses for people without taking into consideration the mixed functions inside the neighborhood.
- The major priority in the planning of new residential quarters is the car not pedestrians.

#### Social Dimension:

- In each city, people respect the rights of pedestrians and the privacy of residents.
- There is modesty in the design of residential buildings as all houses are same from the outside regardless of poor or rich status of families.
- Each neighborhood has a gate, which offers comfort and safety for children to play in public areas.
- In terms of privacy, windows are located in a way that prevents a direct access to the neighbors. Moreover, the height of houses are approximately the same, which provides privacy for each family.
- Connections between houses and nearby windows provide social interaction between neighbors.
- There is a path (called *majaz*) between the entrance of the house and the courtyard, which offers safety and security for the family members, in addition to prevent dust enter the house.
- The expansion of houses is vertical as each family builds a room on the roof as needed.

### **Environmental Dimension:**

- The orientation of houses is from inside to the outside, which offers for the sun and wind to enter the house naturally without depending on any mechanical equipment.
- The courtyard is surrounded with walls that offer shade.
- Most traditional houses have a fountain in the middle of the courtyard.
- There are two major elements that offer sustainability: (a) materials; and (b) construction methods. The use of local and natural materials such as stone, clay, and brick with 80-100 cm thicknesses instead of insulation. The humidity in the clay, and the small size of windows offer comfortable conditions inside rooms, as the climate is hot and dry.
- The use of *mashrabiyyah*, which is similar to louvers, provides privacy and environmental solution as sun breakers.
- The use of wind towers provides the house with low temperatures in the daytime. There is an opening at the end of the tower in the direction of the air (e.g. west direction in Amman), which allows the cold air to enter the courtyard instead of hot air. Sometimes, cubes of straw, with water basins or jars, are used at the top of the wind tower for cooling.

### **Components of Traditional Houses**

- Guest room is located beside the entrance with a toilet. This public zone is connected directly with *majaz*, so they do not need to enter the private zones or the courtyard.
- The courtyard in many traditional houses is connected with semi-open spaces called (iwans) that are raised two steps and used as living areas for the family.
- In large houses, there is a colonnaded path around the courtyard, which is called *riwaq*. People prefer not to use this element in their houses as it prevents the sun to enter rooms.
- The kitchen in traditional houses has a private and small courtyard, or separated from other rooms, in order to prevent smells to be entered the bedrooms and the living spaces of the house.

## **2. Contemporary Houses and High-rise Residential Developments in the Middle-East and North-Africa**

- The current problem in contemporary developments is that it depend on the concept of setbacks, so most of the plot area is a wasteland.
- The current problem in the Gulf area (especially in KSA) is the outside high walls, which prevent the wind and sun entering the house. Moreover, there is no connection between the street and the house and the garden within setbacks.
- The use of terraces around the apartment is a good solution, but not like the courtyard. These terraces are preferred to be directed to the wind (e.g. west direction in Amman).

## **3. Your Design Philosophy**

- The courtyard house is the most suitable type socially and environmentally for our region.
- It is not recommended to increase the height of the ceiling as it increases the cost of the house.

- The most suitable shape for the courtyard is square or rectangle, and located at the center of the house.
- One of the contemporary projects that benefits from the characteristics of traditional building is the German Jordanian University in Amman, Jordan (Design by Dar Al-Omran, Architect Rasem Badran).
  - o All classes are oriented to the north-south axis.
  - o Classes are parallel to circulation paths.
  - o The use of louvers on the south facade.
- The use of sackcloth on skylights is a good solution for preventing the sun from entering directly.
- When we design the house, we should allow the residents to adapt their houses to their needs, as they are the end-users, and know how to solve their problems with trial and error methods.
- The open plan is not suitable for our culture, especially the open kitchen, as each space has its privacy and use.

End of Interview

## Interview # 5 - Architect Wael Al-Masri

Date of Interview: 03/08/2016 (17:00 pm – 18:30 pm)

### 1. Traditional Houses in the Middle-East and North-Africa

- Containment in the spatial arrangement of traditional houses (U-shape layout, or a courtyard in the middle of the house) makes the family members more connected and facilitate the social interaction.
- The bent entrance in traditional houses is a major feature to preserve the privacy of the family.
- In some areas, residents prefer to add curtains on terraces or balconies as a protection from the direct sun.

### 2. Contemporary Houses and High-rise Residential Developments in the Middle-East and North-Africa

- One of the important cases in the residential tower (Kanchanjunga Apartments) designed by Charles Correa in Mumbai, India (height: 84 m, opened: 1970-1983, floors: 27)

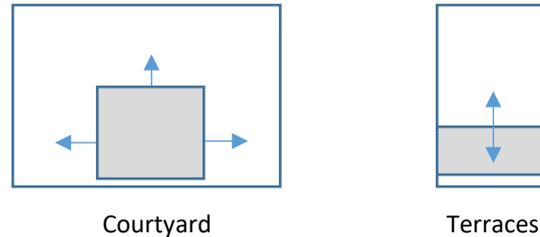


- A main problem in apartment buildings is that the residents do not care with public spaces and plazas inside the building. Therefore, developers do not prefer to include common spaces inside buildings, as it needs regular maintenance.

### 3. Your Design Philosophy

- It is not recommended to include a courtyard for the whole building. Each three to four floors could have a common space (courtyard).

- The problem of terraces in residential buildings is that there is no connection between the inside the outside. It is only connected with the outside environment, and there is no interaction between the users of other spaces. In contrast, spaces around the courtyard facilitate the interaction between the users of these spaces.



- Old typologies of houses should be developed to achieve the modern and recent needs of users. Therefore, it is recommended in contemporary designs to change the location of the courtyard from the middle to the corner of the house or as a U-shape layout in order to fit the standards of living.
- Courtyards should be used as a living space and not as a transitional space.
- As designers depend on the use of air-conditioning, there is no need to divide the house into summer and winter zones.
- The best location of the courtyard is to direct them to the wind and to the view. For instance, the north is the best location of the courtyard in Kuwait. In Jordan, it is not recommended to locate the courtyard toward the north as residents cannot use it in summer.
- In Gulf Area, it is recommended to include an open courtyard, as the climate is very harsh. Courtyards could be covered with skylights and louvers.
- One recent project is a residential tower in Kuwait. The tower is 14 floors. There are three types of apartments: Type (1) is a full floor apartment (guest room, dining room, living space, kitchen, three bedrooms, three toilets, and storage); Type (2) is occupied half of the floor (living area, kitchen, two toilets, and two bedrooms); and type (3) is an apartment is two floors and has a courtyard (guest room, dining room, two living space overlooking a courtyard, kitchen, three bedrooms, three toilets, and storage). Moreover, there are many terraces overlooking the sea, and a green wall for plants.

تصاميم معاصرة ومستدامة من وجه التراث والأصالة



مركز الشركة على التصميم المعماري المتكامل بما في ذلك التخطيط الهيكلي والتصميم الحضري وتقسيم المواقع والتصميم الداخلي للتطوير في العالم العربي. تلتحق عام ومطلة الفتح بشكل خاص. ومركز الشركة على تطوير العمارة المعاصرة استناداً من ثقافة العمارة الإسلامية والتراث المصري الأصيلة لهذا القطاع. ويستخدم فريق التصميم بالشركة التقنيات الحديثة والتقنيات الرقمية في تنفيذ المشاريع المعمارية بينا اقتصادياً وفعالاً.

وتتمثل مشاريع الشركة على المقر الرئيسي للبنك الأهلي في منطقة سفينة عين، الذي تم بناؤه في الشركة في سفينة عين. وأما تم تنفيذ في شهر فبراير 2014 كما تم تنفيذ الشركة على عدة مشاريع في المنطقة بما في ذلك التخطيط الهيكلي للتطوير وربط الشوارع المتعددة الاستخدامات في حي الجزيرة في مكة المكرمة (800.000 متر مربع) ودمج سكني خاص في القاهرة وقصر خاص في الرياض، المملكة العربية السعودية، ويحيطه مساحات خضراء ممتدة في الكويت، وقصر في الشارقة وأخرى من المدن الإمارات العربية المتحدة، وذلك في منطقة سفينة عين، وأربع سكنية في الكويت، فضلاً عن العديد من المشاريع السكنية في عمان، الأردن، ومصر في منطقة الرشا ومركز استراتيجي ومصرف في ليبيا، كما تم إنجاز الشركة في سفينة التصميم الحضري لتقريب خمس كم مساحه 50-000 متر مربع في قطر الشامية.

عملت الشركة على عدة مشاريع في الشارقة الإمارات العربية المتحدة، مع هيئة الشارقة للتخطيط والتطوير (سروك) بما في ذلك تطوير الخطط الهيكلية التفصيلية لتبني الشارقة كإحدى وأحد الخطط الهيكلية والتصميم الحضري لمدينة الشارقة، وهي عملية تشاركية لإحداث التغيير في عام 2012 والمرحلة الثانية من المدينة، بما في ذلك تصميم 12 مخططاً مخططاً (إشياء) بالإضافة إلى تصميم مطور مع تكملة الخدمة لخدمة المدينة وتتمثل مركز سوق وتحتل خمس كم مساحه ومشروع حيا لتطوير جزيرة الفوائد، ومخيم الجابر العمارة.

المصر والى المصري، حصل على اعترافه الدولية من جامعة واشنطن بالوكالة المتحدة (الكلور بوس) وتزودها بالخدمات من مجموعة ماستر بلانز للتطوير والتطوير، مع ماستر بلانز للخدمات الأثرية الأمريكية، وقد عمل بالعمارة الجرمي على مدى الأربعة عقود الماضية، وساهم في تطوير العديد من المشاريع السكنية والخدمية والمعمارية، وقد حازت على العديد من الجوائز المحلية والإقليمية والدولية ومنها "مجازة المعماري العربي" من مؤسسة المعمار العربية في أبوظبي، الإمارات العربية المتحدة، 2008، و"مجازة أفضل مخطط لعام" (2007، 2008) من رابطة مهندسي العمارة المعمارية الإسلامية، بينتسكيب (2007)، "مجازة التصميم المعماري" عام 2007، من المجلس الدولي لدراسة التراث (ICSC)، الولايات المتحدة الأمريكية، ومجازة الجوائز المعماريتين المعماريين الجرميين "RIBA" -مجازة التصميم المعماري (Nipper) 1964.

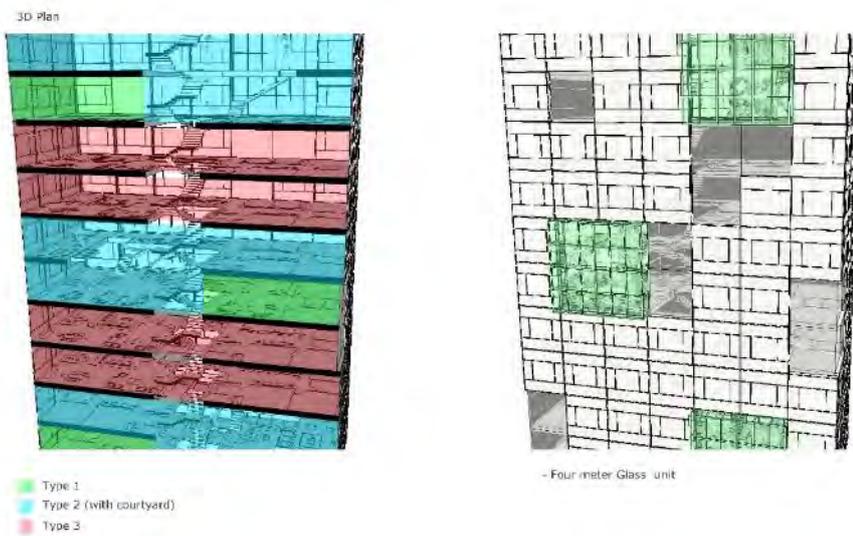


August 22, 2010

3D Shots

Project Location | Shufabab Towers schematic design

K 29

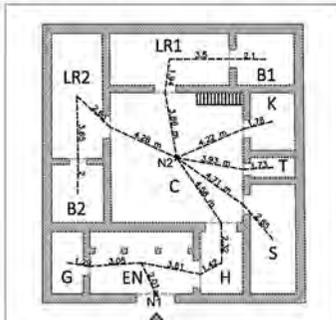


End of Interview

Appendix (4-B-1)

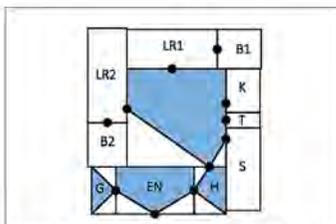
**The Developed Model for carrying out  
Syntactic and Geometric Analyses**

|         |           |           |
|---------|-----------|-----------|
| Region: | Location: | Case No.: |
| Maghrib | Tunis     | M-1       |



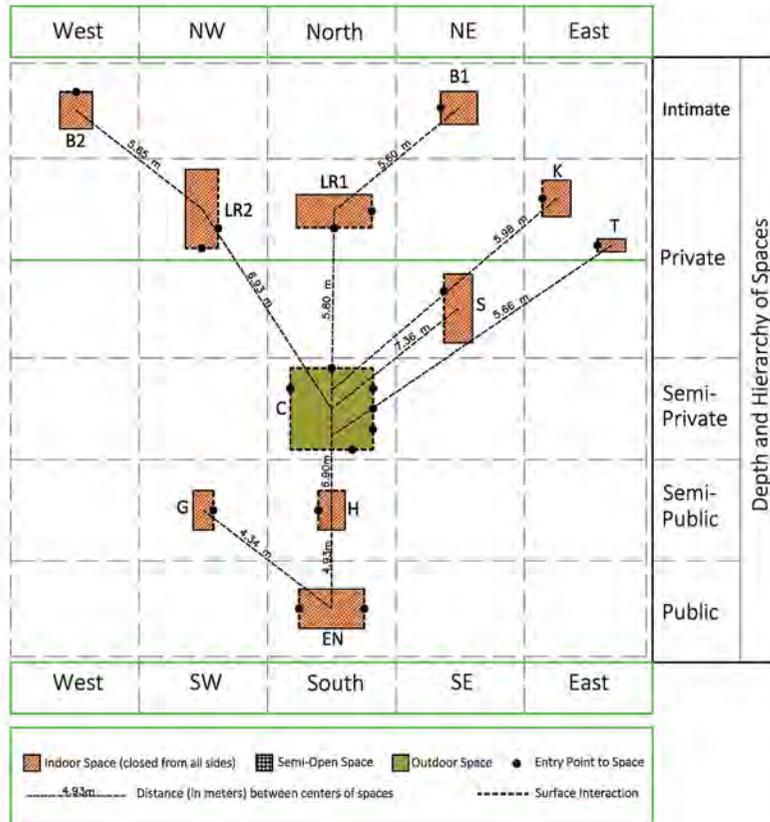
As-Built Plan  
Source: Redrawn by Researcher from (Ragette 2003)  
showing distances between spaces (in meters)

|    |            |    |                          |
|----|------------|----|--------------------------|
| EN | Entry Hall | S  | Storage                  |
| G  | Guest Room | LR | Living Room              |
| C  | Courtyard  | B  | Bedroom                  |
| K  | Kitchen    | H  | Hall (Circulation Space) |
| T  | Toilet     | N1 | The Main Entrance Door   |
|    |            | N2 | Center of the Courtyard  |



Spatial Organization of Spaces and Visual Analysis for Public, Semi-Public and Semi-Private Domains

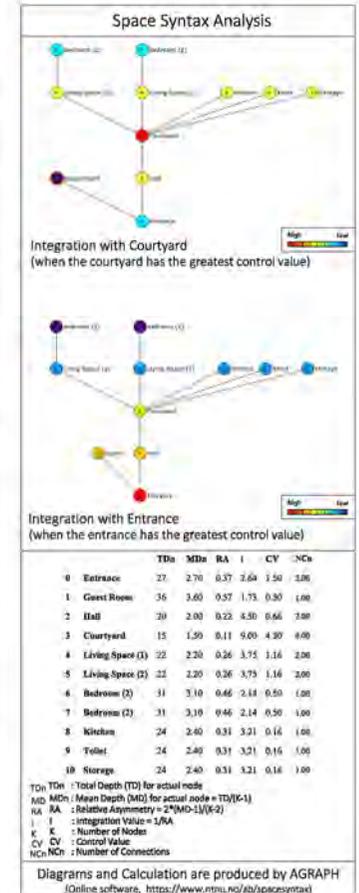
## The Developed Model for carrying out Syntactical and Spatial Analysis



### Spatial and Geometric Relationships

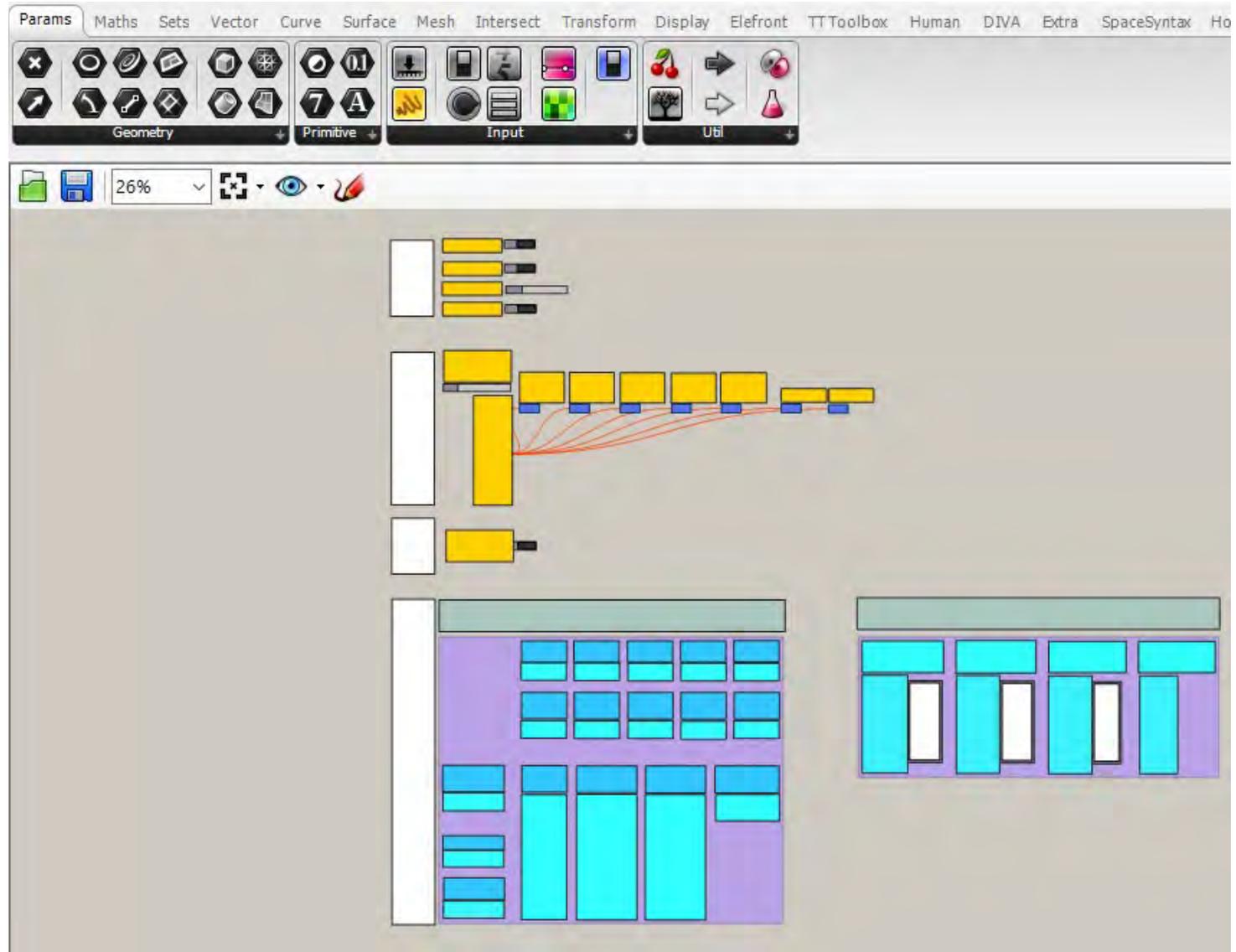
|            |              |              |     |              |              |
|------------|--------------|--------------|-----|--------------|--------------|
| LR2        | XY: 1, 2.45  | %All: 8.52%  | LR1 | XY: 1, 2.30  | %All: 8.89%  |
|            | 1:C: 1, 0.37 | D1: 20.79    |     | 1:C: 1, 0.36 | D1: 19.63    |
| Users: M+F |              | Users: M+F   |     | Users: M+F   |              |
| B2         | XY: 1, 1.11  | %All: 5.46%  | B1  | XY: 1, 1.12  | %All: 5.48%  |
|            | 1:C: 1, 0.18 | D1: 28.45    |     | 1:C: 1, 0.18 | D1: 25.23    |
| Users: M+F |              | Users: M+F   |     | Users: M+F   |              |
| K          | XY: 1, 3.1   | %All: 4.70%  | T   | XY: 1, 2.2   | %All: 1.65%  |
|            | 1:C: 1, 0.15 | D1: 19.71    |     | 1:C: 1, 0.05 | D1: 19.49    |
| Users: F   |              | Users: M+F   |     | Users: M+F   |              |
| S          | XY: 1, 2.45  | %All: 8.94%  | C   | XY: 1, 1.03  | %All: 30.37% |
|            | 1:C: 1, 0.29 | D1: 21.23    |     | 1:C: 1, 1    | D1: 13.83    |
| Users: M+F |              | Users: M+F   |     | Users: M+F   |              |
| G          | XY: 1, 1.90  | %All: 3.62%  | H   | XY: 1, 1.45  | %All: 4.79%  |
|            | 1:C: 1, 0.12 | D1: 6.32     |     | 1:C: 1, 0.16 | D1: 6.93     |
| Users: M   |              | Users: M+F   |     | Users: M+F   |              |
| EN         | XY: 1, 1.67  | %All: 11.67% | EN  | XY: 1, 1.67  | %All: 11.67% |
|            | 1:C: 1, 0.38 | D1: 2.01     |     | 1:C: 1, 0.38 | D1: 2.01     |
| Users: M+F |              | Users: M+F   |     | Users: M+F   |              |

M : Predominant Male Users  
 F : Predominant Female Users  
 XY : Proportion of the Space  
 %All : Percentage of Area from the Overall  
 1:C : Proportion related to the Courtyard  
 D1 : Distance (in Meters) from the Main Entrance (N1) to the Center of Space  
 D2 : Distance (in Meters) from the Center of Courtyard (N2) to the Center of Space

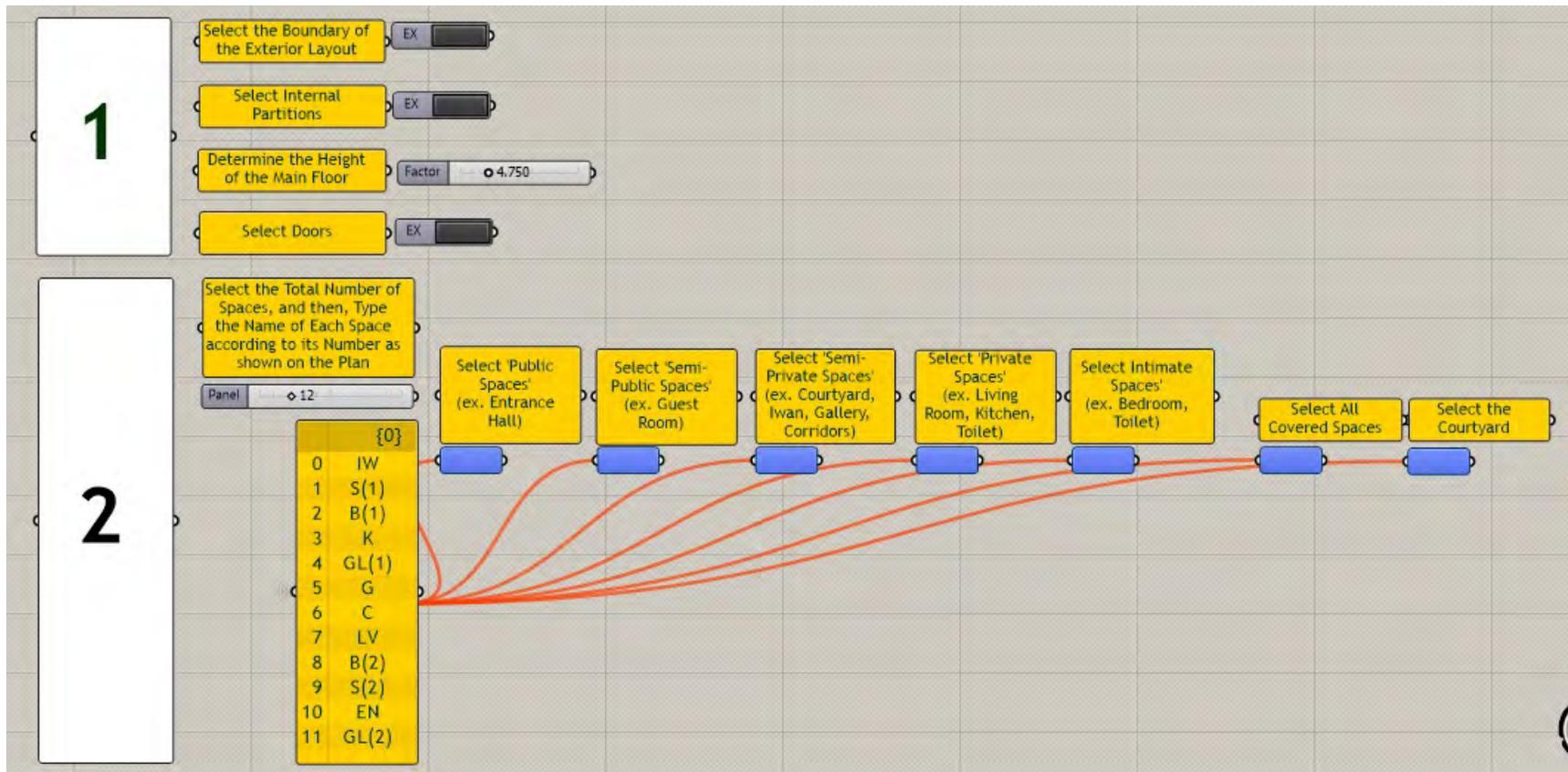


Appendix (4-B-2)

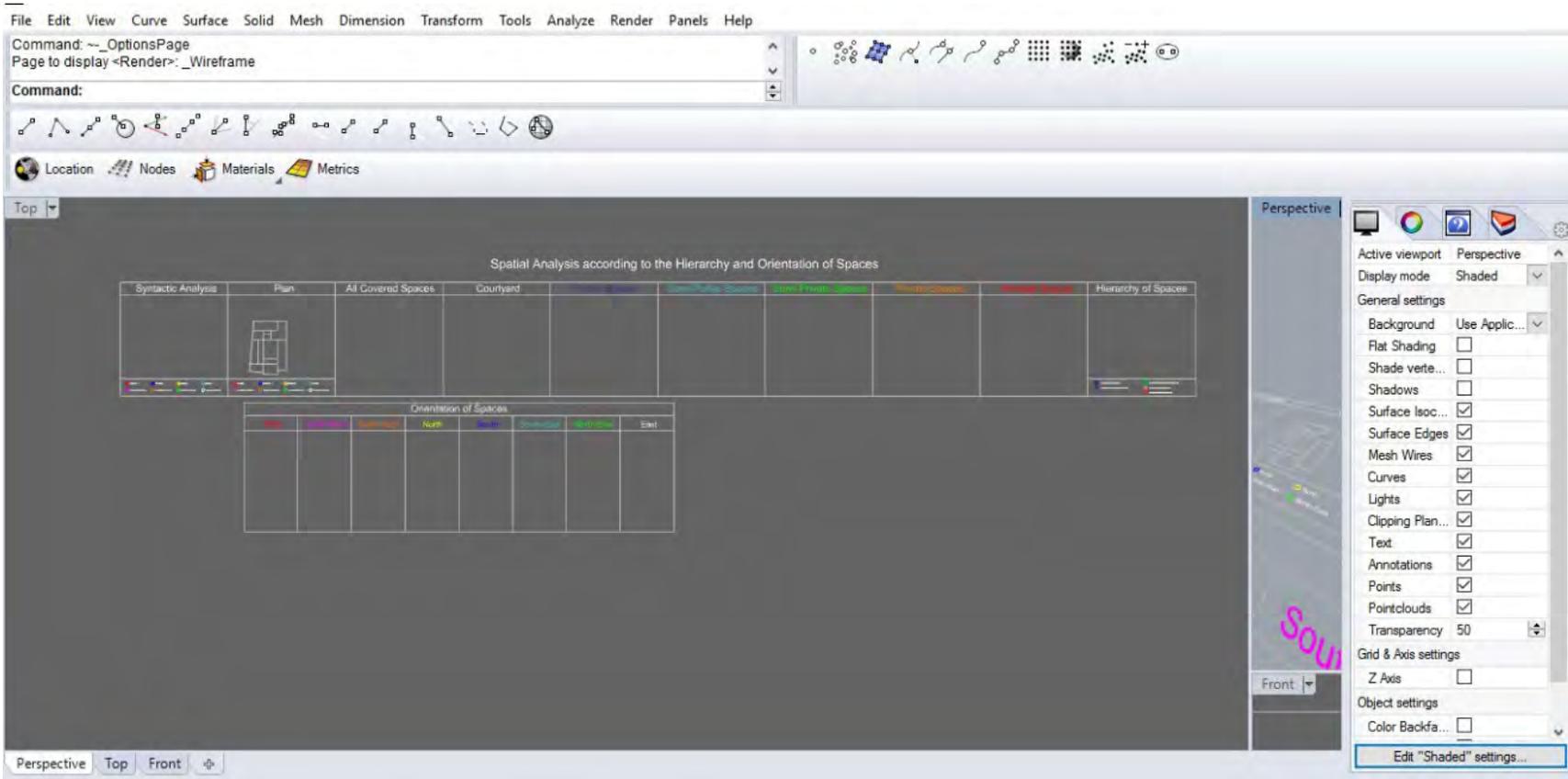
**Screenshots for Components of the Computational  
Model for carrying out Syntactic and Geometric  
Analyses, using Rhino/Grasshopper**



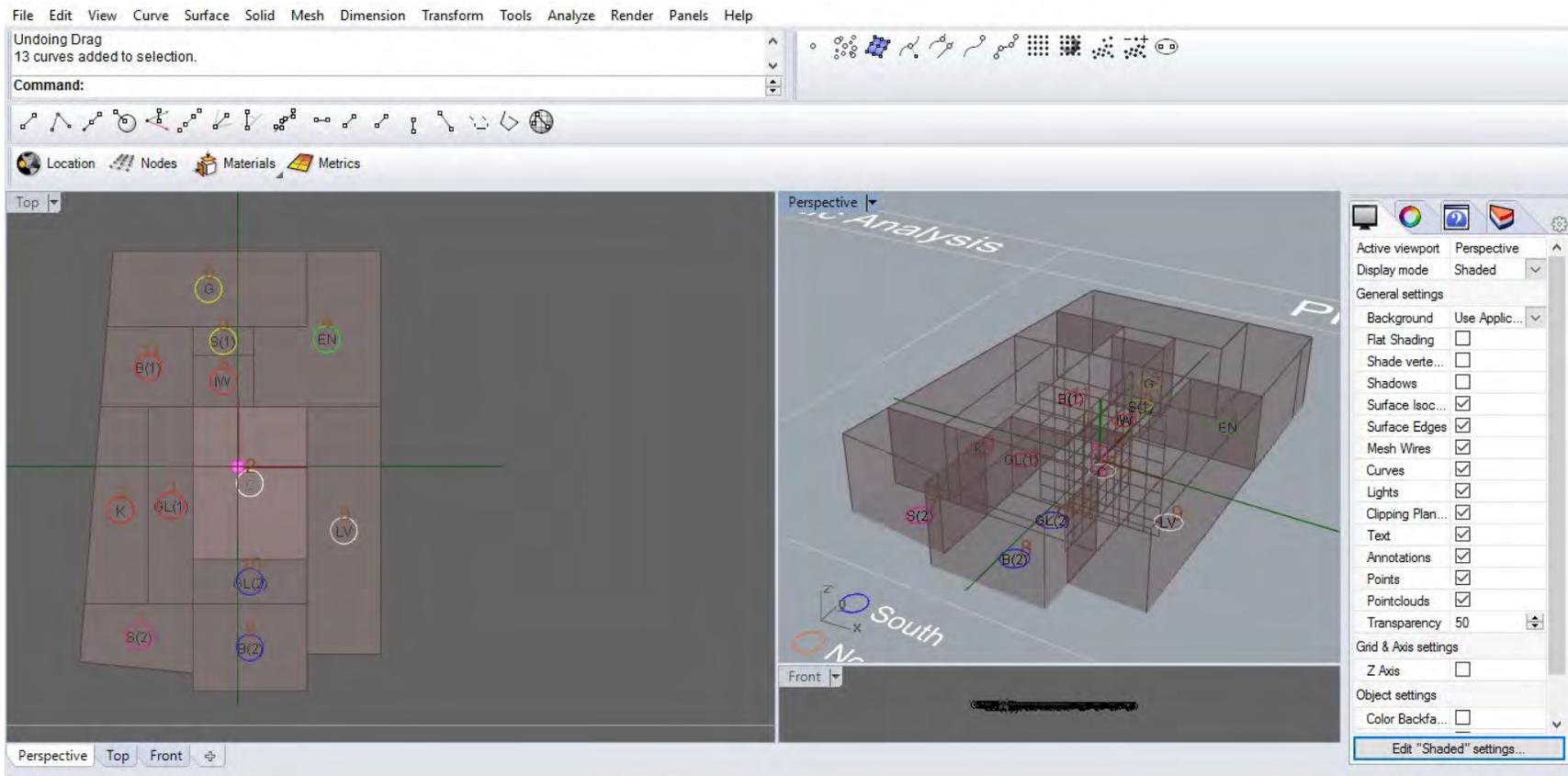
A screenshot showing the interface for the user



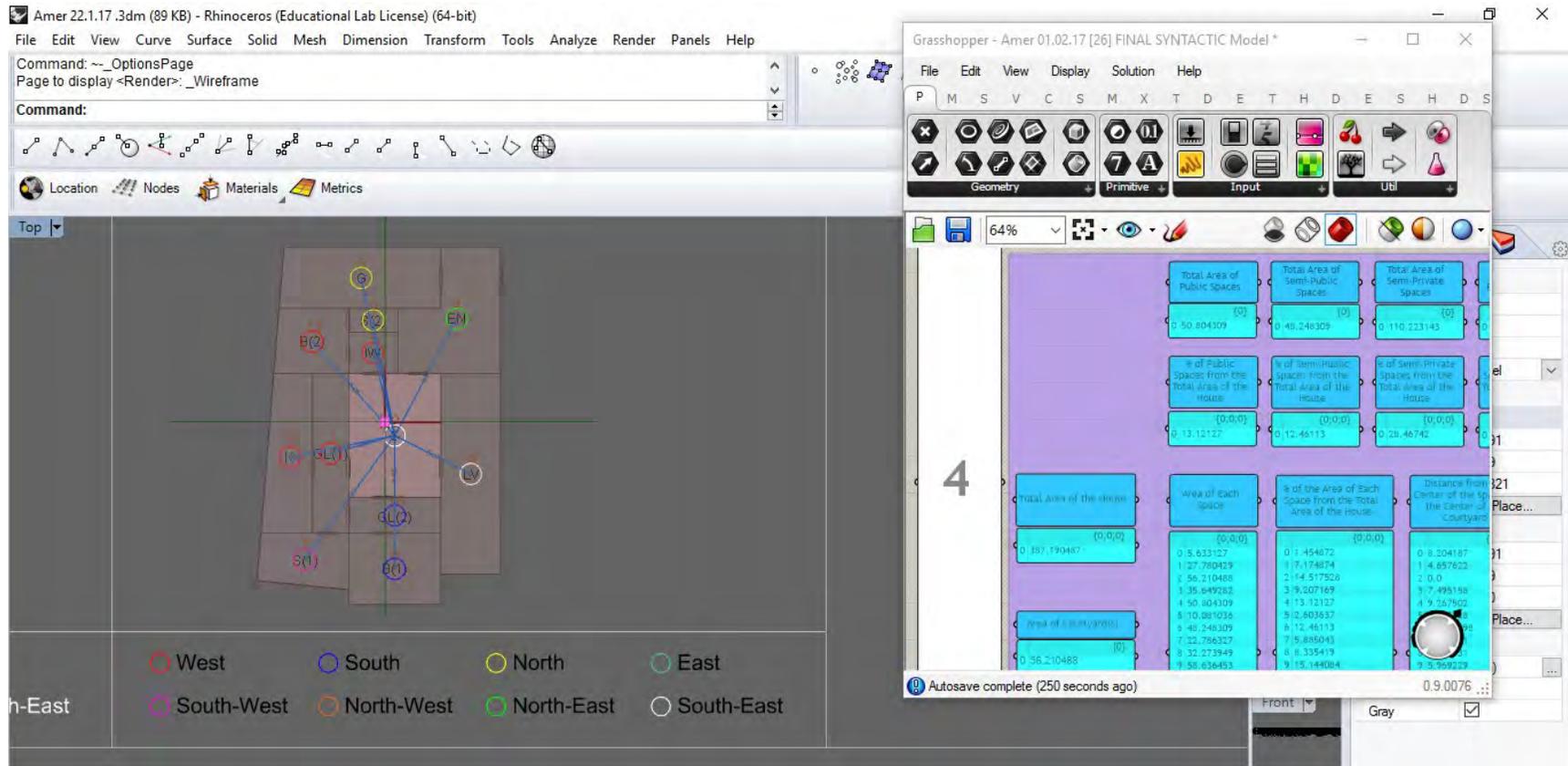
A screenshot showing stages 1 and 2 from the interface for the user  
 Stage (1): selecting the layout for the analysis, and  
 Stage (2): Selecting the different spaces according to the hierarchy of each space



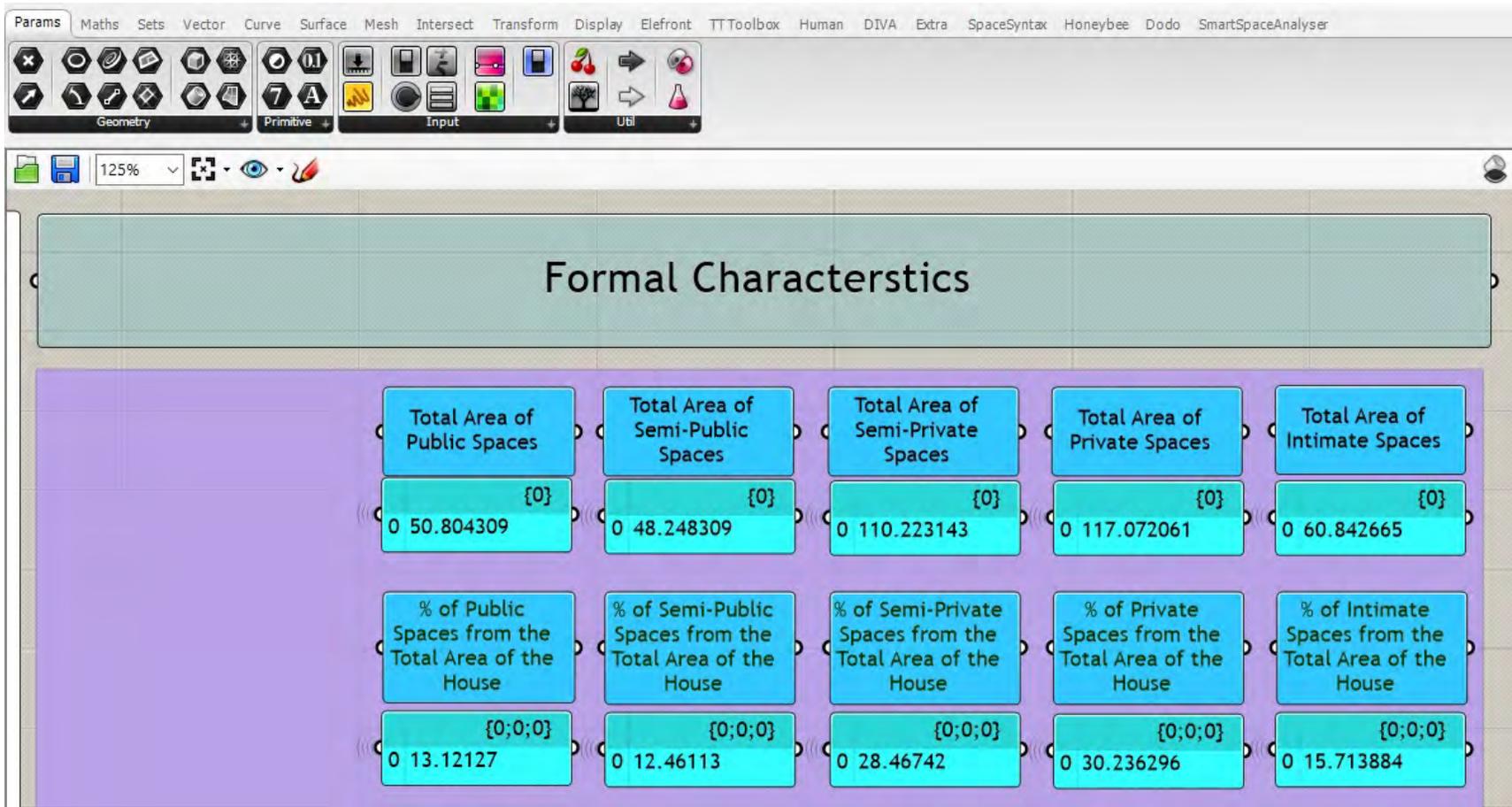
A screenshot showing the layout of the interface before carrying out the analysis



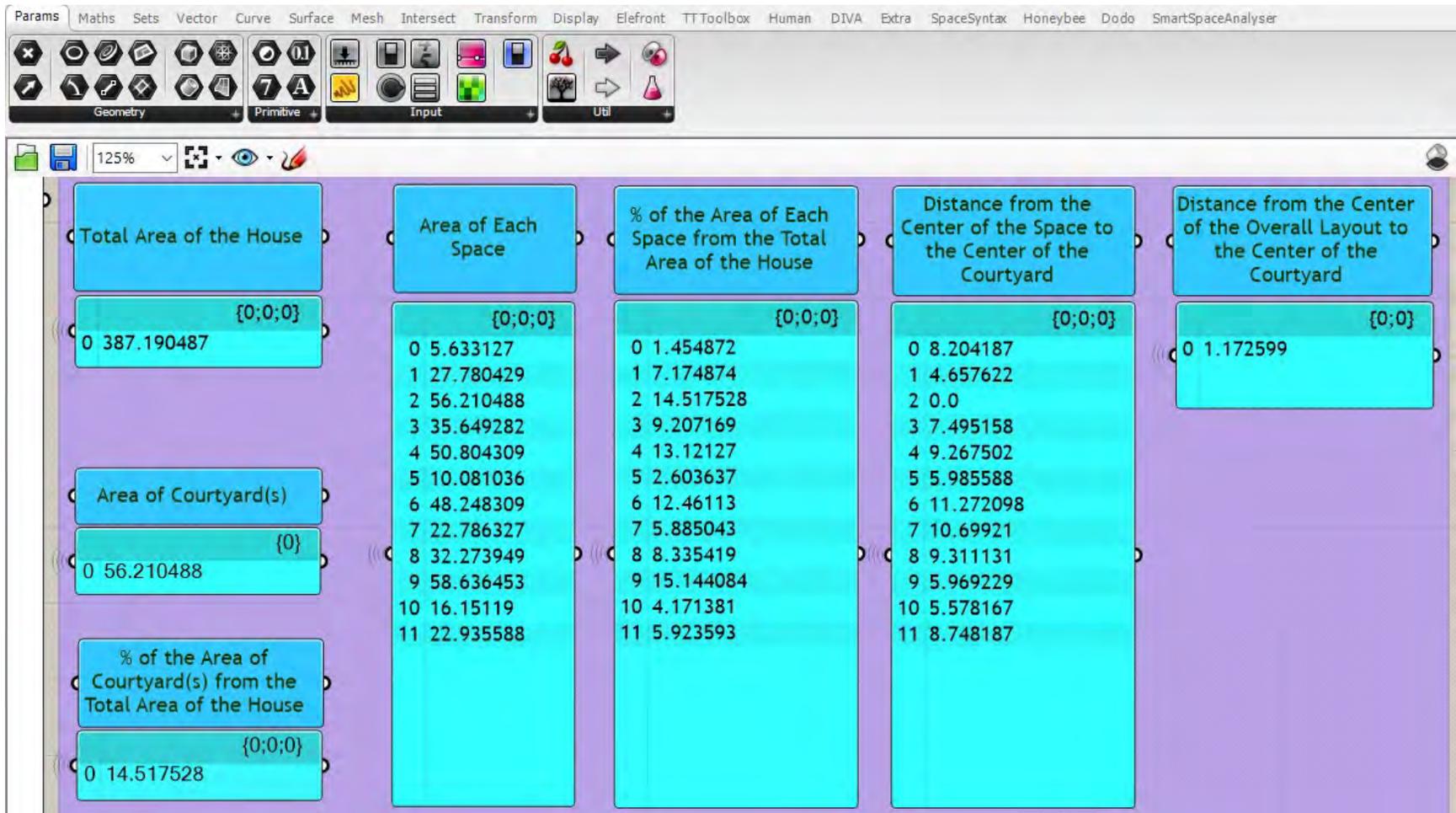
A screenshot showing the analytical diagrams carried out by the model



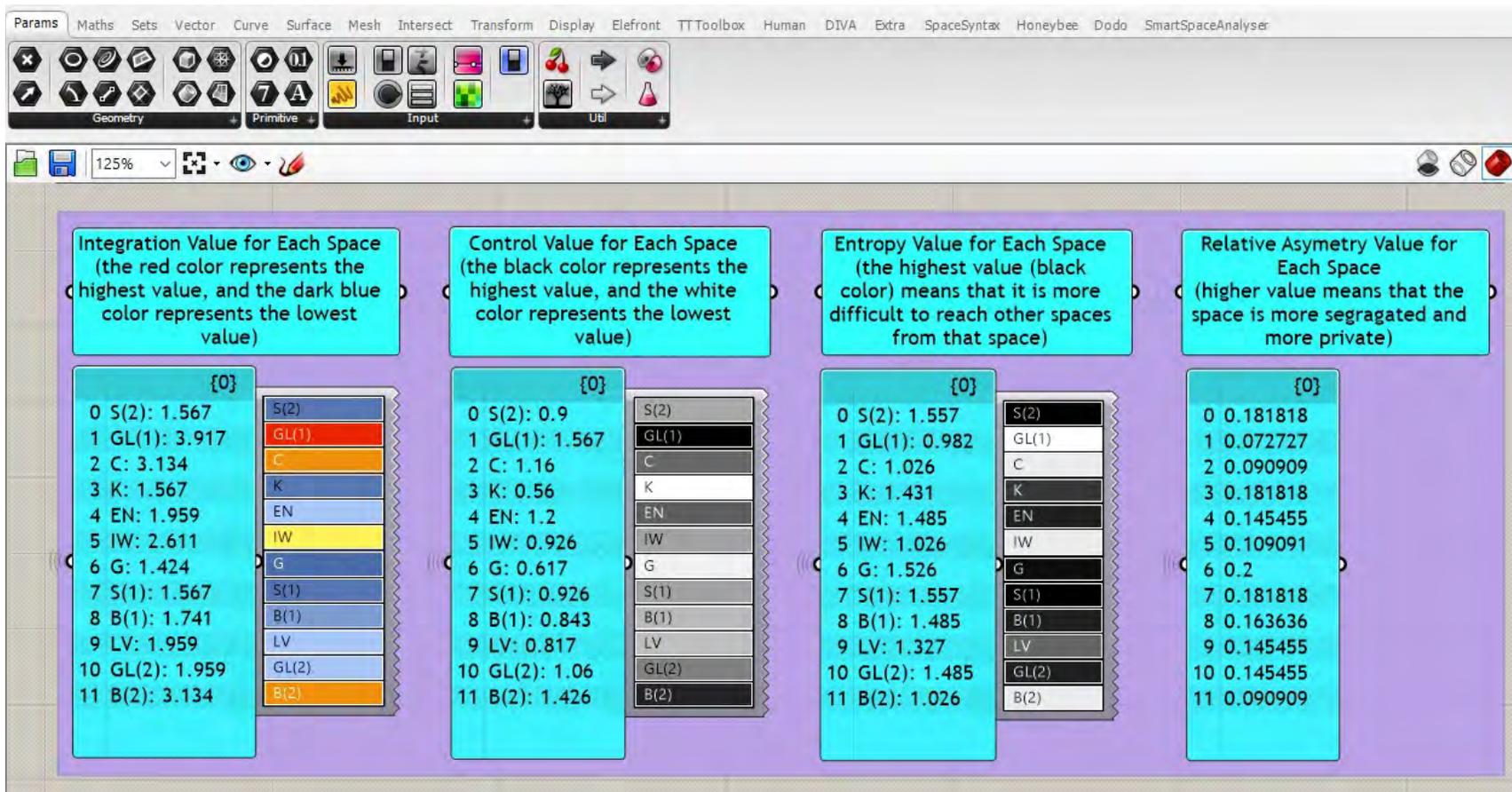
A screenshot showing the analytical diagrams and spatial calculations carried out by the model



A screenshot showing spatial calculations carried out by the model



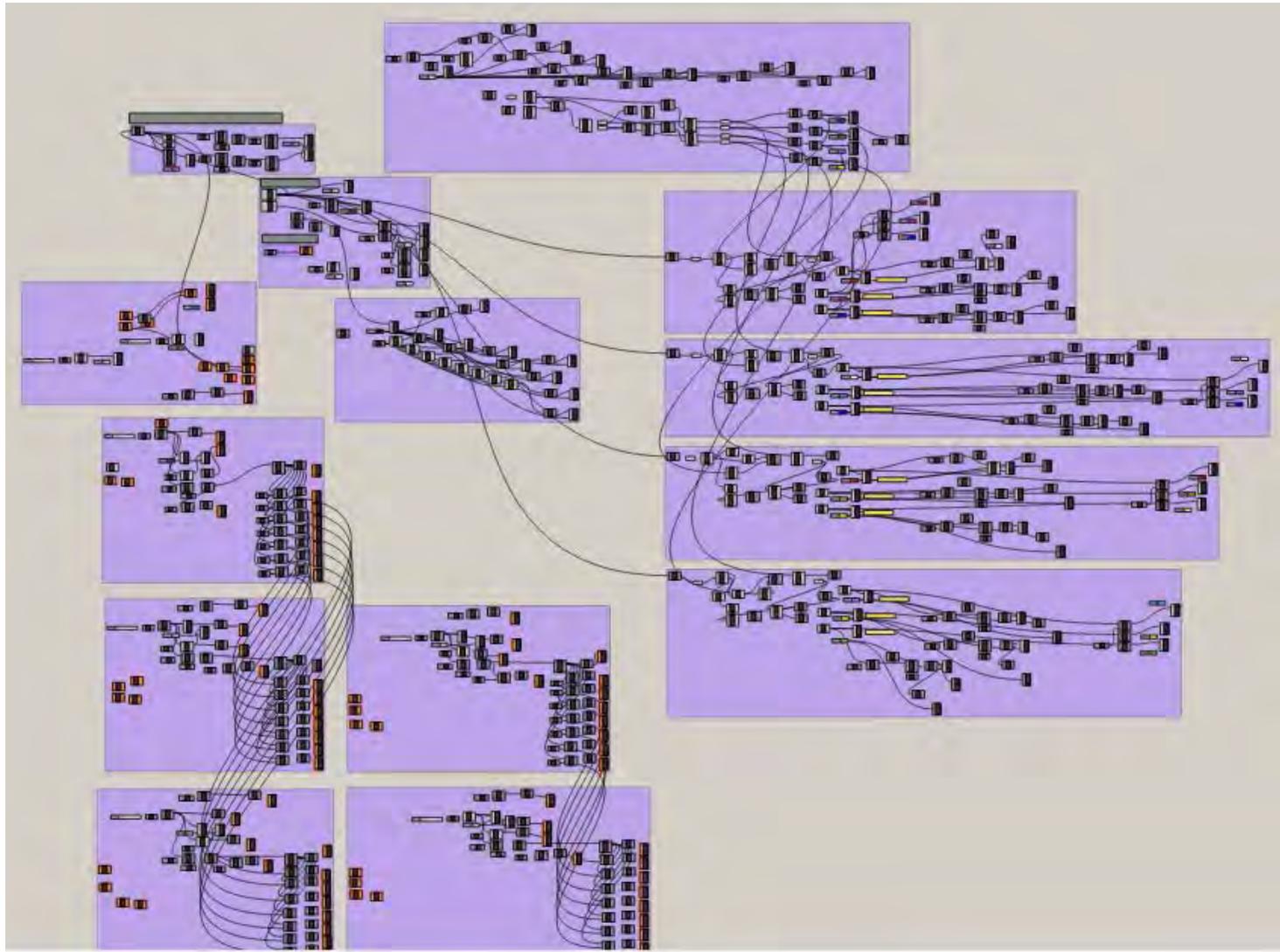
A screenshot showing spatial calculations carried out by the model



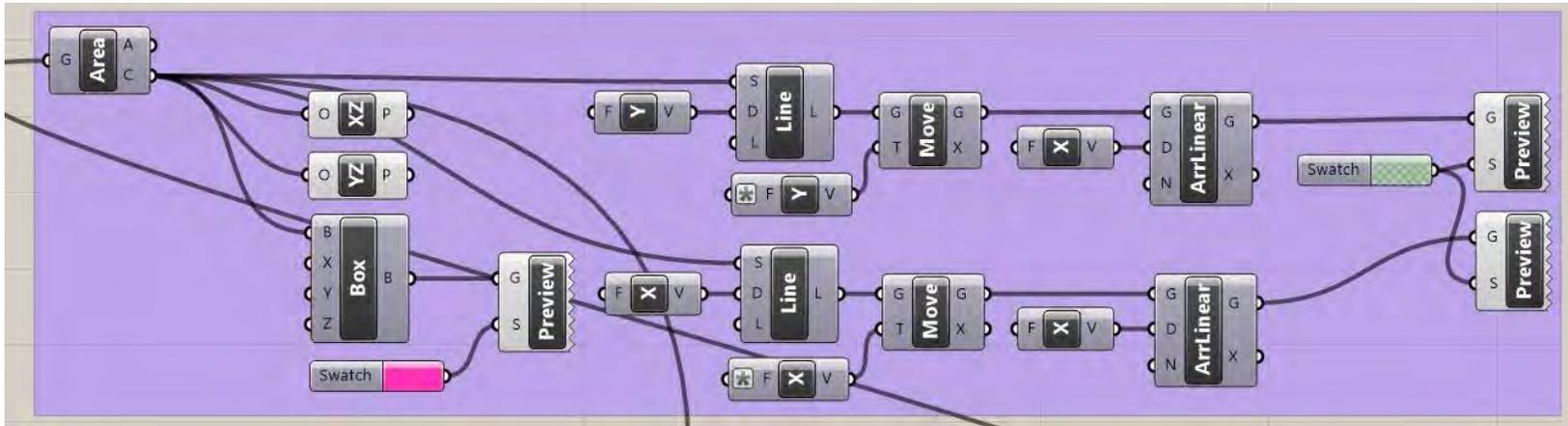
A screenshot showing syntactic calculations carried out by the model

| Microsoft Excel - Ribbon: FILE, HOME, INSERT, PAGE LAYOUT, FORMULAS, DATA, REVIEW, VIEW, ACROBAT |  |                  |                        |   |  |                    |               |               |                          |        |  |
|--|--|------------------|------------------------|---|--|--------------------|---------------|---------------|--------------------------|--------|--|
| Clipboard  |  | Font             |                        |   | Alignment  |                    |               | Number        |                          | Styles |  |
| 1  |  |                  |                        |   |  |                    |               |               |                          |        |  |
| 2  | Total Area of the House (m <sup>2</sup> )                                | 387.19           |                        | Area of Public Spaces (m <sup>2</sup> )       | 50.80  | 13.12%             |               |               |                          |        |  |
| 3  | Area of Courtyard(s) (m <sup>2</sup> )                                   | 56.21            |                        | Area of Semi-Public Spaces (m <sup>2</sup> )  | 48.25  | 12.46%             |               |               |                          |        |  |
| 4  | % of Courtyard(s)  | 14.52%           |                        | Area of Semi-Private Spaces (m <sup>2</sup> ) | 110.22   | 28.47%             |               |               |                          |        |  |
| 5  | Distance (m) from the Center of the House to the Center of the Courtyard | 1.17             |                        | Area of Private Spaces (m <sup>2</sup> )      | 117.07   | 30.24%             |               |               |                          |        |  |
| 6  |  |                  |                        | Area of Intimate Spaces (m <sup>2</sup> )     | 60.84  | 15.71%             |               |               |                          |        |  |
| 7  |  |                  |                        |   | 387.19   | 100.00%            |               |               |                          |        |  |
| 8  |  |                  |                        |   |  |                    |               |               |                          |        |  |
| 9  |  | Spatial Analysis |                        |   |  | Syntactic Analysis |               |               |                          |        |  |
| 10   |  | Spaces           | Area (m <sup>2</sup> ) | % of Area from the Total Area of the House    | Distance (m) from the Center of the Space to the Center of the Courtyard | Integration Value  | Control Value | Entropy Value | Relative Asymmetry Value |        |  |
| 11   |  | S(2)             | 5.63                   | 1.45%   | 8.20   | S(2) 1.57          | 0.90          | 1.56          | 0.18                     |        |  |
| 12   |  | GL(1)            | 27.78                  | 7.17%   | 4.66   | GL(1) 3.92         | 1.57          | 0.98          | 0.07                     |        |  |
| 13   |  | C                | 56.21                  | 14.52%  | 0.00   | C 3.13             | 1.16          | 1.03          | 0.09                     |        |  |
| 14   |  | K                | 35.65                  | 9.21%   | 7.50   | K 1.57             | 0.56          | 1.43          | 0.18                     |        |  |
| 15   |  | EN               | 50.80                  | 13.12%  | 9.27   | EN 1.96            | 1.20          | 1.49          | 0.15                     |        |  |
| 16   |  | IW               | 10.08                  | 2.60%   | 5.99   | IW 2.61            | 0.93          | 1.03          | 0.11                     |        |  |
| 17   |  | G                | 48.25                  | 12.46%  | 11.27  | G 1.42             | 0.62          | 1.53          | 0.20                     |        |  |
| 18   |  | S(1)             | 22.79                  | 5.89%   | 10.70  | S(1) 1.57          | 0.93          | 1.56          | 0.18                     |        |  |
| 19   |  | B(1)             | 32.27                  | 8.34%   | 9.31   | B(1) 1.74          | 0.84          | 1.49          | 0.16                     |        |  |
| 20   |  | LV               | 58.64                  | 15.14%  | 5.97   | LV 1.96            | 0.82          | 1.33          | 0.15                     |        |  |
| 21   |  | GL(2)            | 16.15                  | 4.17%   | 5.58   | GL(2) 1.96         | 1.06          | 1.49          | 0.15                     |        |  |
| 22   |  | B(2)             | 22.94                  | 5.92%   | 8.75   | B(2) 3.13          | 1.43          | 1.03          | 0.09                     |        |  |
| 23   |  |                  |                        |   |  |                    |               |               |                          |        |  |
| 24   |  |                  |                        |   |  |                    |               |               |                          |        |  |
| 25   |  |                  |                        |   |  |                    |               |               |                          |        |  |

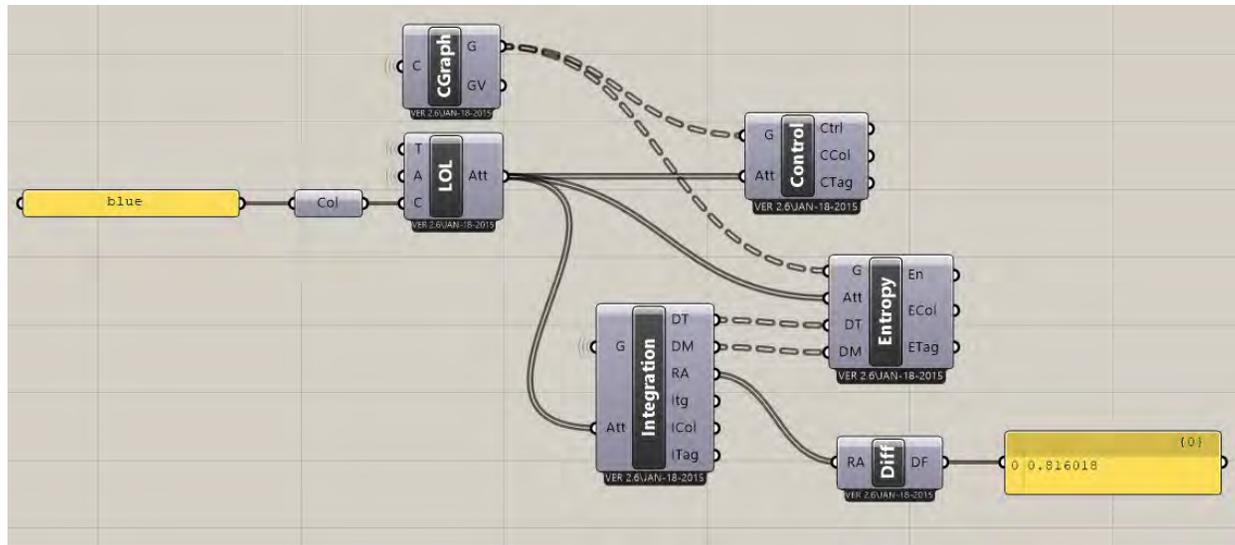
A screenshot showing syntactic calculations carried out by the model



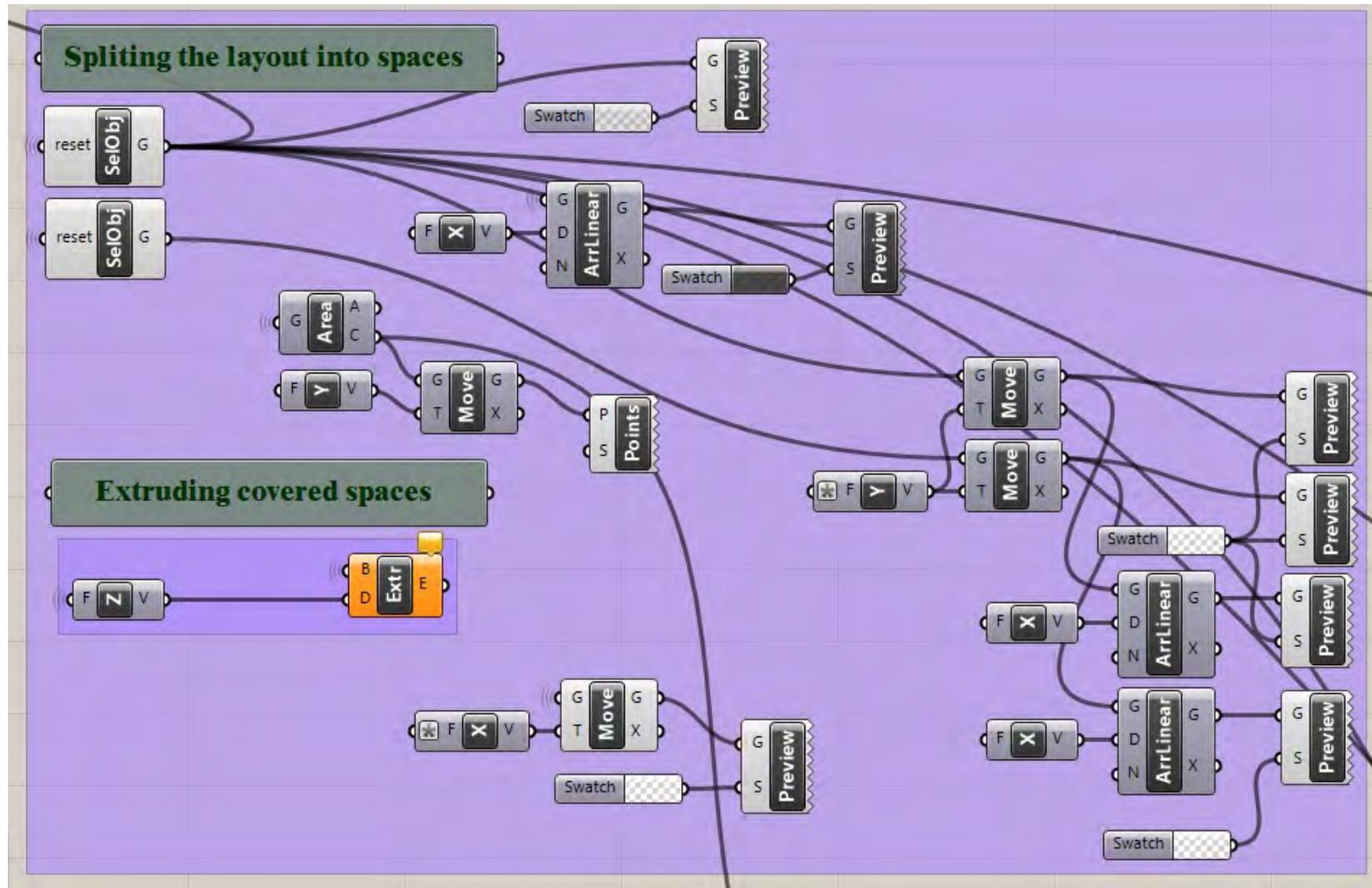
A screenshot showing all components for carrying out spatial and syntactical analysis



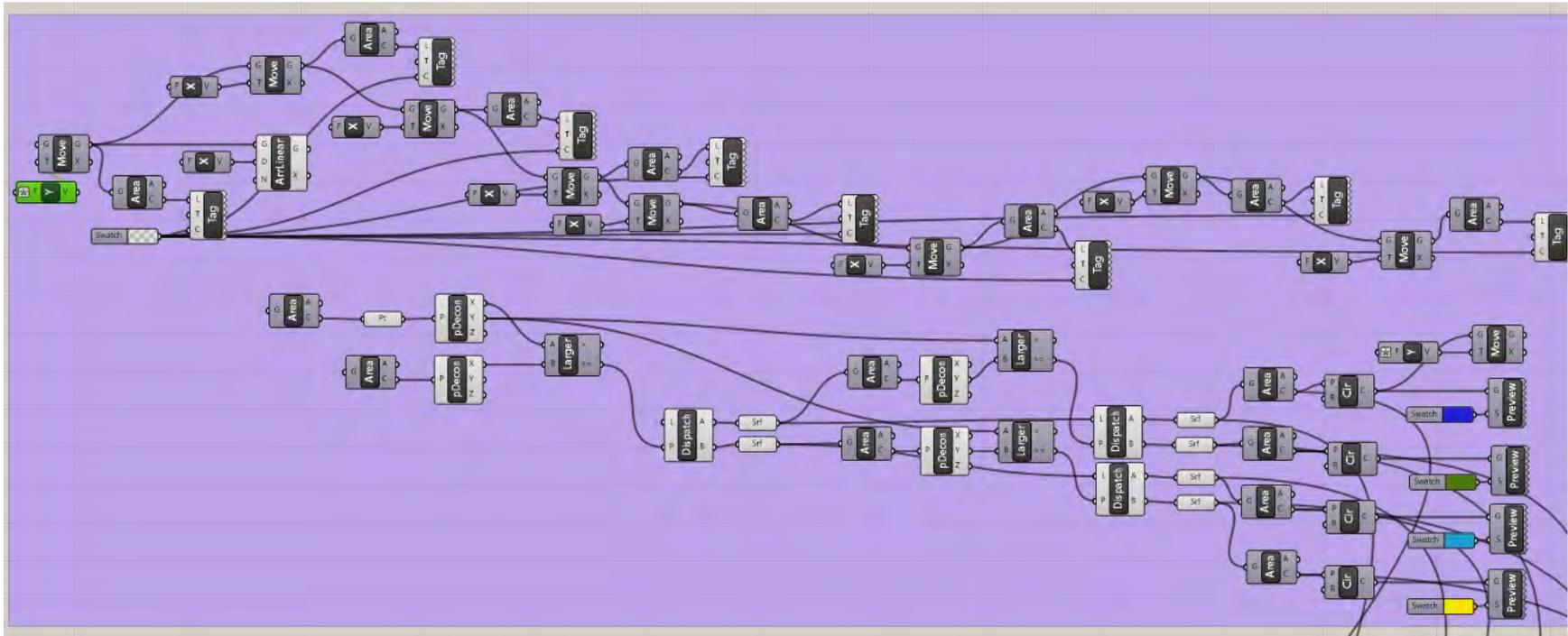
A screenshot showing components for drawing centre lines for the overall layout



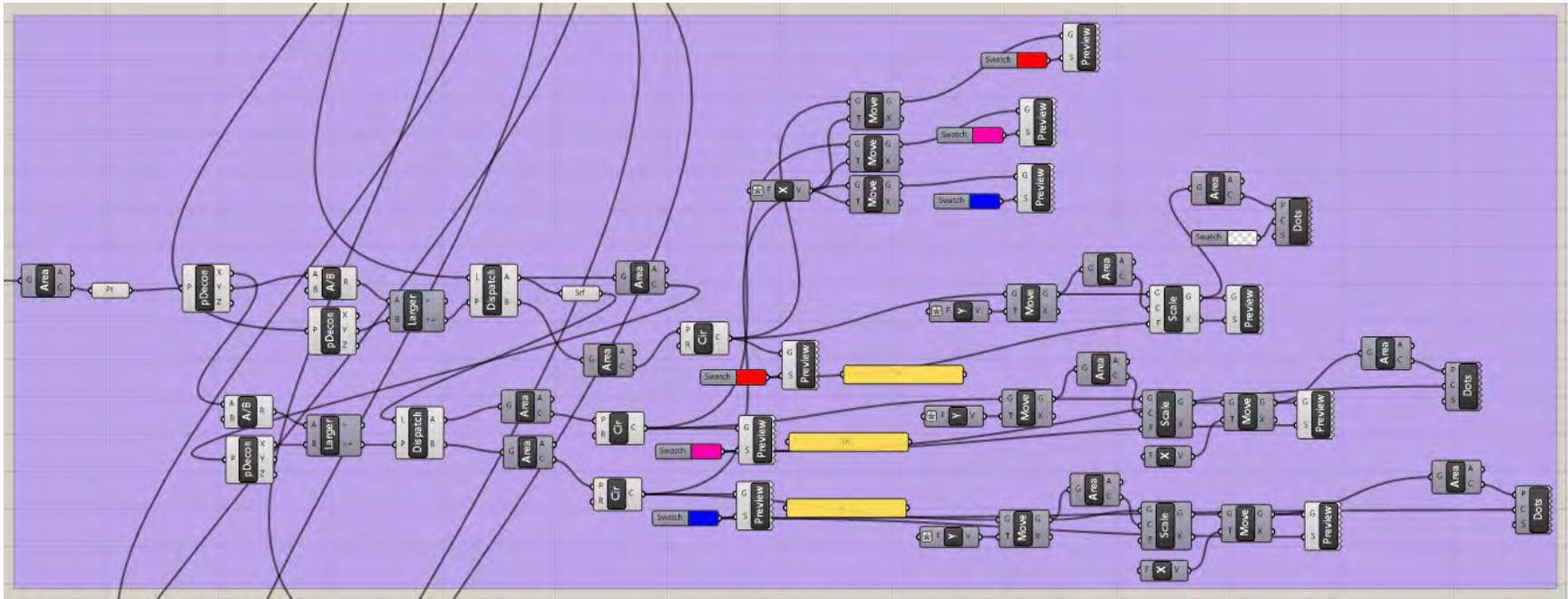
A screenshot showing components for carrying out syntactic calculations



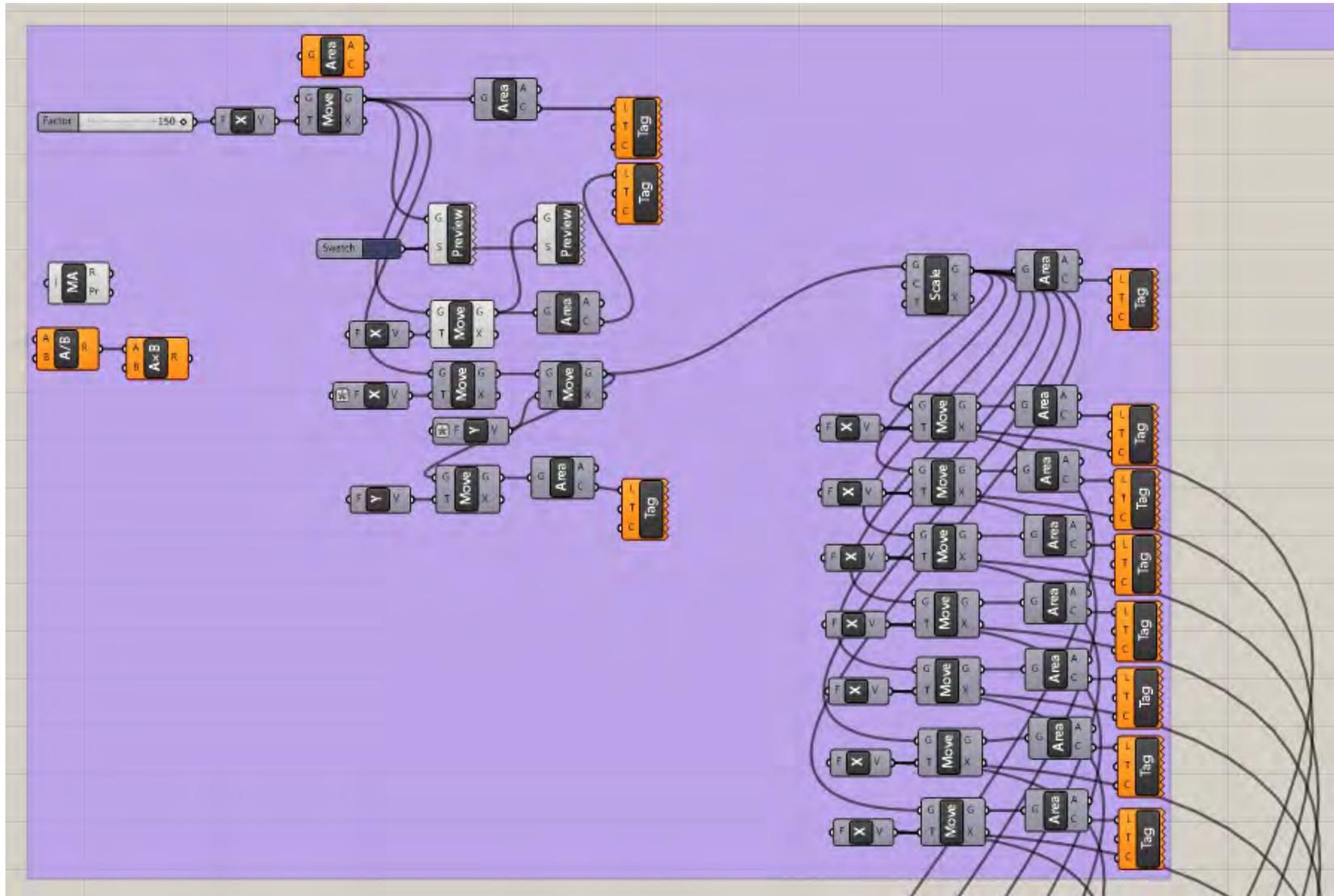
A screenshot showing components for splitting the layout into spaces, and extruding covered spaces



A screenshot showing part of the components for carrying out syntactic analysis



A screenshot showing part of the components for carrying out spatial analysis



A screenshot showing part of the components for carrying out spatial analysis

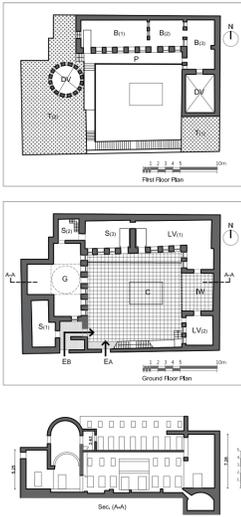
Appendix (4-B-3)

**As-built Drawings for the Selected  
Vernacular Houses**

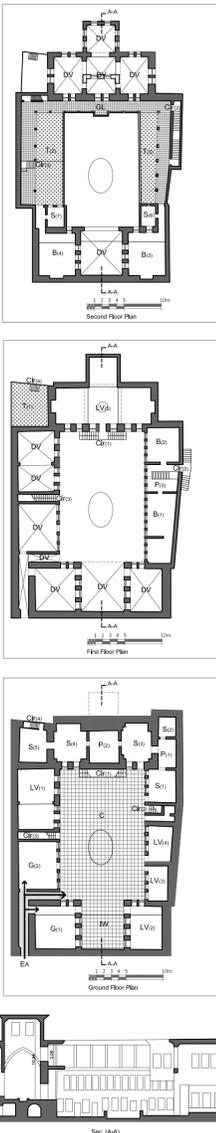
# As-Built Plans - The Middle East (17 cases)

## SYRIA

**SYR-1** A courtyard house, Aleppo, Syria (redrawn by the author, after Ragette, 2016, 157)



**SYR-2** A courtyard house, Damascus, Syria (redrawn by the author, after Ragette, 2016, 158)

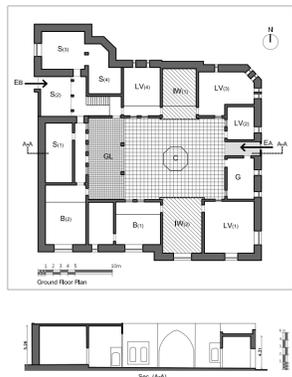


**SYR-3** A courtyard house, Damascus, Syria (redrawn by the author, after Ragette, 2016, 159)

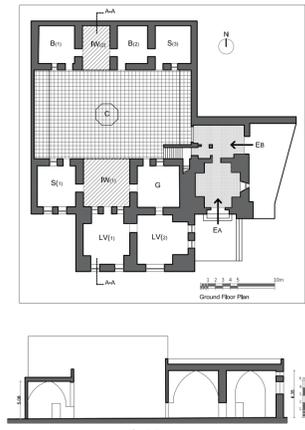


## LEBANON

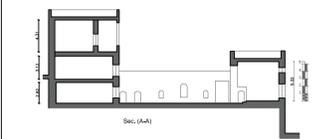
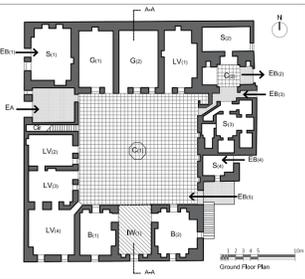
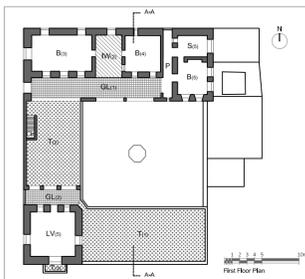
**LBN-1** A courtyard house, Deir Al-Qamar, Lebanon (redrawn by the author, after Ragette, 2016, 171)



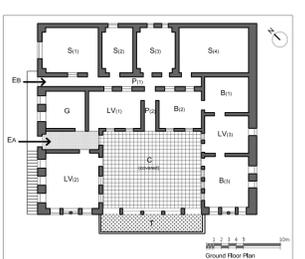
**LBN-2** A courtyard house, Deir Al-Qamar, Lebanon (redrawn by the author, after Ragette, 2016, 172)



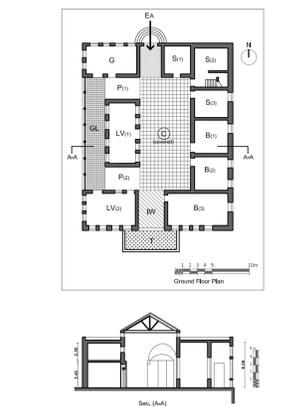
**LBN-3** A courtyard House, Deir Al-Qamar, Lebanon (redrawn by the author, after Ragette, 2016, 173)



**LBN-4** A courtyard house, Amchit, Lebanon (redrawn by the author, after Ragette, 2016, 175)

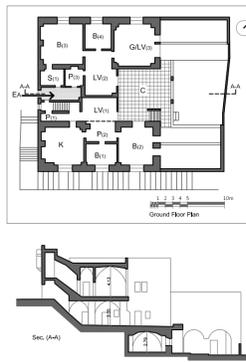


**LBN-5** A courtyard house, Amchit, Lebanon (redrawn by the author, after Ragette, 2016, 177)

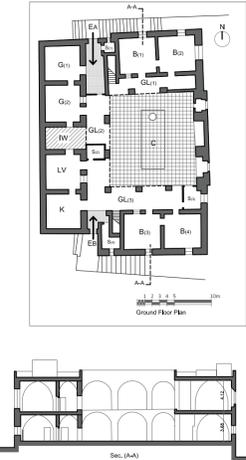


## PALESTINE

**PAL-1** A courtyard house, Bethlehem, Palestine (redrawn by the author, after Ragette, 2016, 184)



**PAL-2** A courtyard house, Bethlehem, Palestine (redrawn by the author, after Ragette, 2016, 184)

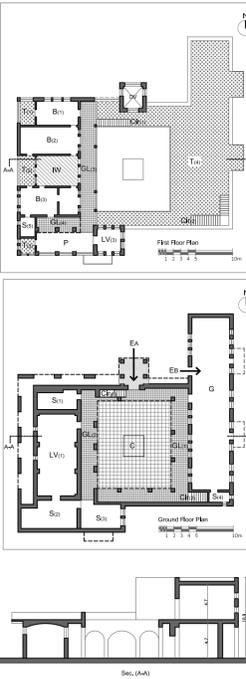


**PAL-3** A courtyard house, Jerusalem, Palestine (redrawn by the author, after Khasawneh, 2001, 100)



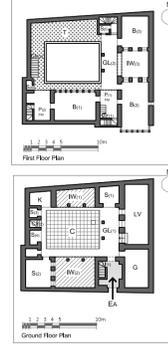
## JORDAN

**JOR-1** A courtyard house, Jerash, Jordan (redrawn by the author, after ??????)

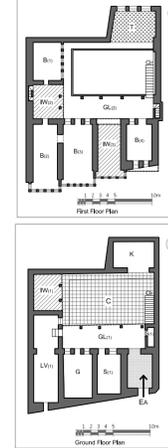


## IRAQ

**IRQ-1** A courtyard house, Baghdad, Iraq (redrawn by the author, after Ragette, 2016, 190)



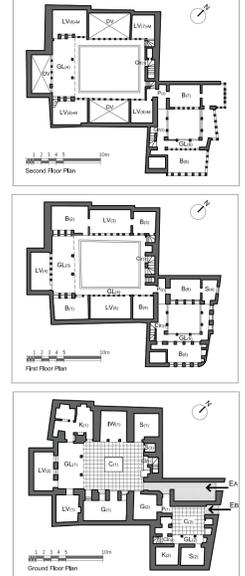
**IRQ-2** A courtyard house, Baghdad, Iraq (redrawn by the author, after Ragette, 2016, 191)



**IRQ-3** A courtyard house, Hilleh, Iraq (redrawn by the author, after Ragette, 2016, 192)



**IRQ-4** A courtyard house, Baghdad, Iraq (redrawn by the author, after Ragette, 2016, 193)



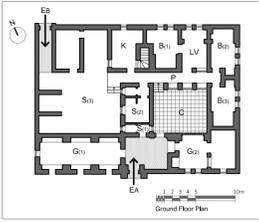
**IRQ-5** A courtyard house, Baghdad, Iraq (redrawn by the author, after Ragette, 2016, 192)



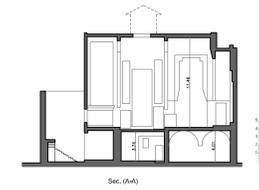
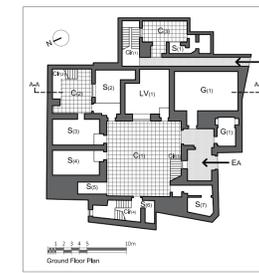
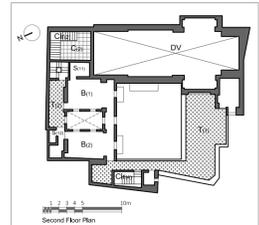
# As-Built Plans - North Africa (15 cases)

## EGYPT

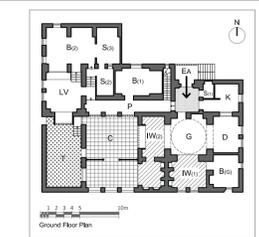
**EGY-1** A courtyard house, Al-Mahameed, Egypt (designed by Hassan Fathy, 1981) (redrawn by the author, after Serageldin, 2007, 27)



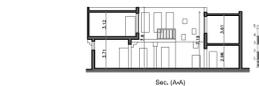
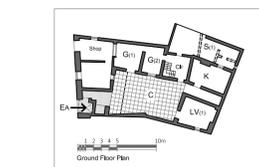
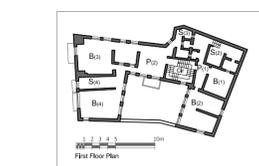
**EGY-2** A courtyard house, Cairo, Egypt (redrawn by the author, after Ragette, 2016, 147)



**EGY-3** A courtyard house, Al-Giza, Egypt (designed by Hassan Fathy, 1978) (redrawn by the author, after Serageldin, 2007, 24)

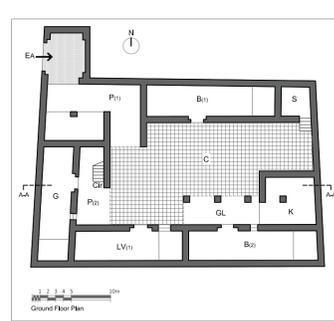
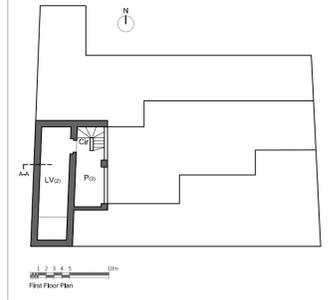


**EGY-4** A courtyard house, Cairo, Egypt (redrawn by the author, after Ragette, 2016, 144)

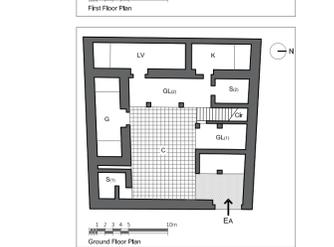
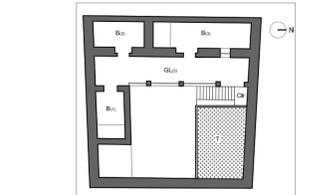


## TUNISIA

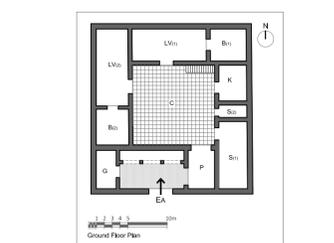
**TUN-1** A courtyard house, Oudrif, Tunis (redrawn by the author, after Ragette, 2016, 127)



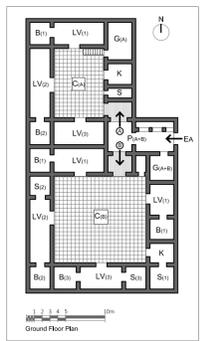
**TUN-2** A courtyard house, Oudrif, Tunis (redrawn by the author, after Ragette, 2016, 127)



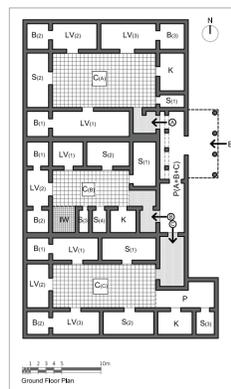
**TUN-3** A courtyard house, Djerid, Tunis (redrawn by the author, after Ragette, 2016, 128)



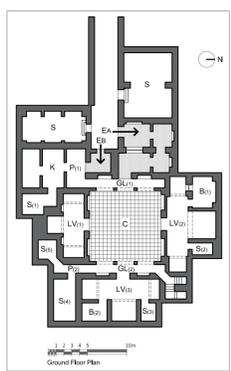
**TUN- 4(A+B)** Two-family courtyard house, Djerid, Tunis (redrawn by the author, after Ragette, 2016, 128)



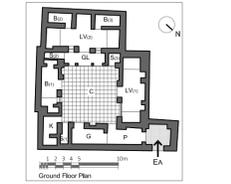
**TUN- 5(A+B+C)** Three-family courtyard house, Djerid, Tunis (redrawn by the author, after Ragette, 2016, 128)



**TUN-6** A courtyard house, Tunis (redrawn by the author, after Ragette, 2016, 130)

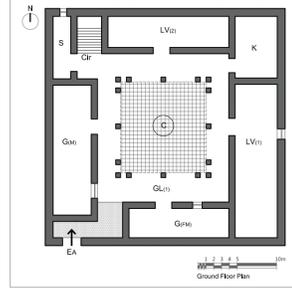
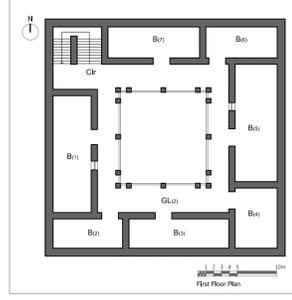


**TUN-7** A courtyard house, Tunis (redrawn by the author, after Hakim, 1986, 97)

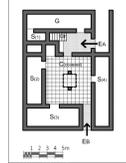
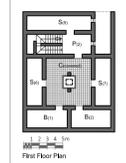
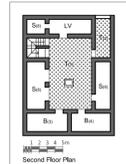


## MOROCCO

**MOR-1** A courtyard house, Tetouan, Morocco (redrawn by the author, after Ragette, 2016, 113)

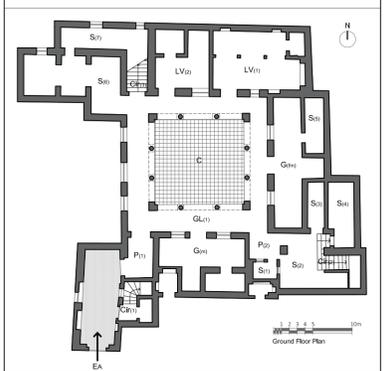
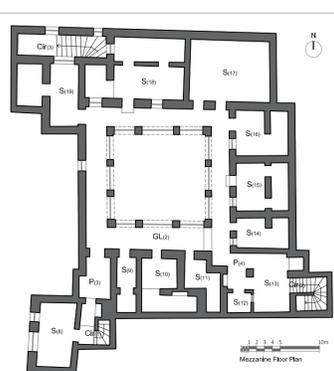
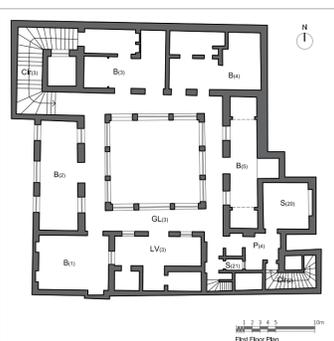


**MOR-2** A courtyard house, Tabouhassamt, Morocco (redrawn by the author, after Ragette, 2016, 110)

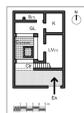
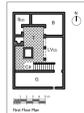


## ALGERIA

**ALG-1** A courtyard house, Constantine, Algeria (redrawn by the author, after Ragette, 2016, 124)



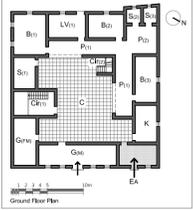
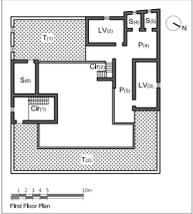
**ALG-2** A house with a central space and roof opening, Mzab, Algeria (redrawn by the author, after Ragette, 2016, 118)



# As-Built Plans - The Gulf Area (12 cases)

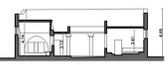
## OMAN

**OMA-1** A courtyard house, Mirbat, Oman (redrawn by the author, after Ragette, 2016, 223)

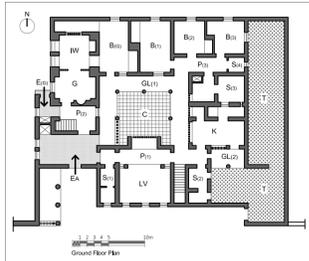


## SAUDI ARABIA

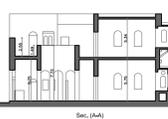
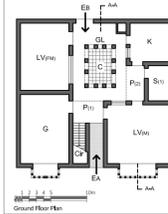
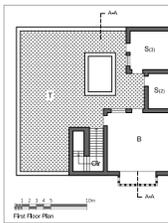
**KSA-1** A courtyard house, Al-Dereyyah Village, KSA (designed by Hassan Fathy, 1965) (redrawn by the author, after Serageldin, 2007, 53)



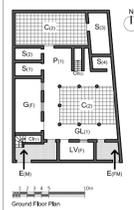
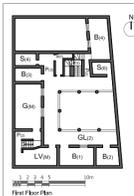
**KSA-2** A courtyard house, Al-Dereyyah Village, KSA (designed by Hassan Fathy, 1985) (redrawn by the author, after Serageldin, 2007, 53)



**KSA-3** A vertical house in Mecca, KSA (redrawn by the author, after Ragette, 2016, 204)

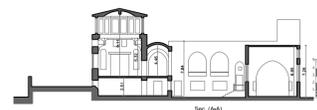
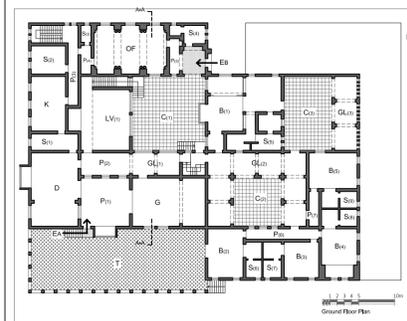


**KSA-4** A vertical house in Najd, KSA (redrawn by the author, after Ragette, 2016, 202)

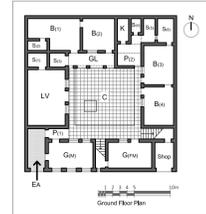


## KUWAIT

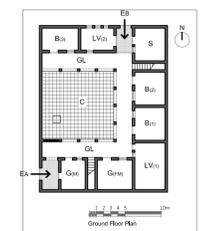
**KUW-1** A courtyard house, Kuwait (designed by Hassan Fathy) (redrawn by the author, after Serageldin, 2007, 31)



**KUW-2** A courtyard house, Failaka, Kuwait (redrawn by the author, after <http://www.kuwait-history.net>, accessed on 25/10/2016)

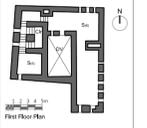
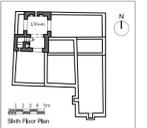


**KUW-3** A courtyard house, Fahahil, Kuwait (redrawn by the author, after <http://www.kuwait-history.net>, accessed on 25/10/2016)

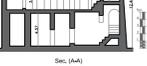
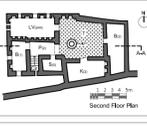


## YEMEN

**YEM-1** A tower house in Sana'a, Yemen (redrawn by the author, after Ragette, 2016, 232)

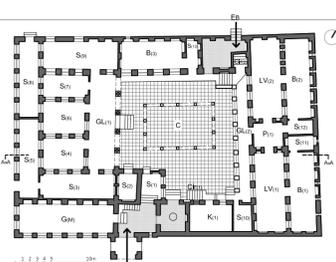
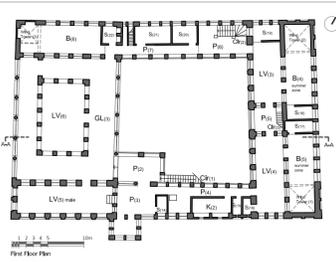


**YEM-2** A vertical house in Damar, Yemen (redrawn by the author, after Ragette, 2016, 235)



## EMIRATES

**UAE-1** A courtyard house, Dubai, UAE (redrawn by the author, after Ragette, 2016, 215)

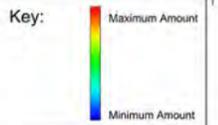


Appendix (4-B-4)

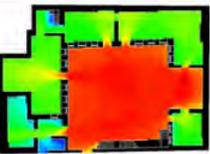
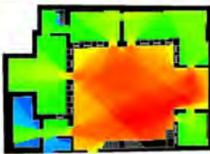
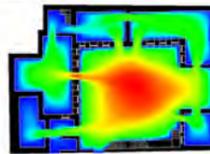
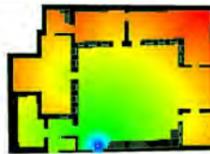
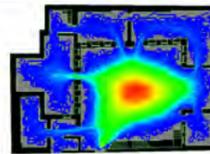
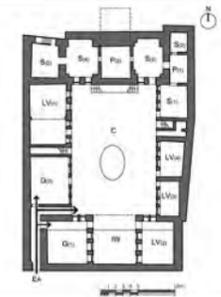
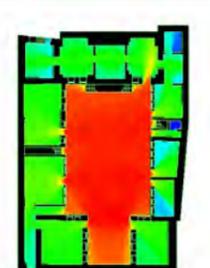
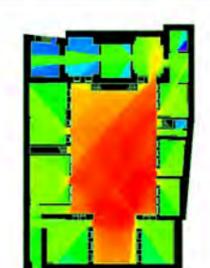
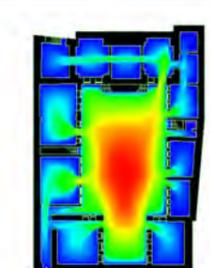
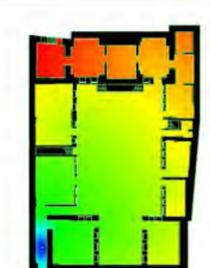
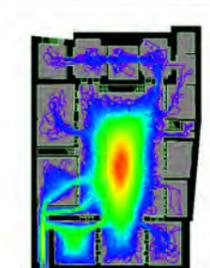
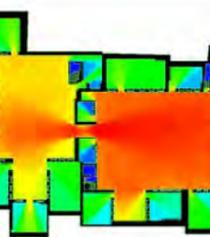
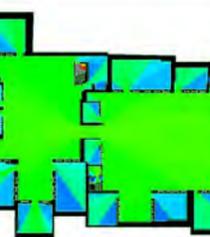
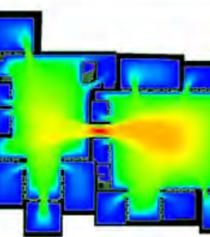
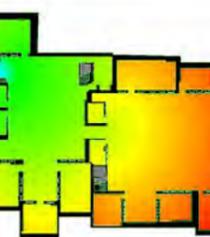
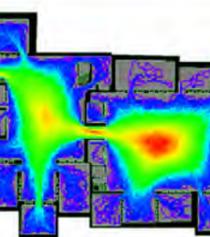
**Visibility Graph Analysis (VGA) for the  
Selected Vernacular Houses**

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
 for the Spatial Configuration of Traditional Town Houses located in the Middle East  
 (Carried out by Author using 'DepthMapX 0.50 Software')

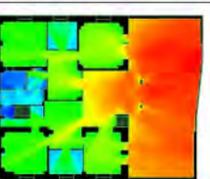
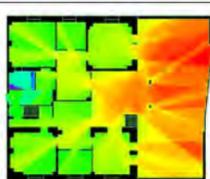
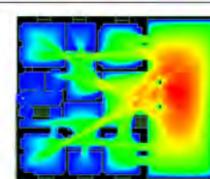
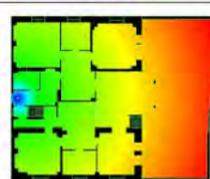
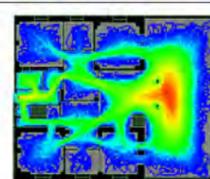
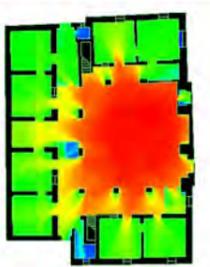
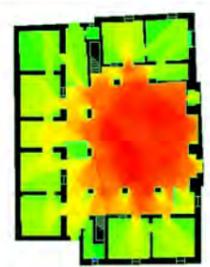
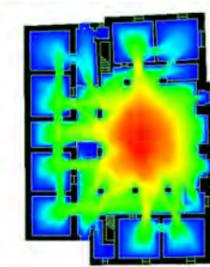
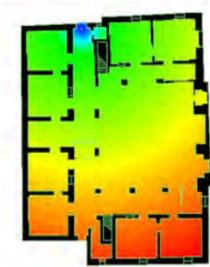
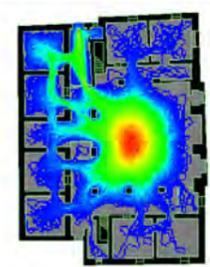
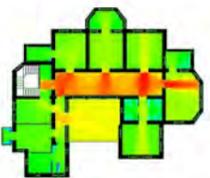
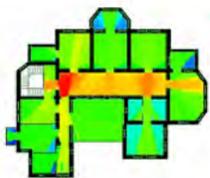
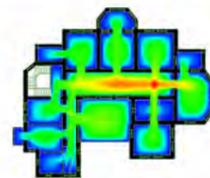
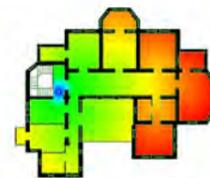
- Syria (SYR)
- Palestine (PAL)
- Lebanon (LBN)
- Jordan (JOR)
- Iraq (IRQ)



SYRIA

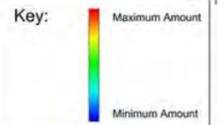
| Case No. | As-Built Plan   | Connectivity<br>(Number of points that are directly connected to other spaces)      | Visual Integration<br>(Representation of potentially core area in the layout)        | Through-Vision Analysis   | Depth of Spaces from the Main Entrance<br>(Metric Step)                               | Agent Analysis<br>(Pattern of movement and frequent use of spaces, released from the main entrance) |
|----------|---|---|--|---|---|---|
| SYR-1    |    |    |    |    |    |                  |
| SYR-2    |   |   |   |   |   |                 |
| SYR-3    |  |  |  |  |  |                |

PALESTINE

| Case No. | As-Built Plan   | Connectivity<br>(Number of points that are directly connected to other spaces)      | Visual Integration<br>(Representation of potentially core area in the layout)        | Through-Vision Analysis   | Depth of Spaces from the Main Entrance<br>(Metric Step)                               | Agent Analysis<br>(Pattern of movement and frequent use of spaces, released from the main entrance) |
|----------|---|---|--|---|---|---|
| PAL-1    |  |  |  |  |  |                |
| PAL-2    |  |  |  |  |  |                |
| PAL-3    |  |  |  |  |  |                |

**Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for the Spatial Configuration of Traditional Town Houses located in the Middle East**  
(Carried out by Author using 'DepthMapX 0.50 Software')

- Syria (SYR)
- Palestine (PAL)
- Lebanon (LBN)
- Jordan (JOR)
- Iraq (IRQ)



**LEBANON**

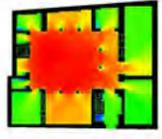
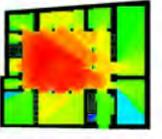
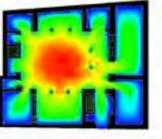
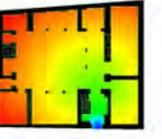
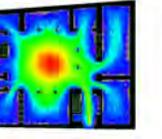
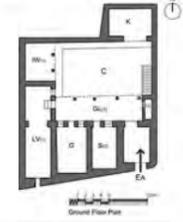
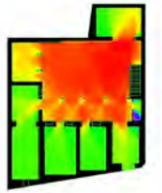
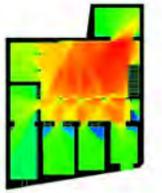
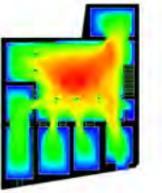
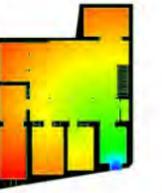
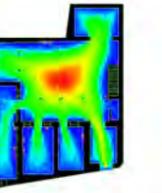
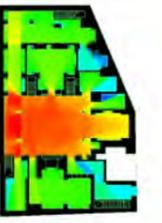
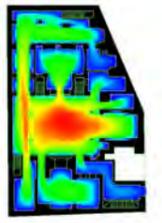
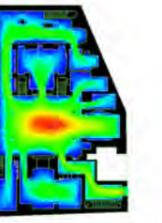
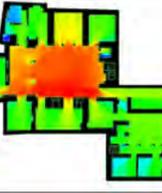
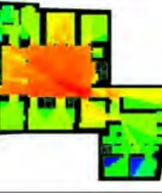
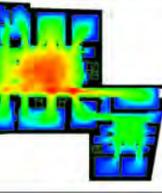
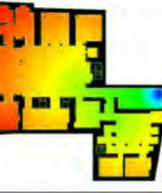
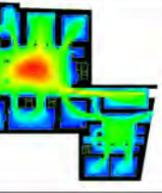
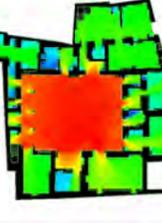
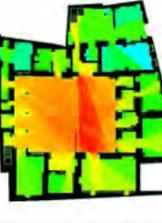
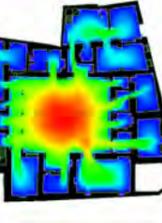
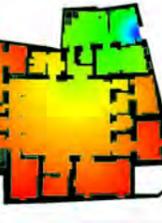
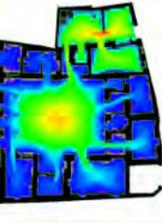
| Case No. | As-Built Plan | Connectivity<br>(Number of points that are directly connected to other spaces) | Visual Integration<br>(Representation of potentially core area in the layout) | Through-Vision Analysis | Depth of Spaces from the Main Entrance<br>(Metric Step) | Agent Analysis<br>(Pattern of movement and frequent use of spaces, released from the main entrance) |
|----------|---------------|--|---|-------------------------|---|---|
| LBN-1    |               |  |   |                         |   |   |
| LBN-2    |               |  |   |                         |   |   |
| LBN-3    |               |  |   |                         |   |   |
| LBN-4    |               |  |   |                         |   |   |
| LBN-5    |               |  |   |                         |   |   |

**Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for the Spatial Configuration of Traditional Town Houses located in the Middle East**  
(Carried out by Author using 'DepthMapX 0.50 Software')

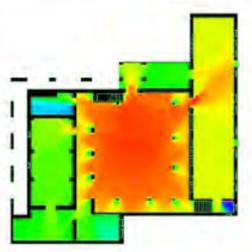
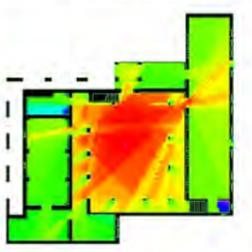
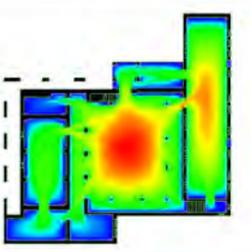
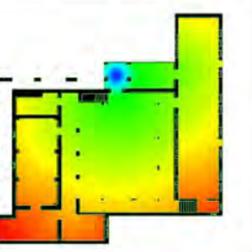
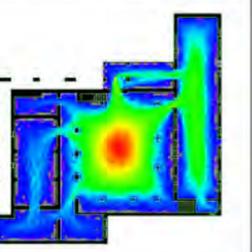
- Syria (SYR)
- Palestine (PAL)
- Lebanon (LBN)
- Jordan (JOR)
- Iraq (IRQ)



**IRAQ**

| Case No. | As-Built Plan   | Connectivity<br>(Number of points that are directly connected to other spaces)      | Visual Integration<br>(Representation of potentially core area in the layout)        | Through-Vision Analysis   | Depth of Spaces from the Main Entrance<br>(Metric Step)                               | Agent Analysis<br>(Pattern of movement and frequent use of spaces, released from the main entrance) |
|----------|---|---|--|---|---|---|
| IRQ-1    |    |    |    |    |    |                  |
| IRQ-2    |  |  |  |  |  |                |
| IRQ-3    |  |  |  |  |  |                |
| IRQ-4    |  |  |  |  |  |                |
| IRQ-5    |  |  |  |  |  |                |

**JORDAN**

| Case No. | As-Built Plan   | Connectivity<br>(Number of points that are directly connected to other spaces)      | Visual Integration<br>(Representation of potentially core area in the layout)        | Through-Vision Analysis   | Depth of Spaces from the Main Entrance<br>(Metric Step)                               | Agent Analysis<br>(Pattern of movement and frequent use of spaces, released from the main entrance) |
|----------|---|---|--|---|---|---|
| JOR-1    |  |  |  |  |  |                |

**Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for the Spatial Configuration of Traditional Town Houses located in North Africa**  
(Carried out by Author using 'DepthMapX 0.50 Software')

|                 |      |
|-----------------|------|
| ■ Egypt (EGY)   | Key: |
| ■ Morocco (MOR) |      |
| ■ Algeria (ALG) |      |
| □ TUNISIA (TUN) |      |

**EGYPT**

| Case No. | As-Built Plan | Connectivity<br>(Number of points that are directly connected to other spaces) | Visual Integration<br>(Representation of potentially core area in the layout) | Through-Vision Analysis | Depth of Spaces from the Main Entrance<br>(Metric Step) | Agent Analysis<br>(Pattern of movement and frequent use of spaces, released from the main entrance) |
|----------|---------------|--|---|-------------------------|---|---|
| EGY-1    |               |  |   |                         |   |   |
| EGY-2    |               |  |   |                         |   |   |
| EGY-3    |               |  |   |                         |   |   |
| EGY-4    |               |  |   |                         |   |   |

**MOROCCO**

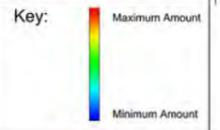
| Case No. | As-Built Plan | Connectivity<br>(Number of points that are directly connected to other spaces) | Visual Integration<br>(Representation of potentially core area in the layout) | Through-Vision Analysis | Depth of Spaces from the Main Entrance<br>(Metric Step) | Agent Analysis<br>(Pattern of movement and frequent use of spaces, released from the main entrance) |
|----------|---------------|--|---|-------------------------|---|---|
| MOR-1    |               |  |   |                         |   |   |
| MOR-2    |               |  |   |                         |   |   |

**ALGERIA**

| Case No. | As-Built Plan | Connectivity<br>(Number of points that are directly connected to other spaces) | Visual Integration<br>(Representation of potentially core area in the layout) | Through-Vision Analysis | Depth of Spaces from the Main Entrance<br>(Metric Step) | Agent Analysis<br>(Pattern of movement and frequent use of spaces, released from the main entrance) |
|----------|---------------|--|---|-------------------------|---|---|
| ALG-1    |               |  |   |                         |   |   |
| ALG-2    |               |  |   |                         |   |   |

**Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for the Spatial Configuration of Traditional Town Houses located in North Africa**  
(Carried out by Author using 'DepthMapX 0.50 Software')

- Egypt (EGY)
- Morocco (MOR)
- Algeria (ALG)
- TUNISIA (TUN)

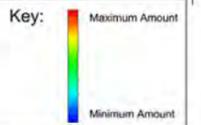


**TUNISIA**

| Case No. | As-Built Plan | Connectivity<br>(Number of points that are directly connected to other spaces) | Visual Integration<br>(Representation of potentially core area in the layout) | Through-Vision Analysis | Depth of Spaces from the Main Entrance<br>(Metric Step) | Agent Analysis<br>(Pattern of movement and frequent use of spaces, released from the main entrance) |
|----------|---------------|--|---|-------------------------|---|---|
| TUN-1    |               |  |   |                         |   |   |
| TUN-2    |               |  |   |                         |   |   |
| TUN-3    |               |  |   |                         |   |   |
| TUN-4    |               |  |   |                         |   |   |
| TUN-5    |               |  |   |                         |   |   |
| TUN-6    |               |  |   |                         |   |   |
| TUN-7    |               |  |   |                         |   |   |

**Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for the Spatial Configuration of Traditional Town Houses located in the Gulf Area**  
(Carried out by Author using 'DepthMapX 0.50 Software')

- Oman (OMA)
- United Arab Emirates (UAE)
- Kingdom of Saudi Arabia (KSA)
- Kuwait (KUW)
- Yemen (YEM)



**OMAN**

| Case No. | As-Built Plan | Connectivity<br>(Number of points that are directly connected to other spaces) | Visual Integration<br>(Representation of potentially core area in the layout) | Through-Vision Analysis | Depth of Spaces from the Main Entrance<br>(Metric Step) | Agent Analysis<br>(Pattern of movement and frequent use of spaces, released from the main entrance) |
|----------|---------------|--|---|-------------------------|---|---|
| OMA-1    |               |  |   |                         |   |   |

**UNITED ARAB EMIRATES**

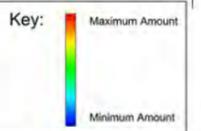
| Case No. | As-Built Plan | Connectivity<br>(Number of points that are directly connected to other spaces) | Visual Integration<br>(Representation of potentially core area in the layout) | Through-Vision Analysis | Depth of Spaces from the Main Entrance<br>(Metric Step) | Agent Analysis<br>(Pattern of movement and frequent use of spaces, released from the main entrance) |
|----------|---------------|--|---|-------------------------|---|---|
| UAE-1    |               |  |   |                         |   |   |

**KINGDOM OF SAUDI ARABIA**

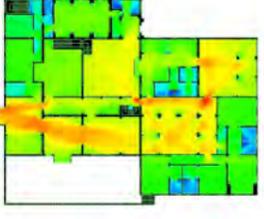
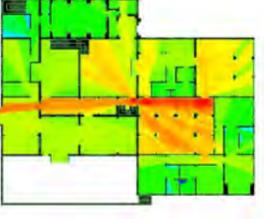
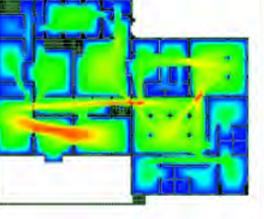
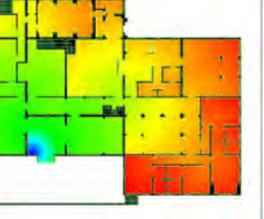
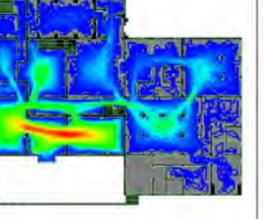
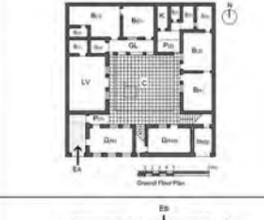
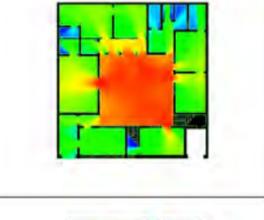
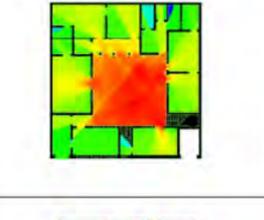
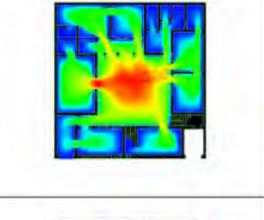
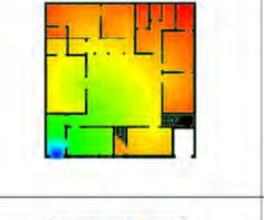
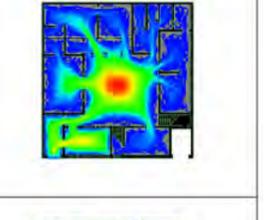
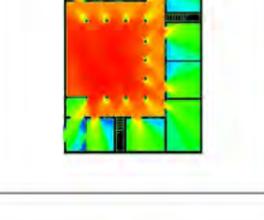
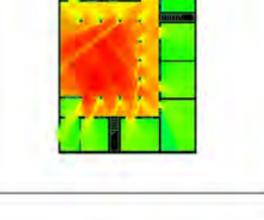
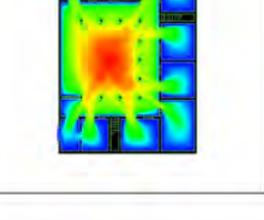
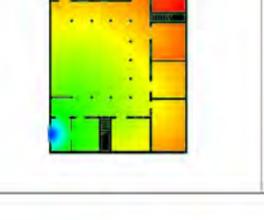
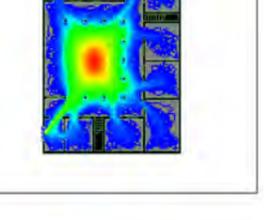
| Case No. | As-Built Plan | Connectivity<br>(Number of points that are directly connected to other spaces) | Visual Integration<br>(Representation of potentially core area in the layout) | Through-Vision Analysis | Depth of Spaces from the Main Entrance<br>(Metric Step) | Agent Analysis<br>(Pattern of movement and frequent use of spaces, released from the main entrance) |
|----------|---------------|--|---|-------------------------|---|---|
| KSA-1    |               |  |   |                         |   |   |
| KSA-2    |               |  |   |                         |   |   |
| KSA-3    |               |  |   |                         |   |   |
| KSA-4    |               |  |   |                         |   |   |
| KSA-5    |               |  |   |                         |   |   |

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for the Spatial Configuration of Traditional Town Houses located in the Gulf Area  
(Carried out by Author using 'DepthMapX 0.50 Software')

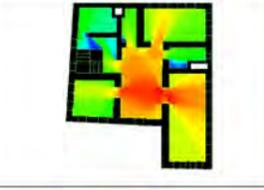
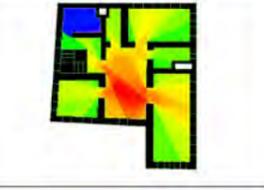
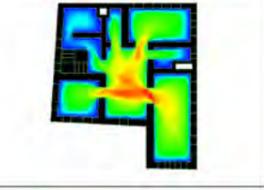
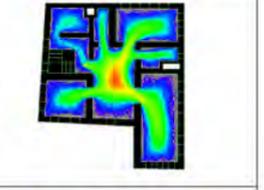
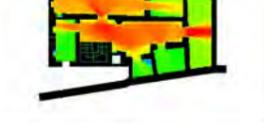
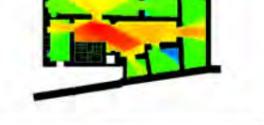
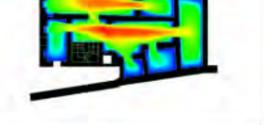
- Oman (OMA)
- United Arab Emirates (UAE)
- Kingdom of Saudi Arabia (KSA)
- Kuwait (KUW)
- Yemen (YEM)



**KUWAIT**

| Case No. | As-Built Plan   | Connectivity<br>(Number of points that are directly connected to other spaces)      | Visual Integration<br>(Representation of potentially core area in the layout)        | Through-Vision Analysis   | Depth of Spaces from the Main Entrance<br>(Metric Step)                               | Agent Analysis<br>(Pattern of movement and frequent use of spaces, released from the main entrance) |
|----------|---|---|--|---|---|---|
| KUW-1    |  |  |  |  |  |                |
| KUW-2    |  |  |  |  |  |                |
| KUW-3    |  |  |  |  |  |                |

**YEMEN**

| Case No. | As-Built Plan   | Connectivity<br>(Number of points that are directly connected to other spaces)      | Visual Integration<br>(Representation of potentially core area in the layout)        | Through-Vision Analysis   | Depth of Spaces from the Main Entrance<br>(Metric Step)                               | Agent Analysis<br>(Pattern of movement and frequent use of spaces, released from the main entrance) |
|----------|---|---|--|---|---|---|
| YEM-1    |  |  |  |  |  |                |
| YEM-2    |  |  |  |  |  |                |

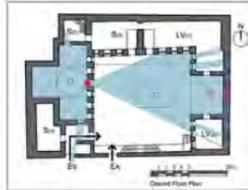
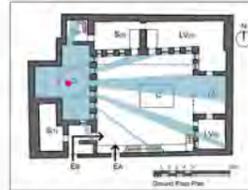
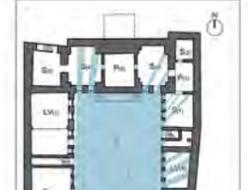
Appendix (4-B-5)

**Isovist Analysis for the Selected  
Vernacular Houses**

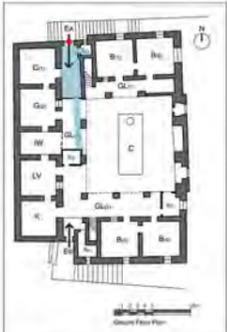
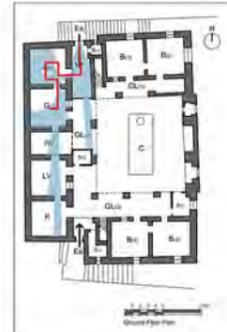
Visibility Study for the Main Floor from Different Points  
 Inside Traditional Town Houses located in the Middle East  
 (Carried out by Author using 'Syntax2D 1.3.0.7 Software')

- Syria (SYR)
- Palestine (PAL)
- Lebanon (LBN)
- Jordan (JOR)
- Iraq (IRQ)

SYRIA

| Case No. | Visual Fields from the Main Entry Point of the House                                | Visual Fields from the Entry Point of the Courtyard                                 | Visual Fields from the Entry Point of the Guest Room                                 | Visual Fields from the Centroid of the Guest Room                                     | Visual Fields along the Movement Path of Guests inside the House                      |
|----------|---|---|--|---|---|
| SYR-1    |    |    |    |    |    |
| SYR-2    |   |   |   |   |   |
| SYR-3    |  |  |  |  |  |

PALESTINE

| Case No. | Visual Fields from the Main Entry Point of the House                                | Visual Fields from the Entry Point of the Courtyard                                 | Visual Fields from the Entry Point of the Guest Room                                  | Visual Fields from the Centroid of the Guest Room                                     | Visual Fields along the Movement Path of Guests inside the House                      |
|----------|---|---|---|---|---|
| PAL-1    |  |  |   |  |  |
| PAL-2    |  |  |  |  |  |
| PAL-3    |  |  |  |  |  |

Visibility Study for the Main Floor from Different Points  
 Inside Traditional Town Houses located in the Middle East  
 (Carried out by Author using 'Syntax2D 1.3.0.7 Software')

- Syria (SYR)
- Palestine (PAL)
- Lebanon (LBN)
- Jordan (JOR)
- Iraq (IRQ)

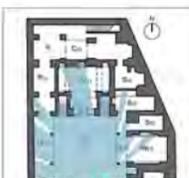
**LEBANON**

| Case No. | Visual Fields from the Main Entry Point of the House | Visual Fields from the Entry Point of the Courtyard | Visual Fields from the Entry Point of the Guest Room | Visual Fields from the Centroid of the Guest Room | Visual Fields along the Movement Path of Guests inside the House |
|----------|--|---|--|---|--|
| LBN-1    |  |   |  |   |  |
| LBN-2    |  |   |  |   |  |
| LBN-3    |  |   |  |   |  |
| LBN-4    |  |   |  |   |  |
| LBN-5    |  |   |  |   |  |

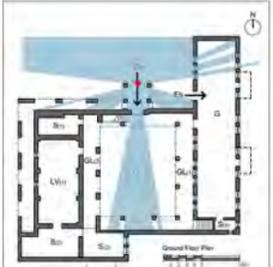
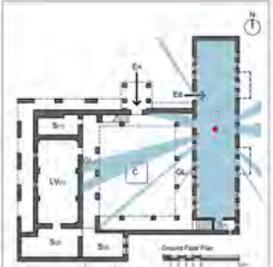
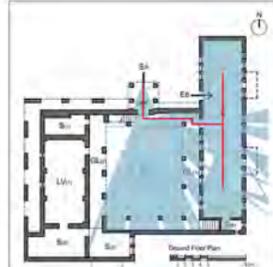
**Visibility Study for the Main Floor from Different Points  
Inside Traditional Town Houses located in the Middle East**  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')

- Syria (SYR)
- Palestine (PAL)
- Lebanon (LBN)
- Jordan (JOR)
- Iraq (IRQ)

**IRAQ**

| Case No. | Visual Fields from the Main Entry Point of the House                                | Visual Fields from the Entry Point of the Courtyard                                 | Visual Fields from the Entry Point of the Guest Room                                  | Visual Fields from the Centroid of the Guest Room                                     | Visual Fields along the Movement Path of Guests inside the House                      |
|----------|---|---|---|---|---|
| IRQ-1    |    |    |    |    |    |
| IRQ-2    |   |   |   |   |   |
| IRQ-3    |  |  |  |  |  |
| IRQ-4    |  |  |  |  |  |
| IRQ-5    |  |  |  |  |  |

**JORDAN**

| Case No. | Visual Fields from the Main Entry Point of the House                                | Visual Fields from the Entry Point of the Courtyard                                 | Visual Fields from the Entry Point of the Guest Room                                 | Visual Fields from the Centroid of the Guest Room                                     | Visual Fields along the Movement Path of Guests inside the House                      |
|----------|---|---|--|---|---|
| JOR-1    |  |  |  |  |  |

# Visibility Study for the Main Floor from Different Points Inside Traditional Town Houses located in North Africa

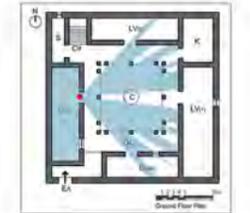
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')

- Egypt (EGY)
- Morocco (MOR)
- Algeria (ALG)
- TUNISIA (TUN)

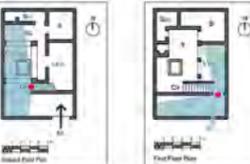
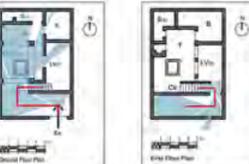
## EGYPT

| Case No. | Visual Fields from the Main Entry Point of the House                                | Visual Fields from the Entry Point of the Courtyard                                 | Visual Fields from the Entry Point of the Guest Room                                 | Visual Fields from the Centroid of the Guest Room                                     | Visual Fields along the Movement Path of Guests inside the House                      |
|----------|---|---|--|---|---|
| EGY-1    |    |    |    |    |    |
| EGY-2    |    |    |    |    |    |
| EGY-3    |   |   |   |   |   |
| EGY-4    |  |  |  |  |  |

## MOROCCO

| Case No. | Visual Fields from the Main Entry Point of the House                                | Visual Fields from the Entry Point of the Courtyard                                 | Visual Fields from the Entry Point of the Guest Room                                 | Visual Fields from the Centroid of the Guest Room                                     | Visual Fields along the Movement Path of Guests inside the House                      |
|----------|---|---|--|---|---|
| MOR-1    |  |  |  |  |  |
| MOR-2    |  |  |  |  |  |

## ALGERIA

| Case No. | Visual Fields from the Main Entry Point of the House                                | Visual Fields from the Entry Point of the Courtyard                                 | Visual Fields from the Entry Point of the Guest Room                                 | Visual Fields from the Centroid of the Guest Room                                     | Visual Fields along the Movement Path of Guests inside the House                      |
|----------|---|---|--|---|---|
| ALG-1    |  |  |  |  |  |
| ALG-2    |  |  |  |  |  |

Visibility Study for the Main Floor from Different Points  
 Inside Traditional Town Houses located in North Africa  
 (Carried out by Author using 'Syntax2D 1.3.0.7 Software')

- Egypt (EGY)
- Morocco (MOR)
- Algeria (ALG)
- TUNISIA (TUN)

TUNISIA

| Case No. | Visual Fields from the Main Entry Point of the House | Visual Fields from the Entry Point of the Courtyard | Visual Fields from the Entry Point of the Guest Room | Visual Fields from the Centroid of the Guest Room | Visual Fields along the Movement Path of Guests inside the House |
|----------|--|---|--|---|--|
| TUN-1    |  |   |  |   |  |
| TUN-2    |  |   |  |   |  |
| TUN-3    |  |   |  |   |  |
| TUN-4    |  |   |  |   |  |
| TUN-5    |  |   |  |   |  |
| TUN-6    |  |   |  |   |  |
| TUN-7    |  |   |  |   |  |

Visibility Study for the Main Floor from Different Points  
 Inside Traditional Town Houses located in the Gulf Area  
 (Carried out by Author using 'Syntax2D 1.3.0.7 Software')

- Oman (OMA)
- United Arab Emirates (UAE)
- Kingdom of Saudi Arabia (KSA)
- Kuwait (KUW)
- Yemen (YEM)

OMAN

| Case No. | Visual Fields from the Main Entry Point of the House | Visual Fields from the Entry Point of the Courtyard | Visual Fields from the Entry Point of the Guest Room | Visual Fields from the Centroid of the Guest Room | Visual Fields along the Movement Path of Guests inside the House |
|----------|--|---|--|---|--|
| OMA-1    |  |   |  |   |  |

UNITED ARAB EMIRATES

| Case No. | Visual Fields from the Main Entry Point of the House | Visual Fields from the Entry Point of the Courtyard | Visual Fields from the Entry Point of the Guest Room | Visual Fields from the Centroid of the Guest Room | Visual Fields along the Movement Path of Guests inside the House |
|----------|--|---|--|---|--|
| UAE-1    |  |   |  |   |  |

KINGDOM OF SAUDI ARABIA

| Case No. | Visual Fields from the Main Entry Point of the House | Visual Fields from the Entry Point of the Courtyard | Visual Fields from the Entry Point of the Guest Room | Visual Fields from the Centroid of the Guest Room | Visual Fields along the Movement Path of Guests inside the House |
|----------|--|---|--|---|--|
| KSA-1    |  |   |  |   |  |
| KSA-2    |  |   |  |   |  |
| KSA-3    |  |   |  |   |  |
| KSA-4    |  |   |  |   |  |
| KSA-5    |  |   |  |   |  |

**Visibility Study for the Main Floor from Different Points  
Inside Traditional Town Houses located in the Gulf Area  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')**

- Oman (OMA)
- United Arab Emirates (UAE)
- Kingdom of Saudi Arabia (KSA)
- Kuwait (KUW)
- Yemen (YEM)

**KUWAIT**

| Case No. | Visual Fields from the Main Entry Point of the House | Visual Fields from the Entry Point of the Courtyard | Visual Fields from the Entry Point of the Guest Room | Visual Fields from the Centroid of the Guest Room | Visual Fields along the Movement Path of Guests inside the House |
|----------|--|---|--|---|--|
| KUW-1    |  |   |  |   |  |
| KUW-2    |  |   |  |   |  |
| KUW-3    |  |   |  |   |  |

**YEMEN**

| Case No. | Visual Fields from the Main Entry Point of the House | Visual Fields from the Entry Point of the Courtyard | Visual Fields from the Entry Point of the Guest Room | Visual Fields from the Centroid of the Guest Room | Visual Fields along the Movement Path of Guests inside the House |
|----------|--|---|--|---|--|
| YEM-1    |  |   |  |   |  |
| YEM-2    |  |   |  |   |  |

Appendix (4-B-6)

**Hierarchy of Spaces for the Selected  
Vernacular Houses**

# Hierarchy of Spaces

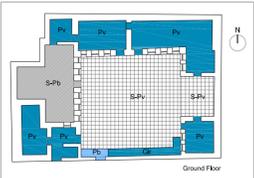
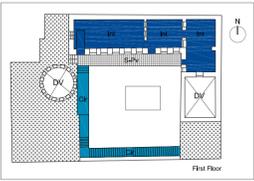
## The Middle East (17 cases)

Key:

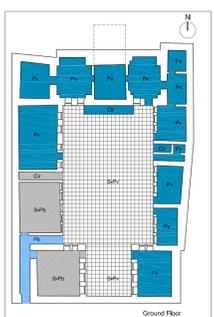
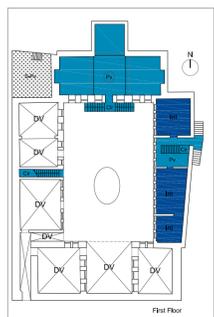
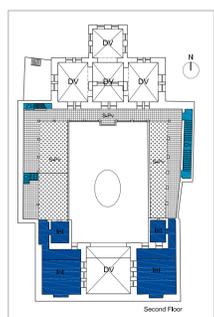
- Public Spaces (Pb)  
(Main Entry Hall)
- Semi-Private Spaces (S-Pv)  
(Courtyard, Gallery, Iwan, Service Entrance)
- Semi-Public Spaces (S-Pb)  
(Guest Room, Toilet for Guests)
- Private Spaces (Pv)  
(Living Room, Multi-Purpose Hall, Toilet, Kitchen, Storage Area)
- Intimate Spaces (Int)  
(Bedroom, Bathroom)

### SYRIA

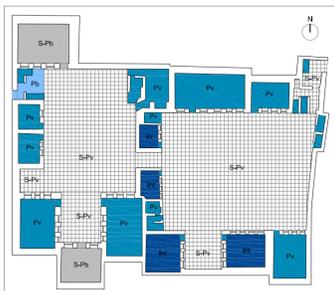
SYR-1



SYR-2



SYR-3



### LEBANON

LBN-1



LBN-2



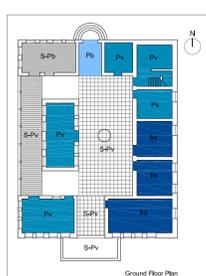
LBN-3



LBN-4



LBN-5

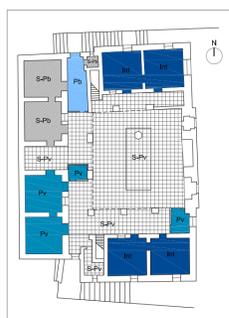


### PALESTINE

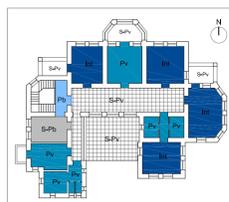
PAL-1



PAL-2

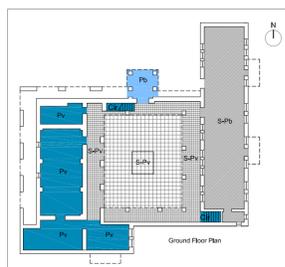
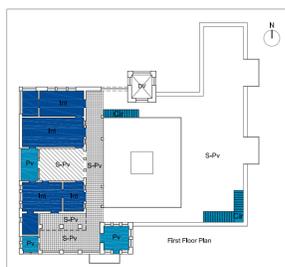


PAL-3



### JORDAN

JOR-1



### IRAQ

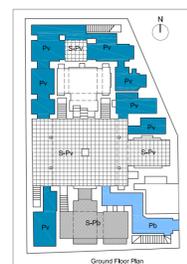
IRQ-1



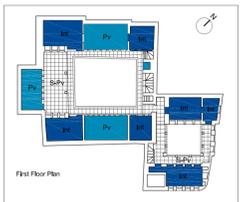
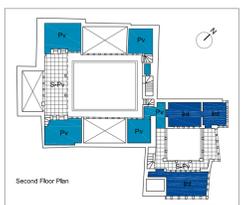
IRQ-2



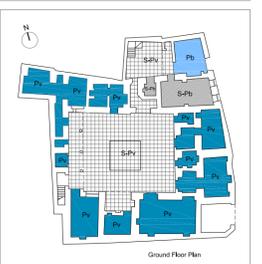
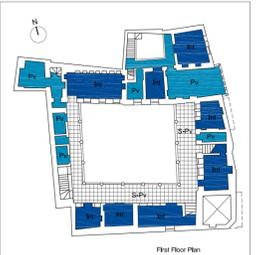
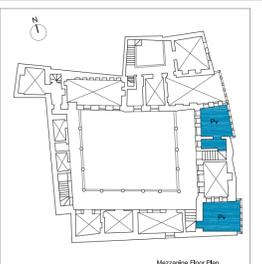
IRQ-3



IRQ-4



IRQ-5



# Hierarchy of Spaces

## North Africa (15 cases)

Key:

- Public Spaces (Pb)  
(Main Entry Hall)
- Semi-Private Spaces (S-Pv)  
(Courtyard, Gallery, Iwan, Service Entrance)
- Semi-Public Spaces (S-Pb)  
(Guest Room, Toilet for Guests)
- Private Spaces (Pv)  
(Living Room, Multi-Purpose Hall, Toilet, Kitchen, Storage Area)
- Intimate Spaces (Int)  
(Bedroom, Bathroom)

### EGYPT

#### EGY-1

#### EGY-2

Second Floor Plan

Ground Floor Plan

#### EGY-3

Ground Floor Plan

#### EGY-4

First Floor Plan

Ground Floor Plan

### TUNISIA

#### TUN-1

First Floor Plan

#### TUN-2

First Floor Plan

#### TUN-3

Ground Floor Plan

#### TUN-4(A+B)

Ground Floor Plan

#### TUN-5(A+B+C)

Ground Floor Plan

#### TUN-6

Ground Floor Plan

#### TUN-7

Ground Floor Plan

### MOROCCO

#### MOR-1

First Floor Plan

Ground Floor Plan

#### MOR-2

Second Floor Plan

First Floor Plan

Ground Floor Plan

### ALGERIA

#### ALG-1

First Floor Plan

Mezzanine Floor Plan

Ground Floor Plan

#### ALG-2

First Floor Plan

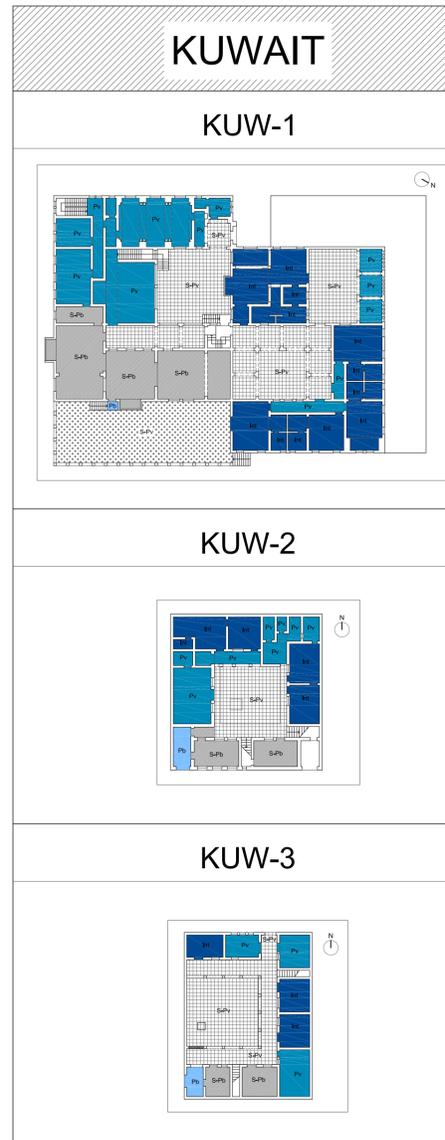
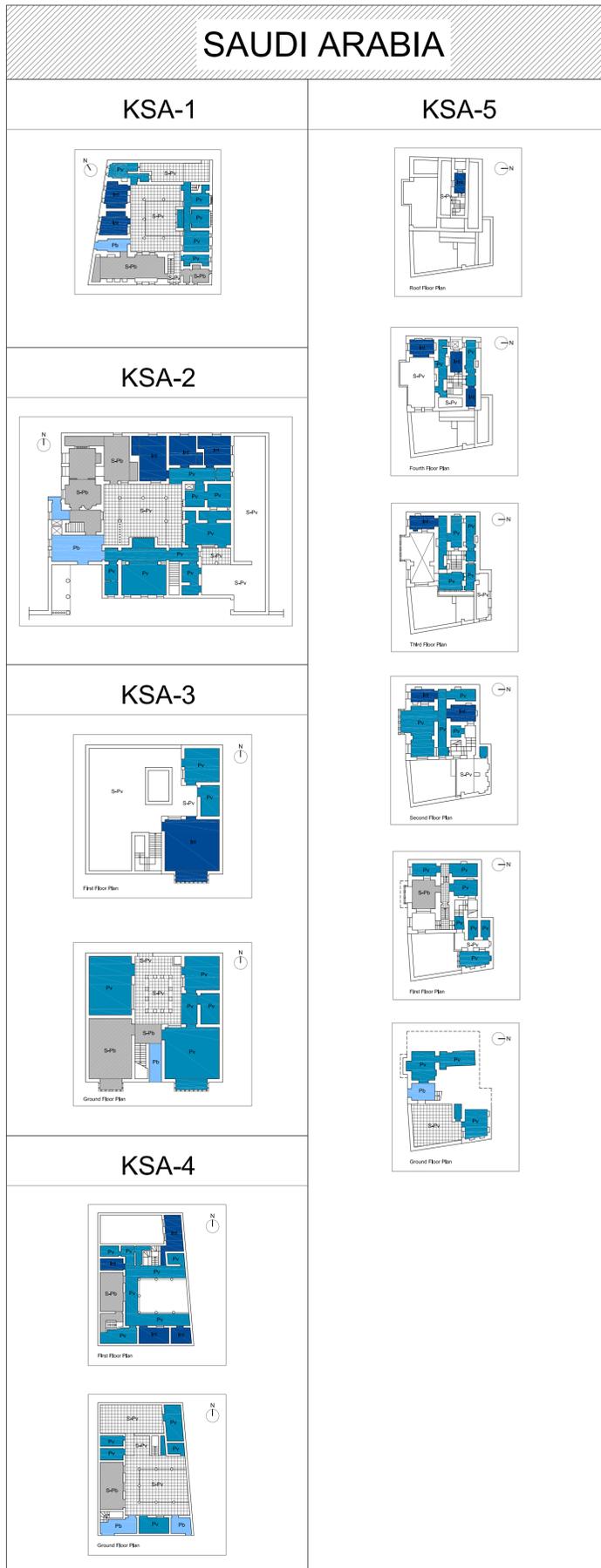
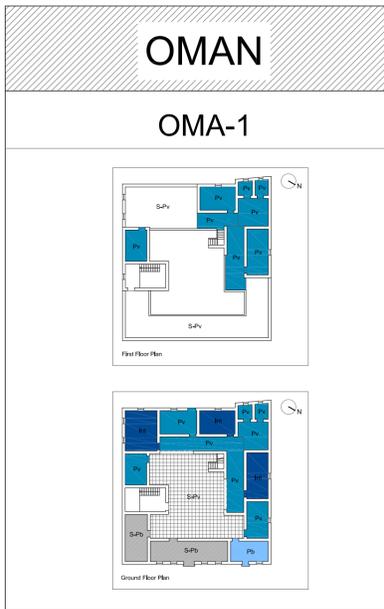
Ground Floor Plan

# Hierarchy of Spaces

## The Gulf Area (12 cases)

Key:

- Public Spaces (Pb)  
(Main Entry Hall)
- Semi-Private Spaces (S-Pv)  
(Courtyard, Gallery, Iwan, Service Entrance)
- Semi-Public Spaces (S-Pb)  
(Guest Room, Toilet for Guests)
- Private Spaces (Pv)  
(Living Room, Multi-Purpose Hall, Toilet, Kitchen, Storage Area)
- Intimate Spaces (Int)  
(Bedroom, Bathroom)



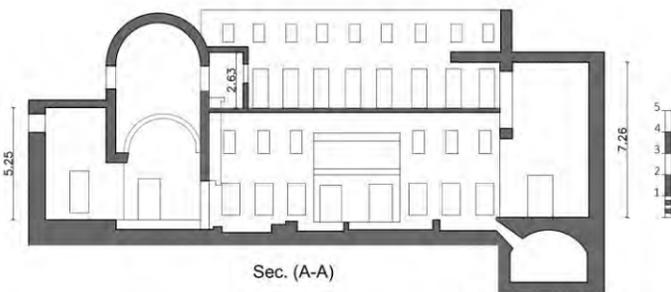
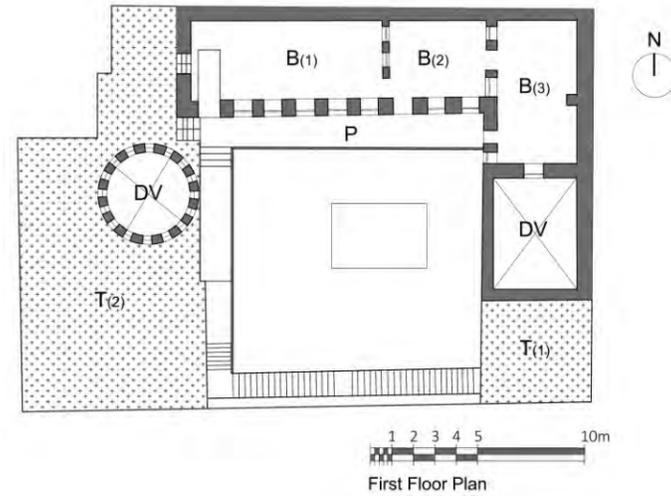
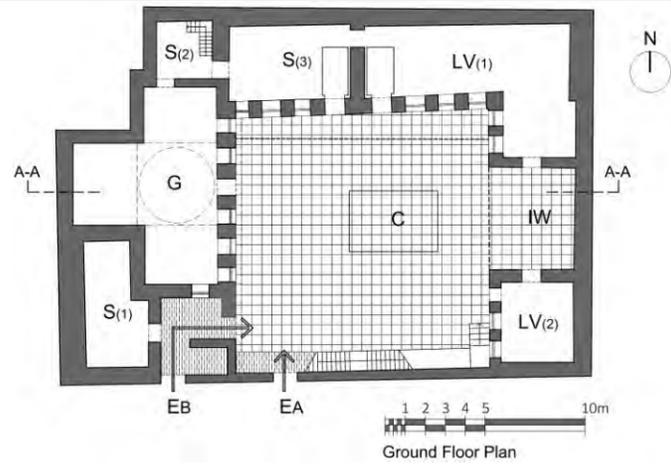
Appendix (4-B-7)

**Syntactic Diagrams for the Selected  
Vernacular Houses**

# The Social Logic of the Spatial Arrangement of a Courtyard House in Aleppo, Syria

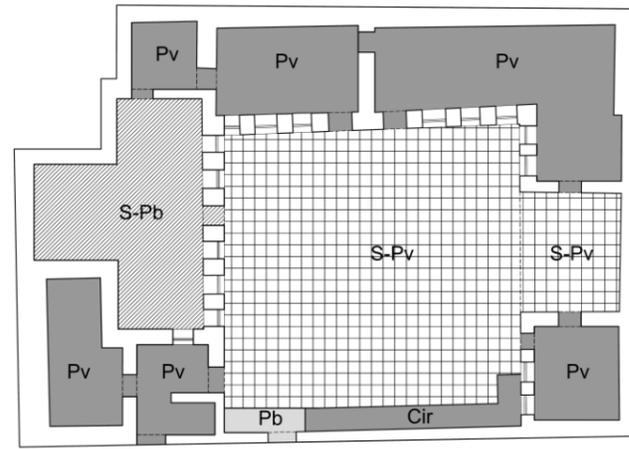
|        |             |         |       |          |        |
|--------|-------------|---------|-------|----------|--------|
| Region | Middle East | Country | Syria | Case No. | ME-S-1 |
|--------|-------------|---------|-------|----------|--------|

## Architectural Plans for a Courtyard House, Aleppo, Syria (Redrawn by Researcher, after (Ragette, 2016, 157))



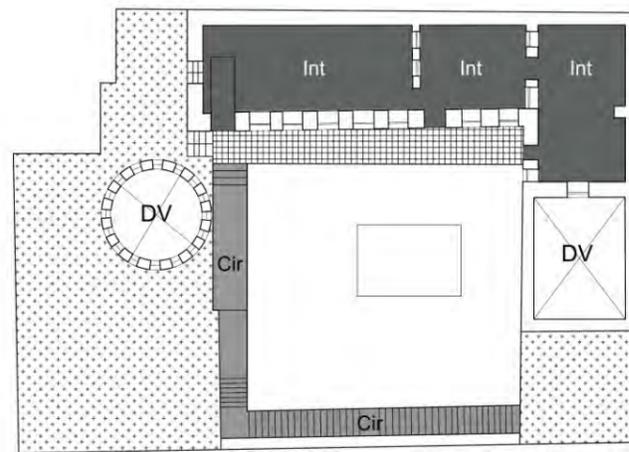
- EA: Main Entrance Hall/Corridor
- EB: Services Entrance
- C: Courtyard
- IW: Iwan
- GL: Gallery
- T: Roof Terrace / Balcony
- G: Guest Room (Reception)
- LV: Family Living Room
- B: Intimate Spaces (Bedrooms)
- S: Services (Kitchen, Toilets, Storage)
- P: Passage / Transitional Space
- DV: Double Volume

## Hierarchy and Depth of Spaces (according to the orientation, and type of spaces) (Researcher)

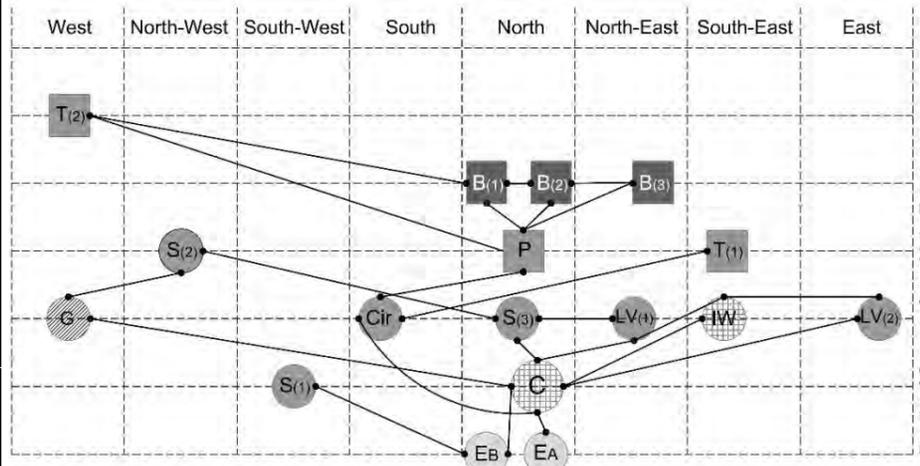


- Pb Public Zone (Main Entrance)
- S-Pb Semi-Public Zone (Reception / Men Guest Room)
- S-Pv Semi-Private Zone (Courtyard, Iwan)
- Pv Private Zone (Family Rooms, Services)
- Int Intimate Zone (Bedrooms)
- Cir Vertical Circulation (Stairs to roof / upper floors)

Ground Floor



First Floor



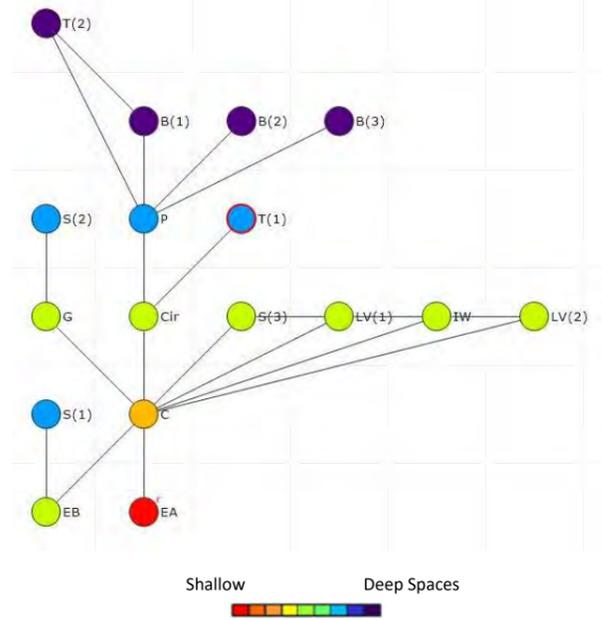
- Spaces located on the Ground Floor
- Spaces located on the First Floor
- Direction of Surface Interaction between Spaces

Living and Intimate Spaces

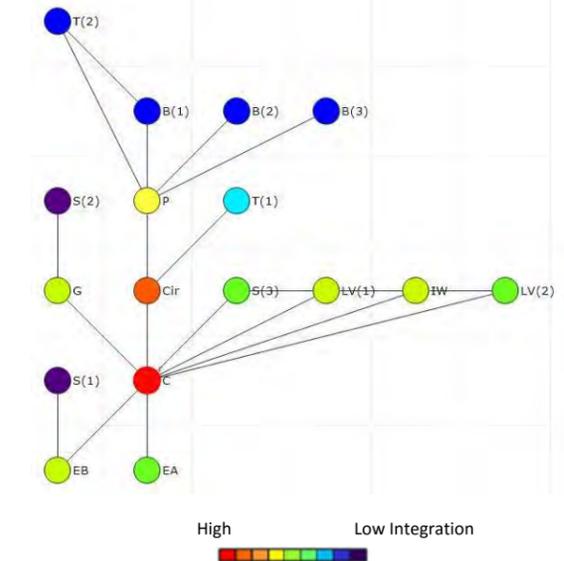
## Space Syntax Analysis

Diagrams produced by Researcher using AGRAPH Online software  
(<https://www.ntnu.no/ab/spacesyntax>)

### Depth of Spaces from the Main Entrance



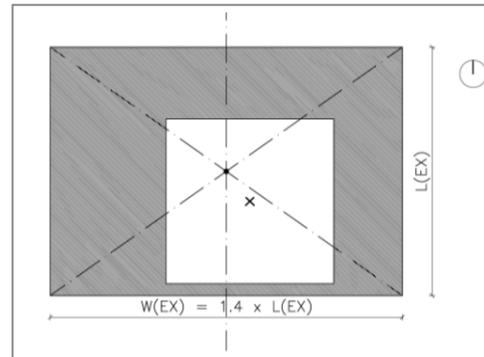
### Integration of Spaces with the Courtyard (the courtyard has the greatest control value)



## The Social Logic of the Spatial Design of a Courtyard House in Aleppo, Syria

Region Middle East Country Syria Case No. ME-S-1

### Typology and Geometric Properties of the House (Researcher)



|   |   |
|---|---|
| <b>Typology</b>   | Rectangular layout with one courtyard adjacent to the edge of the house |
| <b>Exterior layout</b>  | 1 : 1.4   |
| <b>Courtyard</b>  | 1 : 1<br>25 % of the total area of the house, 37% of the GF             |
| <b>Distance (D) between the center of the exterior layout (●) and the center of the courtyard (x)</b> | Dx = 1/12 W(Ex)<br>Dy = - (Dx)  |
| <b>Thickness of exterior walls</b>  | 80 cm   |
| <b>Height of Guest/Living spaces on the Ground Floor</b>  | 525 – 725 cm  |
| <b>Height of Bedrooms on the First Floor</b>  | 400 cm  |

|   | Dominant Users (Male / Female) | Percentage of area of this space related to the total area of the house | Percentage of area related to the floor area where it is located |                 | Proportion of the area of this space, to the area of the courtyard | Proportion of Spaces         |
|---|--------------------------------|---|--|-----------------|--|------------------------------|
|   |                                |   | G  | 1 <sup>st</sup> |  |                              |
| <b>Courtyard</b>                                | M+F                            | 25 %  | 37 %   | -               | 1 : 1  | 1 : 1                        |
| <b>Iwan</b>                                     | M+F                            | 4 %   | 5 %  | -               | 0.13 : 1   | 1 : 1.1                      |
| <b>Terraces</b>                                 | M+F                            | 23 %  | -  | 56 %            | 0.90 : 1   |                              |
| <b>Guest Room</b>                               | M                              | 9 %   | 13 %   | -               | 0.34 : 1   | 1 : 2.7 , 1 : 1.15 , 1 : 1.2 |
| <b>Living Rooms</b>                             | M+F                            | 9 %   | 13 %   | -               | 0.36 : 1   | 1 : 1.1 , 1 : 3              |
| <b>Bedrooms</b>                                 | M+F                            | 15 %  | 68 %   | 37 %            | 0.50 : 1   | 1 : 2.5 , 1 : 1.25 , 1 : 1.8 |
| <b>Services (kitchen and storage) (Toilets)</b> | F<br>M+F                       | 8 %   | 12 %   | -               | 0.32 : 1   |                              |

### Integration of Spaces using Space Syntax Theory

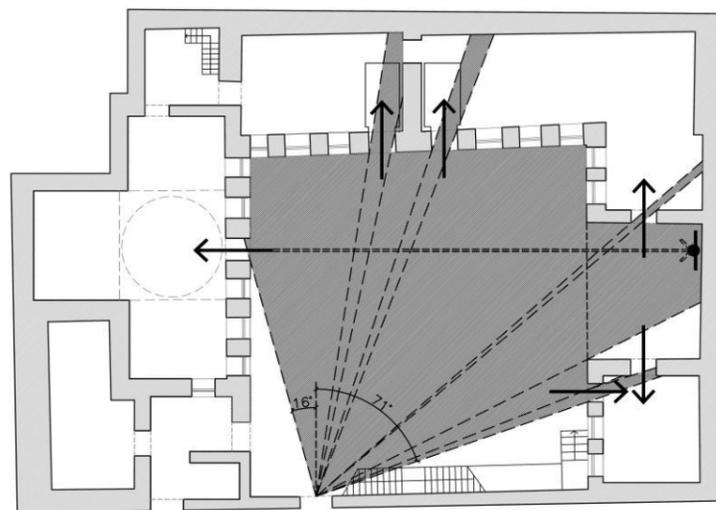
(Calculations produced by AGRAPH Online software)  
(<https://www.ntnu.no/ab/spacesyntax>)

#### Control and Integration Values for each space

TDn Total Depth (TD) for actual node  
MDn Mean Depth (MD) for actual node = TD/(K-1)  
K Number of Nodes  
NCn Number of Connections from Node  
RA Relative Asymmetry = 2\*(MD-1)/(K-2)  
i Integration Value = 1/RA  
CV Control Value

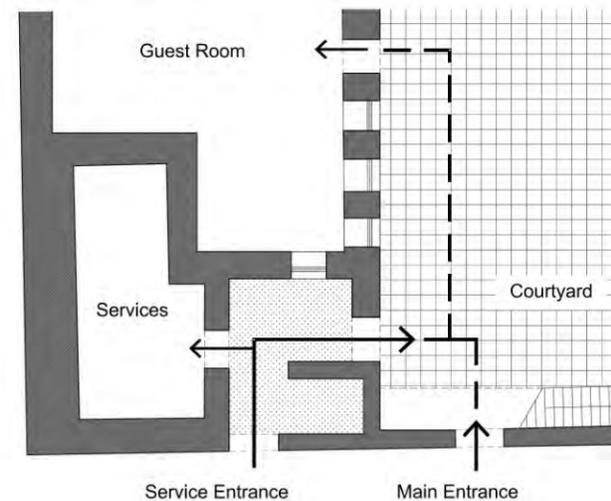
| Spaces | TDn   | MDn  | RA   | i     | CV   | NCn  |
|--------|-------|------|------|-------|------|------|
| EA     | 43    | 2.68 | 0.22 | 4.44  | 0.12 | 1.00 |
| EB     | 41    | 2.56 | 0.20 | 4.80  | 1.12 | 2.00 |
| C      | 28    | 1.75 | 0.10 | 10.00 | 4.00 | 8.00 |
| S(1)   | 56    | 3.50 | 0.33 | 3.00  | 0.50 | 1.00 |
| G      | 41    | 2.56 | 0.20 | 4.80  | 1.12 | 2.00 |
| Cir    | 31    | 1.93 | 0.12 | 8.00  | 1.32 | 3.00 |
| LV(1)  | 41    | 2.56 | 0.20 | 4.80  | 0.95 | 3.00 |
| IW     | 41    | 2.56 | 0.20 | 4.80  | 0.95 | 3.00 |
| LV(2)  | 42    | 2.62 | 0.21 | 4.61  | 0.45 | 2.00 |
| S(2)   | 56    | 3.50 | 0.33 | 3.00  | 0.50 | 1.00 |
| P      | 38    | 2.37 | 0.18 | 5.45  | 3.33 | 5.00 |
| B(1)   | 52    | 3.25 | 0.30 | 3.33  | 0.70 | 2.00 |
| B(2)   | 53    | 3.31 | 0.30 | 3.24  | 0.20 | 1.00 |
| B(3)   | 53    | 3.31 | 0.30 | 3.24  | 0.20 | 1.00 |
| T(2)   | 52    | 3.25 | 0.30 | 3.33  | 0.70 | 2.00 |
| T(1)   | 46    | 2.87 | 0.25 | 4.00  | 0.33 | 1.00 |
| S(3)   | 42    | 2.62 | 0.21 | 4.61  | 0.45 | 2.00 |
| Min    | 28.00 | 1.75 | 0.10 | 3.00  | 0.12 |      |
| Mean   | 44.47 | 2.77 | 0.23 | 4.67  | 1.00 |      |
| Max    | 56.00 | 3.50 | 0.33 | 10.00 | 4.00 |      |

### Visual Analysis from the Main Entrance towards inside the House (Researcher)



- Visual access from the main entrance towards guest rooms, and from guest rooms towards living areas and intimate spaces
- Entry points for spaces
- Continuity of the visual axis, with no access at the end

### Strategies for achieving Visual Privacy between the Main Entrance and inside the House (Researcher)



Two entrances: one for guests and family members, and the other is for services. The main entrance is located near the reception room for guests

#### Integration Values:

Courtyard > Vertical Circulation > Entrance, Guest Room > Living Rooms, Iwan > Bedrooms > Services (Kitchen, Storage, and Toilets)

#### Lowest Integration Values:

- Intimate spaces (bedrooms)
- Services

#### Highest Integration and Control Values:

- Courtyard
- Vertical circulation (stairs)
- Passage on the first floor

# The Social Logic of the Spatial Arrangement of a Courtyard House in Damascus, Syria

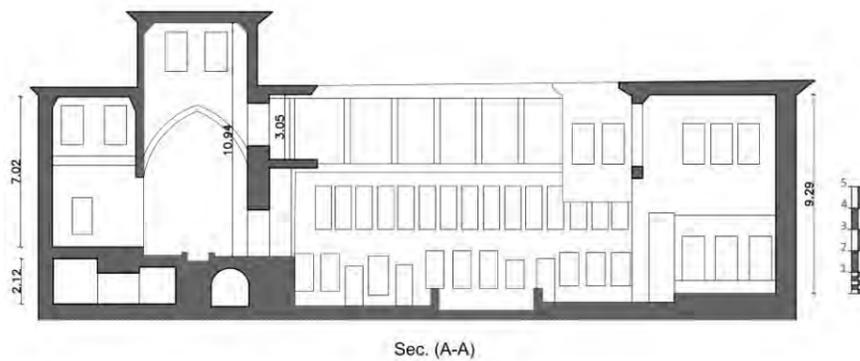
|        |             |         |       |          |        |
|--------|-------------|---------|-------|----------|--------|
| Region | Middle East | Country | Syria | Case No. | ME-S-2 |
|--------|-------------|---------|-------|----------|--------|

## Architectural Plans for a Courtyard House, Damascus, Syria (Redrawn by Researcher, after (Ragette, 2016, 158))

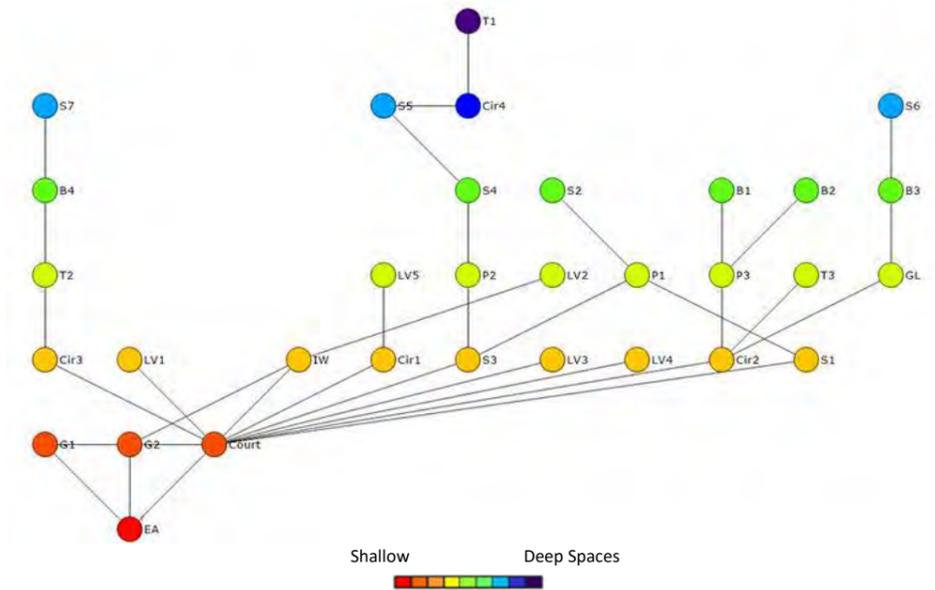
**Space Syntax Analysis**  
Diagrams produced by Researcher using AGRAPH Online software  
(<https://www.ntnu.no/ab/spacesyntax>)



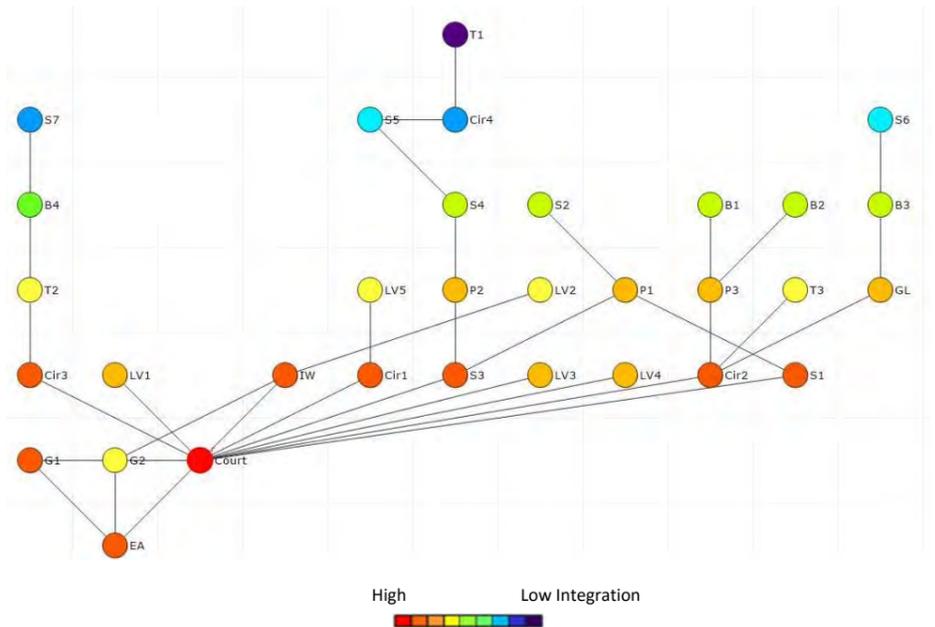
- EA: Main Entrance Hall/Corridor
- EB: Services Entrance
- C : Courtyard
- IW: Iwan
- GL: Gallery
- T : Roof Terrace / Balcony
- G : Guest Room (Reception)
- LV: Family Living Room
- B : Intimate Spaces (Bedrooms)
- S : Services (Kitchen, Toilets, Storage)
- P : Passage / Transitional Space
- DV: Double Volume



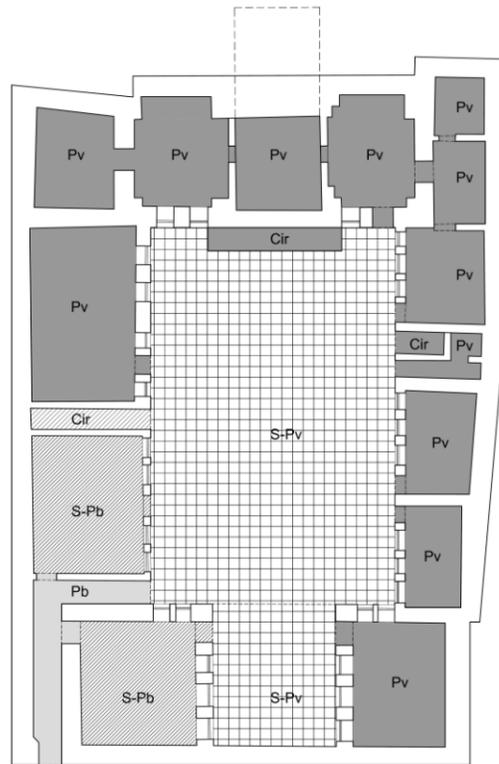
### Depth of Spaces from the Main Entrance



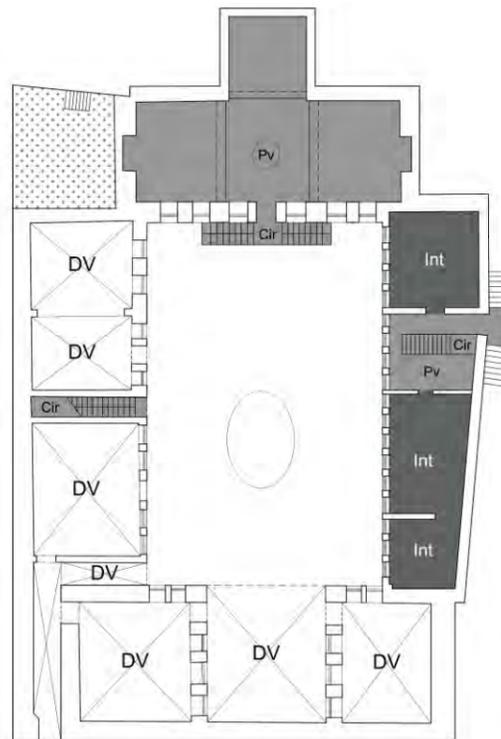
### Integration of Spaces with the Courtyard (the courtyard has the greatest control value)



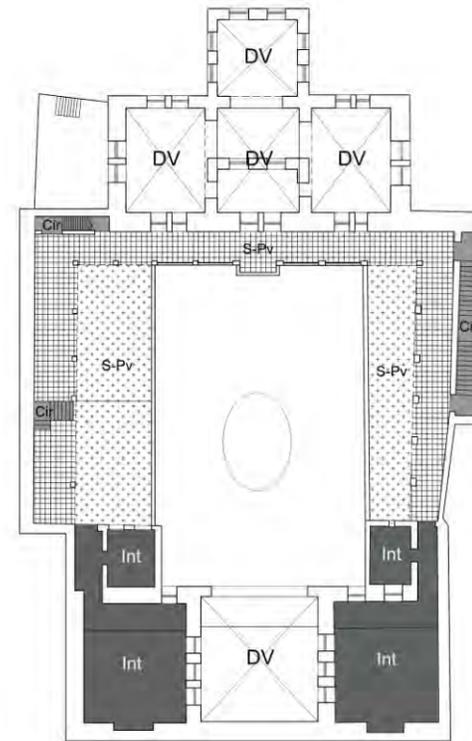
Hierarchy and Depth of Spaces (according to the orientation, and type of spaces)  
(Researcher)



Ground Floor

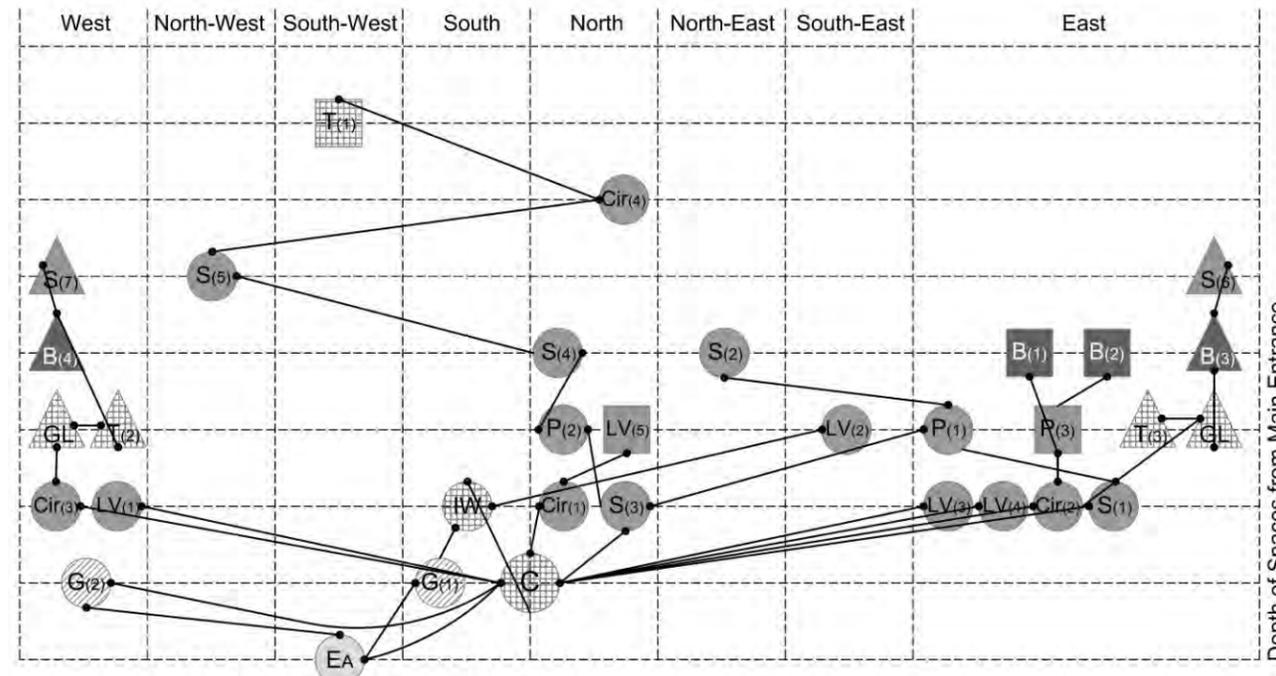


First Floor



Second Floor

- Pb Public Zone (Main Entrance)
- S-Pb Semi-Public Zone (Reception / Men Guest Room)
- S-Pv Semi-Private Zone (Courtyard, Iwan)
- Pv Private Zone (Family Rooms, Services)
- Int Intimate Zone (Bedrooms)
- Cir Vertical Circulation (Stairs to roof / upper floors)



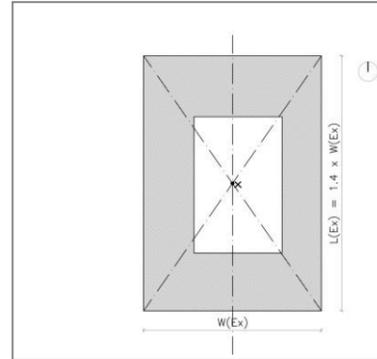
- Spaces located on the Ground Floor
- Spaces located on the 1st Floor
- △ Spaces located on the 2nd Floor
- Direction of Surface Interaction between Spaces

← Living and Intimate Spaces →

# The Social Logic of the Spatial Design of a Courtyard House in Damascus, Syria

|        |             |         |       |          |        |
|--------|-------------|---------|-------|----------|--------|
| Region | Middle East | Country | Syria | Case No. | ME-S-2 |
|--------|-------------|---------|-------|----------|--------|

## Typology and Geometric Properties of the House (Researcher)



|   |  |
|---|--|
| <b>Typology</b>   | Rectangular layout with one courtyard at the center of the house |
| <b>Exterior layout</b>  | 1 : 1.4  |
| <b>Courtyard</b>  | 1 : 1.55   |
|   | 17 % of the total area of the house, 33 % of the GF              |
| <b>Distance (D) between the center of the exterior layout (●) and the center of the courtyard (x)</b> | Center of the Courtyard ≈ Center of the House                    |
| <b>Thickness of exterior walls</b>  | 80 cm  |
| <b>Height of Guest/Living spaces on the Ground Floor</b>  | 415 cm   |
| <b>Height of Bedrooms on the First Floor</b>  | 305 cm   |

## Integration of Spaces using Space Syntax Theory (Calculations produced by AGRAPH Online software) (<https://www.ntnu.no/ab/spacesyntax>)

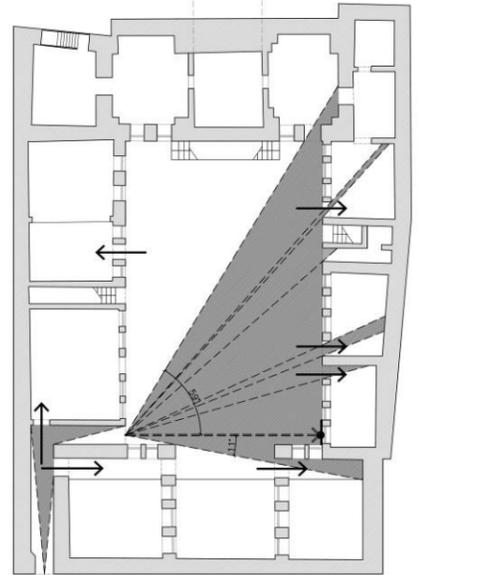
### Control and Integration Values for each space

TDn Total Depth (TD) for actual node  
 MDn Mean Depth (MD) for actual node = TD/(K-1)  
 K Number of Nodes  
 NCn Number of Connections from Node  
 RA Relative Asymmetry = 2\*(MD-1)/(K-2)  
 I Integration Value = 1/RA  
 CV Control Value

| Spaces | TDn    | MDn  | RA   | i     | CV   | NCn   |
|--------|--------|------|------|-------|------|-------|
| EA     | 97     | 3.12 | 0.14 | 7.04  | 1.09 | 3.00  |
| G2     | 123    | 3.96 | 0.19 | 5.05  | 0.66 | 2.00  |
| G1     | 98     | 3.16 | 0.14 | 6.94  | 0.42 | 2.00  |
| Court  | 70     | 2.25 | 0.08 | 11.92 | 6.25 | 11.00 |
| Cir3   | 94     | 3.03 | 0.13 | 7.38  | 0.59 | 2.00  |
| LV1    | 100    | 3.22 | 0.14 | 6.73  | 0.09 | 1.00  |
| T2     | 120    | 3.87 | 0.19 | 5.22  | 1.00 | 2.00  |
| B4     | 148    | 4.77 | 0.25 | 3.97  | 1.50 | 2.00  |
| S5     | 158    | 5.09 | 0.27 | 3.66  | 1.00 | 2.00  |
| IW     | 96     | 3.09 | 0.13 | 7.15  | 1.59 | 3.00  |
| Cir1   | 98     | 3.16 | 0.14 | 6.94  | 1.09 | 2.00  |
| S3     | 86     | 2.77 | 0.11 | 8.45  | 0.92 | 3.00  |
| LV3    | 100    | 3.22 | 0.14 | 6.73  | 0.09 | 1.00  |
| LV4    | 100    | 3.22 | 0.14 | 6.73  | 0.09 | 1.00  |
| Cir2   | 86     | 2.77 | 0.11 | 8.45  | 1.92 | 4.00  |
| S1     | 96     | 3.09 | 0.13 | 7.15  | 0.42 | 2.00  |
| LV5    | 128    | 4.12 | 0.20 | 4.79  | 0.50 | 1.00  |
| P2     | 108    | 3.48 | 0.16 | 6.03  | 0.83 | 2.00  |
| S4     | 132    | 4.25 | 0.21 | 4.60  | 1.00 | 2.00  |
| S2     | 142    | 4.58 | 0.23 | 4.18  | 0.33 | 1.00  |
| LV2    | 126    | 4.06 | 0.20 | 4.89  | 0.33 | 1.00  |
| P1     | 112    | 3.61 | 0.17 | 5.74  | 1.83 | 3.00  |
| P3     | 112    | 3.61 | 0.17 | 5.74  | 2.25 | 3.00  |
| T3     | 116    | 3.74 | 0.18 | 5.47  | 0.25 | 1.00  |
| GL     | 112    | 3.61 | 0.17 | 5.74  | 0.75 | 2.00  |
| S7     | 178    | 5.74 | 0.31 | 3.16  | 0.50 | 1.00  |
| B1     | 142    | 4.58 | 0.23 | 4.18  | 0.33 | 1.00  |
| B2     | 142    | 4.58 | 0.23 | 4.18  | 0.33 | 1.00  |
| B3     | 140    | 4.51 | 0.23 | 4.26  | 1.50 | 2.00  |
| S6     | 170    | 5.48 | 0.29 | 3.34  | 0.50 | 1.00  |
| Cir4   | 186    | 6.00 | 0.33 | 3.00  | 1.50 | 2.00  |
| T1     | 216    | 6.96 | 0.39 | 2.51  | 0.50 | 1.00  |
| Min    | 70.00  | 2.25 | 0.08 | 2.51  | 0.09 |       |
| Mean   | 122.87 | 3.96 | 0.19 | 5.67  | 1.00 |       |
| Max    | 216.00 | 6.96 | 0.39 | 11.92 | 6.25 |       |

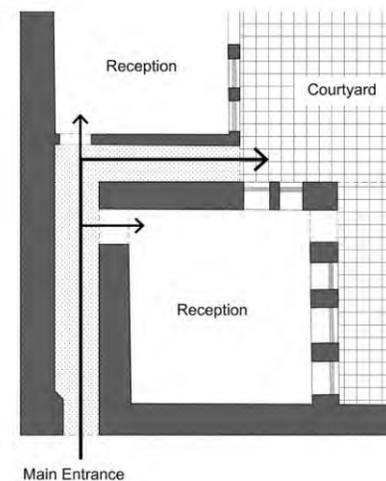
|  | Dominant Users (Male / Female) | Percentage of area of this space related to the total area of the house | Percentage of area of this space related to the floor area where it is located |                 |                 | Proportion of the area of this space, to the area of the courtyard | Proportion of Spaces        |
|--|--------------------------------|---|--|-----------------|-----------------|--|-----------------------------|
|  |                                |   | G  | 1 <sup>st</sup> | 2 <sup>nd</sup> |  |                             |
| Courtyard                                | M+F                            | 17 %  | 33 %   | -               | -               | 1 : 1  | 1 : 1.55                    |
| Iwan and Gallery                         | M+F                            | 2 %   | 6 %  | -               | 30 %            | 1.05 : 1   | 1 : 1.15                    |
| Terraces                                 | M+F                            | 2 %   | -  | 16 %            | 30 %            |  |                             |
| Guest Rooms                              | M                              | 5 %   | 11 %   | -               | -               | 0.32 : 1   | 1 : 1.07 , 1 : 1.25         |
| Living Rooms                             | M+F                            | 14 %  | 15 %   | 43 %            | -               | 0.85 : 1   | 1 : 1.07 , 1 : 1 , 1 : 2.56 |
| Bedrooms                                 | M+F                            | 13 %  | -  | 32 %            | 21 %            | 0.77 : 1   | 1 : 1.07 , 1 : 1.15         |
| Services (kitchen and storage) (Toilets) | F<br>M+F                       | 10 %  | 17 %   | 9 %             | 5 %             | 0.60 : 1   |                             |

### Visual analysis from the main entrance towards guest rooms and private/intimate spaces (Researcher)



Visual access from the main entrance towards guest rooms, and from guest rooms towards living areas and intimate spaces  
 Entry points for spaces  
 Continuity of the visual axis, with no access at the end

### Strategies for achieving visual privacy between the entrance and semi-public spaces (Researcher)



The use of 'bent entrance', which is connected directly with guest rooms, and separated spatially and visually from the courtyard and family living spaces.

### Integration Values:

Courtyard > Vertical Circulation, Service > Entrance > Living Rooms, Iwan > , Guest Room > Bedrooms > Services (Kitchen, Storage, and Toilets) > Terraces

### Lowest Integration Values:

- Terraces
- Intimate spaces (bedrooms), and services

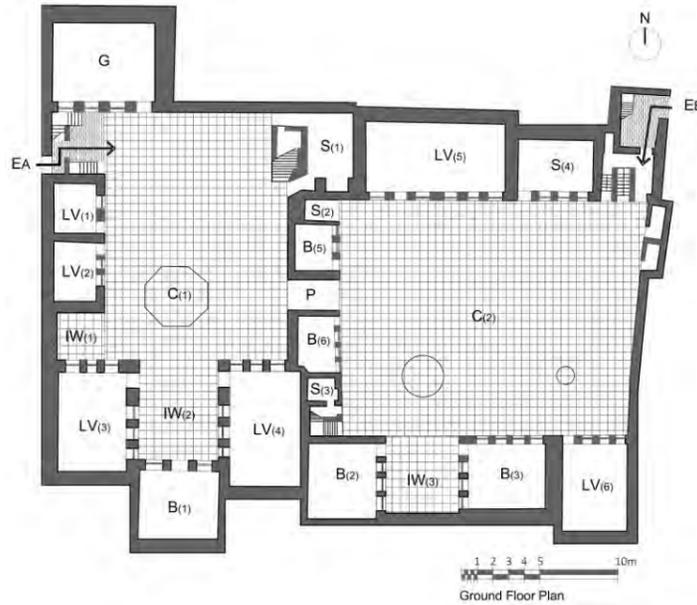
### Highest Integration and Control Values:

- Courtyard
- Vertical circulation (stairs)
- Iwan (as a semi-open living area)
- Main entrance

# The Social Logic of the Spatial Arrangement of a Courtyard House in Damascus, Syria

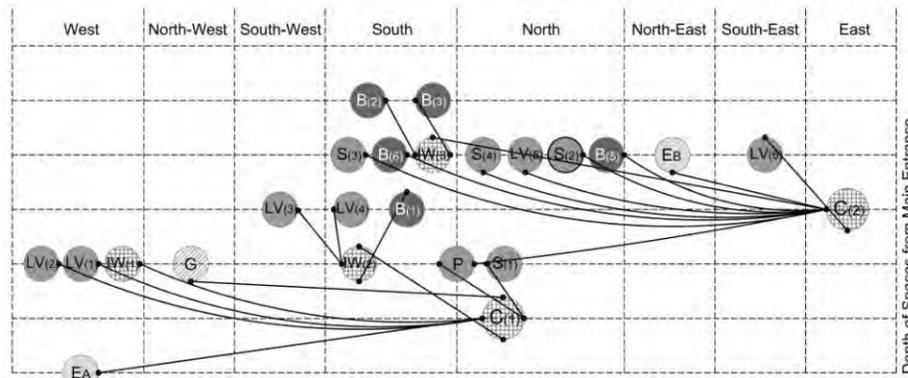
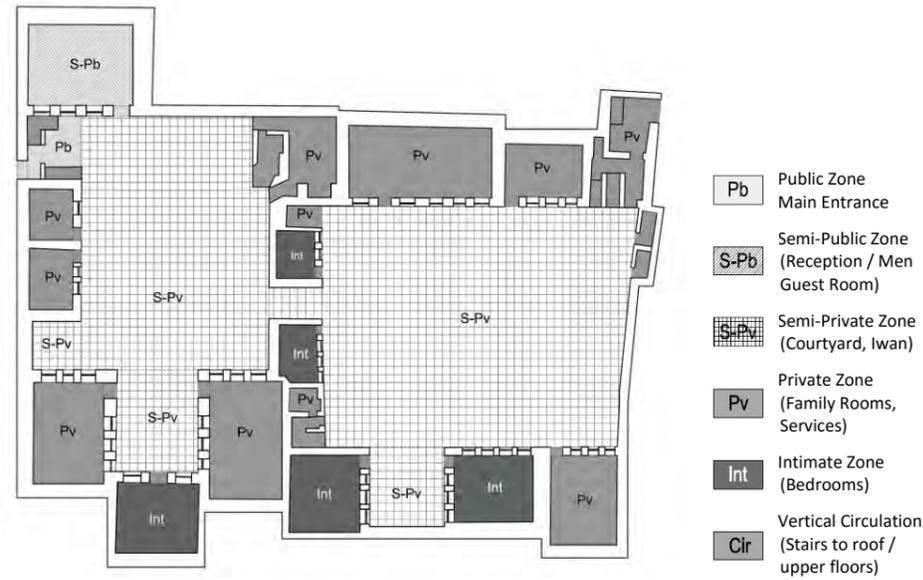
|        |             |         |       |          |        |
|--------|-------------|---------|-------|----------|--------|
| Region | Middle East | Country | Syria | Case No. | ME-S-3 |
|--------|-------------|---------|-------|----------|--------|

## Architectural Plans for a Courtyard House, Damascus, Syria (Redrawn by Researcher, after (Ragette, 2016, 159))



- EA: Main Entrance Hall/Corridor
- EB: Services Entrance
- C : Courtyard
- IW: Iwan
- GL: Gallery
- T : Roof Terrace / Balcony
- G : Guest Room (Reception)
- LV: Family Living Room
- B : Intimate Spaces (Bedrooms)
- S : Services (Kitchen, Toilets, Storage)
- P : Passage / Transitional Space
- DV: Double Volume

## Hierarchy and Depth of Spaces (according to the orientation, and type of spaces) (Researcher)

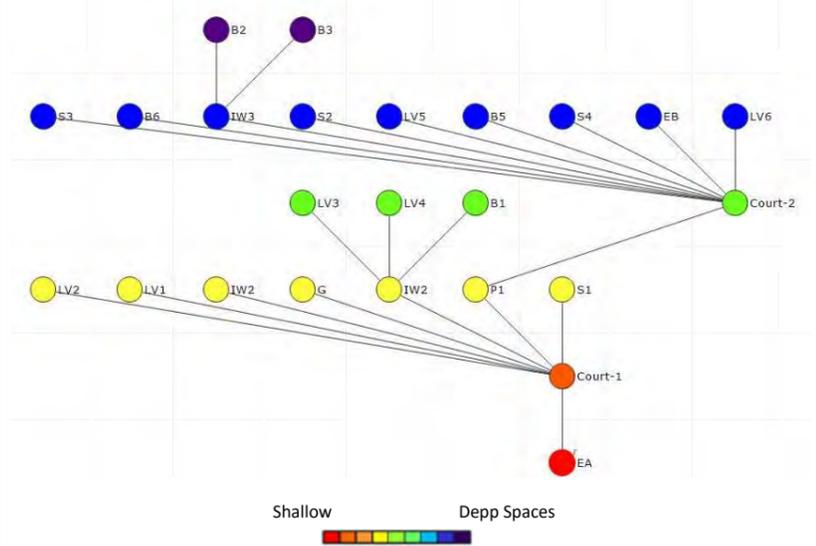


- Spaces located on the Ground Floor
- Direction of Surface Interaction between Spaces

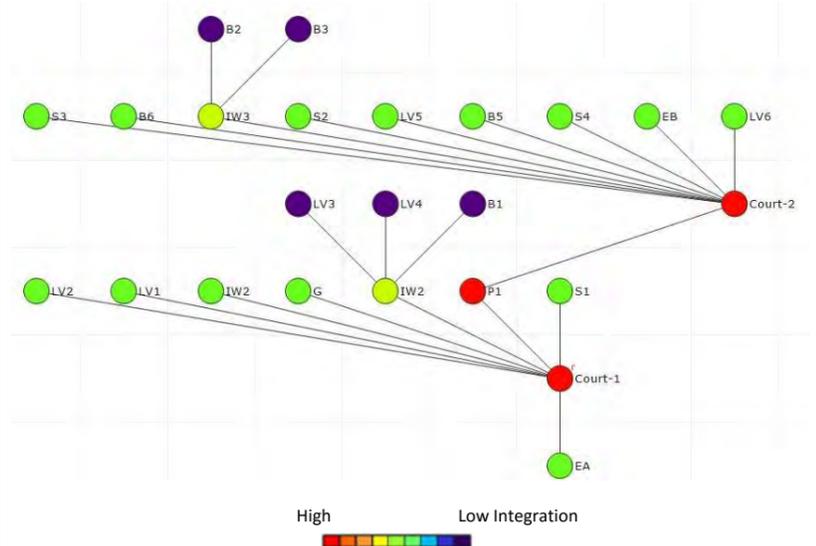
## Space Syntax Analysis

Diagrams produced by Researcher using AGRAPH Online software  
(<https://www.ntnu.no/ab/spacesyntax>)

### Depth of Spaces from the Main Entrance



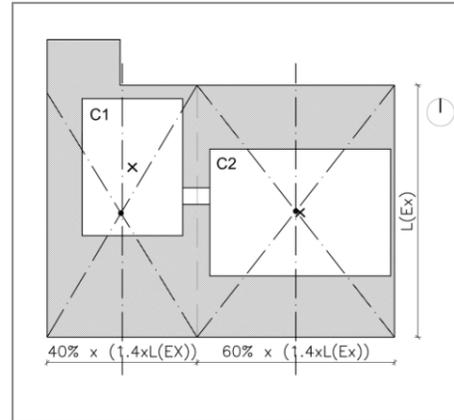
### Integration of Spaces with Courtyards (the courtyard has the greatest control value)



# The Social Logic of the Spatial Design of a Courtyard House in Damascus, Syria

|        |             |         |       |          |        |
|--------|-------------|---------|-------|----------|--------|
| Region | Middle East | Country | Syria | Case No. | ME-S-3 |
|--------|-------------|---------|-------|----------|--------|

## Typology and Geometric Properties of the House (Researcher)



|  |  |
|--|--|
| <b>Typology</b>  | Rectangular layout with two courtyards, both are adjacent to the edge of the house   |
| <b>Exterior layout</b>   | 1: 1.4 (for the overall exterior layout)<br>Zone(1): $W(Ex1) = 40\% \times (1.4 \times L(Ex))$<br>Zone(2): $W(Ex2) = 60\% \times (1.4 \times L(Ex))$ |
| <b>Courtyard</b>   | C1: 1 : 1.35 , C2: 1 : 1.25<br>39 % of the total area of the house<br>(C1: 37% of Zone (1), C2: 46% of Zone (2))                                     |
| <b>Distance (D) between the center of the exterior layout (●) and the center of the courtyard C1 (x)</b> | $Dx1 = 1/15 \times W(Ex1)$<br>$Dy1 = 5 \times W(Ex1)$  |
| <b>Distance (D) between the center of the exterior layout (●) and the center of the courtyard C2 (x)</b> | Center of Courtyard C2 $\approx$ Center of Zone (2)<br>$Dx2 = 0 , Dy2 = 0$   |
| <b>Thickness of exterior walls</b>   | 55 cm  |
| <b>Height of Ceiling</b>   |  |

|   | Dominant Users (Male / Female) | Percentage of area of this space related to the total area of the house | Percentage of area of this space related to the zone where it is located Zone-1 and Zone-2 |      | Proportion of the area of this space, to the area of courtyards C1 and C2 |          | Proportion of Spaces          |
|---|--------------------------------|---|--|------|---|----------|-------------------------------|
| <b>Courtyards</b>                               | M+F                            | 48 %  | 47 %   | 48 % | 1 : 1   | 1 : 1    | (C1) 1 : 1.35 , (C2) 1 : 1.25 |
| <b>Iwan</b>                                     | M+F                            | 7 %   | 11 %   | 10 % | 0.23 : 1  | 0.07 : 1 | 1 : 1 , 1 : 1.25              |
| <b>Guest Room</b>                               | M                              | 4 %   | 8 %  | -    | 0.18 : 1  | -        | 1 : 1.30                      |
| <b>Living Rooms</b>                             | M+F                            | 15 %  | 20 %   | 11 % | 0.43 : 1  | 0.23 : 1 | 1 : 1.4 , 1 : 1.35 , 1 : 2.25 |
| <b>Bedrooms</b>                                 | M+F                            | 9 %   | 6 %  | 10 % | 0.13 : 1  | 0.21 : 1 | 1 : 1.15 , 1 : 1              |
| <b>Services (kitchen and storage) (Toilets)</b> | F                              | 5 %   | 6 %  | 4 %  | 0.12 : 1  | 0.08 : 1 |                               |

## Integration of Spaces using Space Syntax Theory

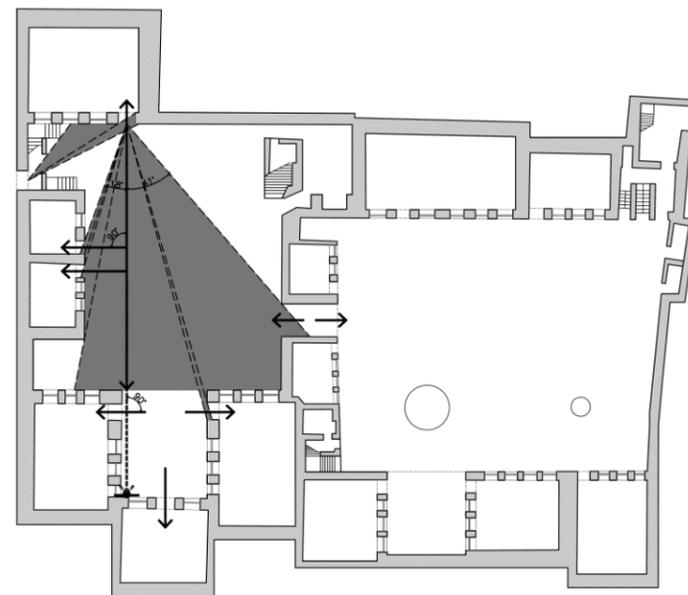
(Calculations produced by AGRAPH Online software)  
(<https://www.ntnu.no/ab/spacesyntax>)

### Control and Integration Values for each space

TDn Total Depth (TD) for actual node  
MDn Mean Depth (MD) for actual node =  $TD/(K-1)$   
K Number of Nodes  
NCn Number of Connections from Node  
RA Relative Asymmetry =  $2*(MD-1)/(K-2)$   
i Integration Value =  $1/RA$   
CV Control Value

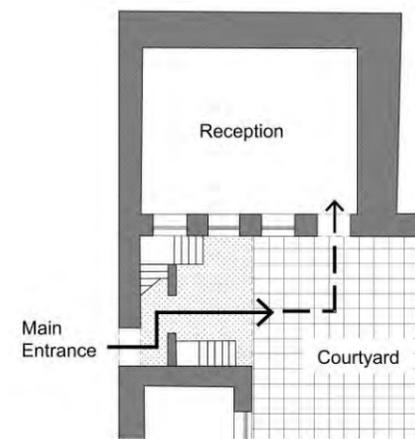
| Spaces         | TDn          | MDn         | RA          | i           | CV          | NCn          |
|----------------|--------------|-------------|-------------|-------------|-------------|--------------|
| EA             | 73           | 3.17        | 0.19        | 5.06        | 0.12        | 1.00         |
| <b>Court-1</b> | 51           | 2.21        | 0.11        | <b>9.03</b> | <b>6.75</b> | <b>8.00</b>  |
| S1             | 73           | 3.17        | 0.19        | 5.06        | 0.12        | 1.00         |
| P1             | 49           | 2.13        | 0.10        | <b>9.73</b> | 0.22        | <b>2.00</b>  |
| IW2            | 67           | 2.91        | 0.17        | <b>5.75</b> | <b>3.12</b> | <b>4.00</b>  |
| G              | 73           | 3.17        | 0.19        | 5.06        | 0.12        | 1.00         |
| IW2            | 73           | 3.17        | 0.19        | 5.06        | 0.12        | 1.00         |
| LV1            | 73           | 3.17        | 0.19        | 5.06        | 0.12        | 1.00         |
| LV2            | 73           | 3.17        | 0.19        | 5.06        | 0.12        | 1.00         |
| LV3            | 89           | 3.86        | 0.26        | 3.83        | 0.25        | 1.00         |
| LV4            | 89           | 3.86        | 0.26        | <b>3.83</b> | 0.25        | 1.00         |
| B1             | 89           | 3.86        | 0.26        | <b>3.83</b> | 0.25        | 1.00         |
| <b>Court-2</b> | 49           | 2.13        | 0.10        | <b>9.73</b> | <b>8.83</b> | <b>10.00</b> |
| LV6            | 71           | 3.08        | 0.18        | 5.27        | 0.10        | 1.00         |
| EB             | 71           | 3.08        | 0.18        | 5.27        | 0.10        | 1.00         |
| S4             | 71           | 3.08        | 0.18        | 5.27        | 0.10        | 1.00         |
| B5             | 71           | 3.08        | 0.18        | 5.27        | 0.10        | 1.00         |
| LV5            | 71           | 3.08        | 0.18        | 5.27        | 0.10        | 1.00         |
| S2             | 71           | 3.08        | 0.18        | 5.27        | 0.10        | 1.00         |
| <b>IW3</b>     | 67           | 2.91        | 0.17        | <b>5.75</b> | <b>2.10</b> | <b>3.00</b>  |
| B6             | 71           | 3.08        | 0.18        | 5.27        | 0.10        | 1.00         |
| S3             | 71           | 3.08        | 0.18        | 5.27        | 0.10        | 1.00         |
| B2             | 89           | 3.86        | 0.26        | <b>3.83</b> | 0.33        | 1.00         |
| B3             | 89           | 3.86        | 0.26        | <b>3.83</b> | 0.33        | 1.00         |
| Min            | 49.00        | 2.13        | 0.10        | 3.83        | 0.10        |              |
| Mean           | <b>72.25</b> | <b>3.14</b> | <b>0.19</b> | <b>5.48</b> | <b>1.00</b> |              |
| Max            | 89.00        | 3.86        | 0.26        | 9.73        | 8.83        |              |

### Visual analysis from the main entrance towards guest rooms and private/intimate spaces (Researcher)



■ Visual access from the main entrance towards guest rooms, and from guest rooms towards living areas and intimate spaces  
← Entry points for spaces  
⚡ Continuity of the visual axis, with no access at the end

### Strategies for achieving visual privacy between the entrance and semi-public spaces (Researcher)



The use of 'bent entrance', with an entry hall located near the reception room for guests

### Integration Values:

Courtyard-2 > Courtyard-1 > Iwan > Entrance, Guest Room, Living Rooms, Services > Bedrooms

### Lowest Integration Values:

- Intimate spaces (bedrooms)

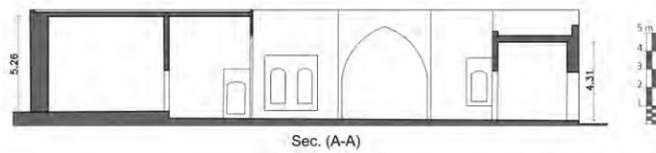
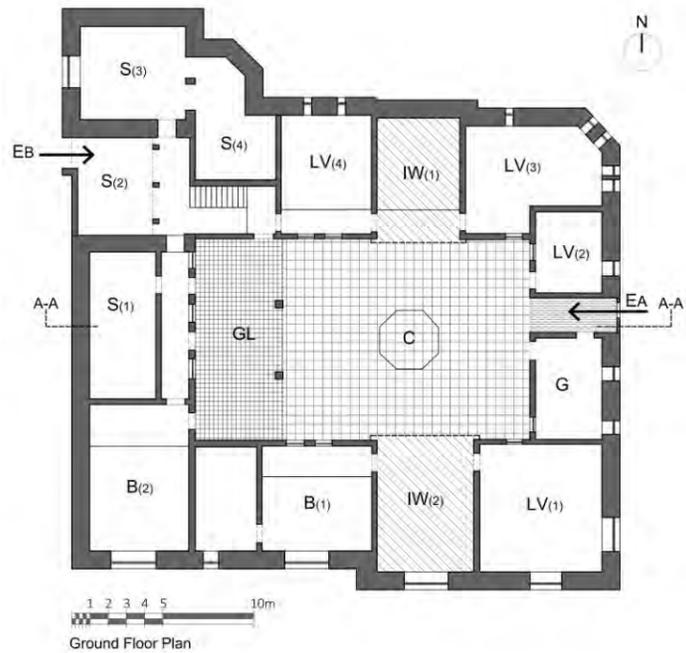
### Highest Integration and Control Values:

- Courtyard-2 (the family zone with intimate spaces)
- Courtyard-1 (connected with the main entrance)
- Iwans (as a semi-open living spaces)
- Passage between the two courtyards

# The Social Logic of the Spatial Arrangement of a Courtyard House in Lebanon

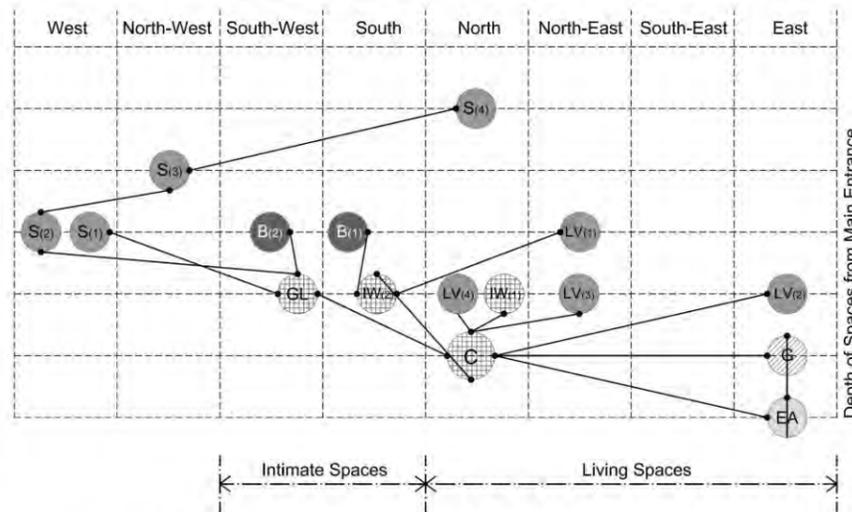
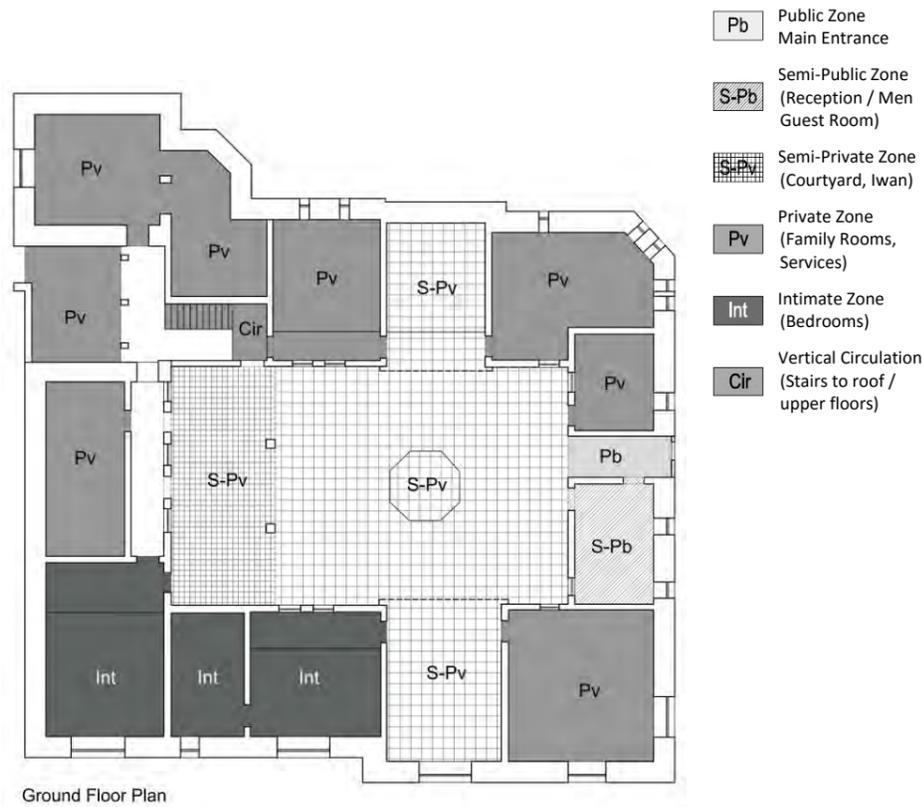
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|--------|-------------|---------|---------|----------|--------|
| Region | Middle East | Country | Lebanon | Case No. | ME-L-1 |
|--------|-------------|---------|---------|----------|--------|

## Architectural Plans for a Courtyard House, Lebanon (Redrawn by Researcher, after (Ragette, 2016, 171))



- EA: Main Entrance Hall/Corridor
- EB: Services Entrance
- C : Courtyard
- IW: Iwan
- GL : Gallery
- T : Roof Terrace / Balcony
- G : Guest Room (Reception)
- LV: Family Living Room
- B : Intimate Spaces (Bedrooms)
- S : Services (Kitchen, Toilets, Storage)
- P : Passage / Transitional Space
- DV: Double Volume

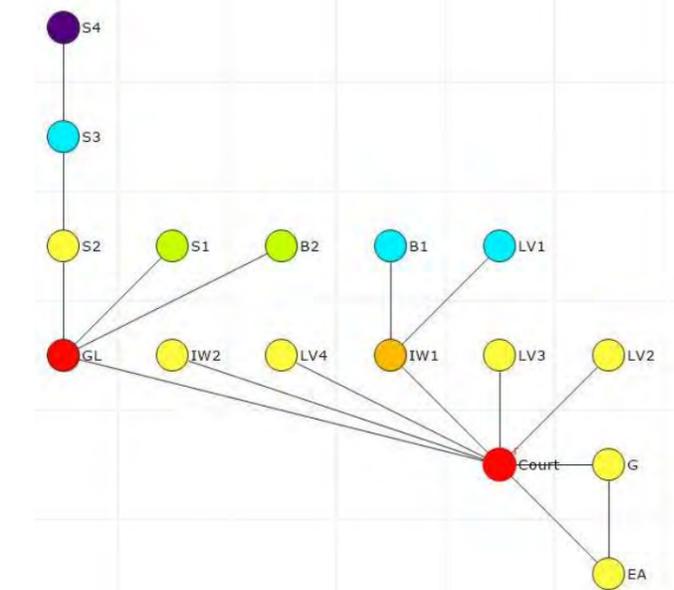
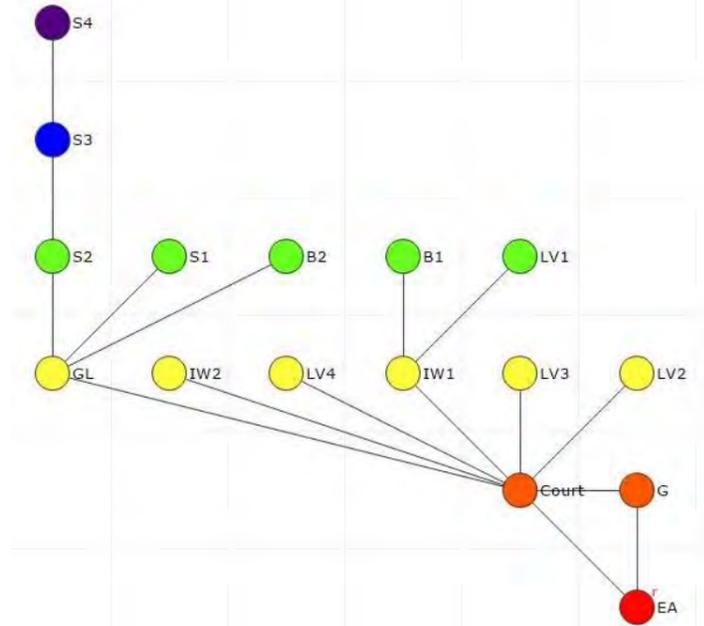
## Hierarchy and Depth of Spaces (according to the orientation, and type of spaces) (Researcher)



- Spaces located on the Ground Floor
- Direction of Surface Interaction between Spaces

## Space Syntax Analysis

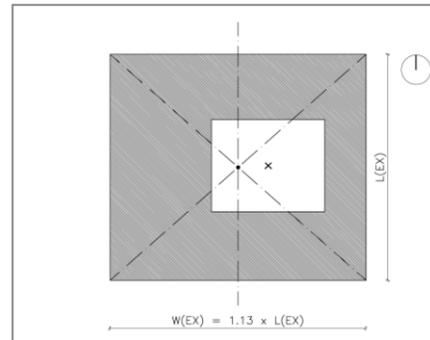
Diagrams produced by Researcher using AGRAPH Online software  
(<https://www.ntnu.no/ab/spacesyntax>)



## The Social Logic of the Spatial Arrangement of a Courtyard House in Lebanon

Region: Middle East, Country: Lebanon, Case No.: ME-L-1

### Typology and Geometric Properties of the House (Researcher)



|   |  |
|---|--|
| <b>Typology</b>   | Rectangular layout with one courtyard at the center of the house |
| <b>Exterior layout</b>  | 1 : 1.13   |
| <b>Courtyard</b>  | 1 : 1.25<br>21 % of the total area of the house                  |
| <b>Distance (D) between the center of the exterior layout (•) and the center of the courtyard (x)</b> | $Dx = 1/8 W(EX)$<br>$Dy = 0$                                     |
| <b>Thickness of exterior walls</b>  | 95 cm  |
| <b>Height of spaces located on the ground floor</b>   | 430 – 530 cm   |

|   | Dominant Users (Male / Female) | Percentage of area of this space related to the total area of the house | Percentage of area of this space related to the floor area where it is located | Proportion of the area of this space, to the area of the courtyard | Proportion of Spaces           |
|---|--------------------------------|---|--|--|--------------------------------|
| <b>Courtyard</b>                                | M+F                            | 21 %  | 21 %   | 1 : 1  | 1 : 1.25                       |
| <b>Iwan</b>                                     | M+F                            | 9 %   | 9 %  | 0.42 : 1   | 1 : 1.1 , 1 : 1.35             |
| <b>Gallery</b>                                  | M+F                            | 7 %   | 7 %  | 0.35 : 1   |                                |
| <b>Guest Room</b>                               | M                              | 3 %   | 3 %  | 0.14 : 1   | 1 : 1.5                        |
| <b>Living Rooms</b>                             | M+F                            | 18 %  | 18 %   | 0.85 : 1   | 1 : 1.05 , 1 : 1.70 , 1 : 1.25 |
| <b>Bedrooms</b>                                 | M+F                            | 14 %  | 14 %   | 0.65 : 1   | 1 : 1.5 , 1 : 1.05             |
| <b>Services (kitchen and storage) (Toilets)</b> | F<br>M+F                       | 15 %  | 15 %   | 0.72 : 1   |                                |

### Integration of Spaces using Space Syntax Theory

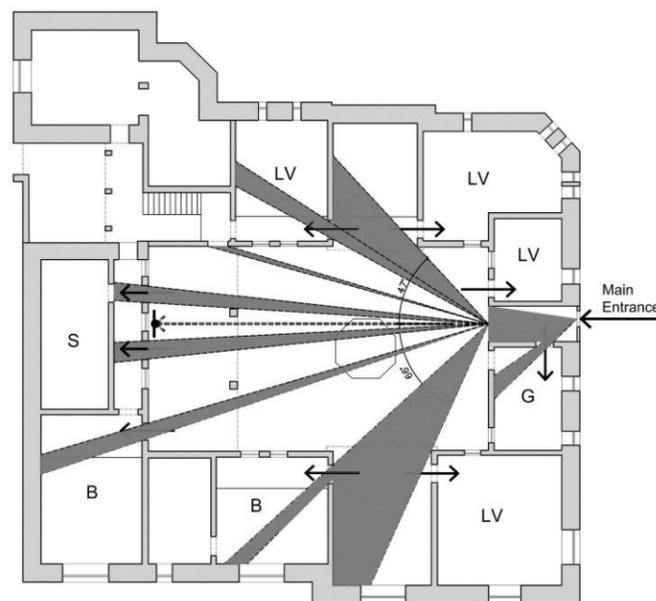
(Calculations produced by AGRAPH Online software)  
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#### Control and Integration Values for each space

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RA Relative Asymmetry =  $2*(MD-1)/(K-2)$   
i Integration Value =  $1/RA$   
CV Control Value

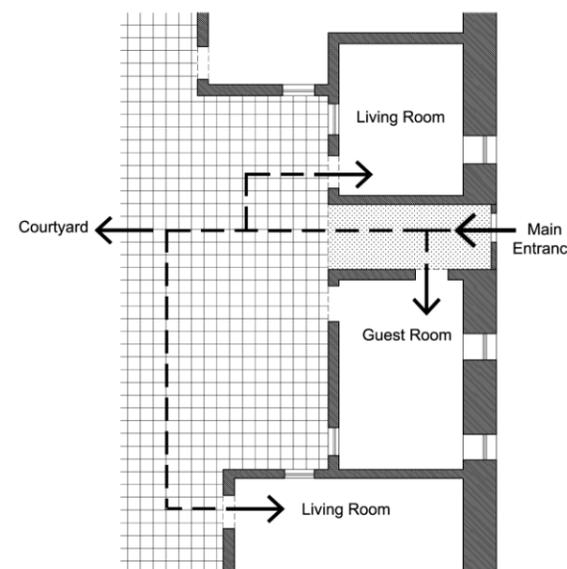
| Spaces       | TDn          | MDn         | RA          | i            | CV          | NCn         |
|--------------|--------------|-------------|-------------|--------------|-------------|-------------|
| EA           | 38           | 2.53        | 0.21        | 4.56         | 0.62        | 2.00        |
| G            | 38           | 2.53        | 0.21        | 4.56         | 0.62        | 2.00        |
| <b>Court</b> | 25           | 1.66        | 0.09        | <b>10.50</b> | <b>5.58</b> | <b>8.00</b> |
| LV2          | 39           | 2.60        | 0.22        | 4.37         | 0.12        | 1.00        |
| LV3          | 39           | 2.60        | 0.22        | 4.37         | 0.12        | 1.00        |
| IW1          | 35           | 2.33        | 0.19        | 5.25         | 2.12        | 3.00        |
| LV4          | 39           | 2.60        | 0.22        | 4.37         | 0.12        | 1.00        |
| IW2          | 39           | 2.60        | 0.22        | 4.37         | 0.12        | 1.00        |
| <b>GL</b>    | 29           | 1.93        | 0.13        | <b>7.50</b>  | <b>2.62</b> | <b>4.00</b> |
| LV1          | 49           | 3.26        | 0.32        | 3.08         | 0.33        | 1.00        |
| B1           | 49           | 3.26        | 0.32        | 3.08         | 0.33        | 1.00        |
| B2           | 43           | 2.86        | 0.26        | 3.75         | 0.25        | 1.00        |
| S1           | 43           | 2.86        | 0.26        | 3.75         | 0.25        | 1.00        |
| S2           | 39           | 2.60        | 0.22        | 4.37         | 0.75        | 2.00        |
| S3           | 51           | 3.40        | 0.34        | 2.91         | 1.50        | 2.00        |
| S4           | 65           | 4.33        | 0.47        | 2.10         | 0.50        | 1.00        |
| <b>Min</b>   | 25.00        | 1.66        | 0.09        | 2.10         | 0.12        |             |
| <b>Mean</b>  | <b>41.25</b> | <b>2.75</b> | <b>0.25</b> | <b>4.55</b>  | <b>1.00</b> |             |
| <b>Max</b>   | 65.00        | 4.33        | 0.47        | 10.50        | 5.58        |             |

### Visual Analysis from the Main Entrance towards inside the House (Researcher)



■ Visual access from the main entrance towards guest rooms, and from guest rooms towards living areas and intimate spaces  
← Entry points for spaces  
⚡ Continuity of the visual axis, with no access at the end

### Strategies for achieving Visual Privacy between the Main Entrance and inside the House (Researcher)



The entry hall is connected directly with the guest room before entering the courtyard. This preserves the privacy of the family

#### Integration Values:

Courtyard > Gallery > Iwan > Entrance, Guest Room > Living Rooms > Bedrooms > Services (Kitchen, Storage, and Toilets)

#### Lowest Integration Values:

- Intimate spaces (bedrooms)
- Services

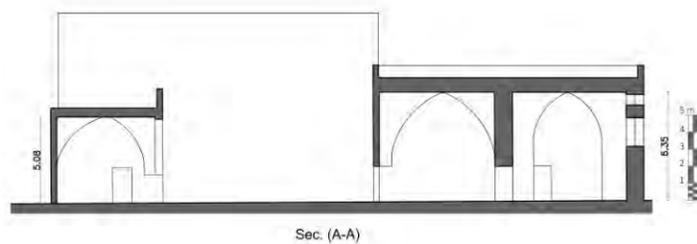
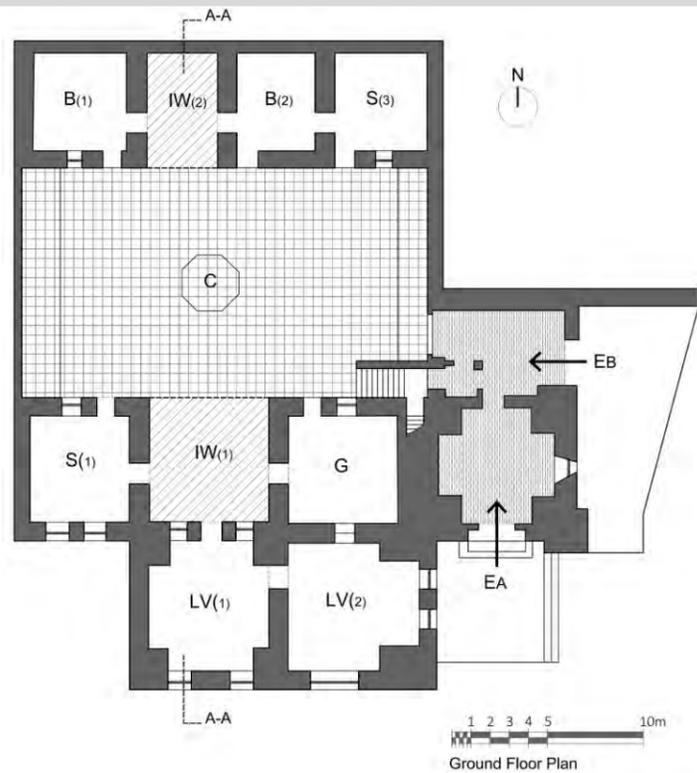
#### Highest Integration and Control Values:

- Courtyard
- Gallery
- Iwan

# The Social Logic of the Spatial Arrangement of a Courtyard House in Lebanon

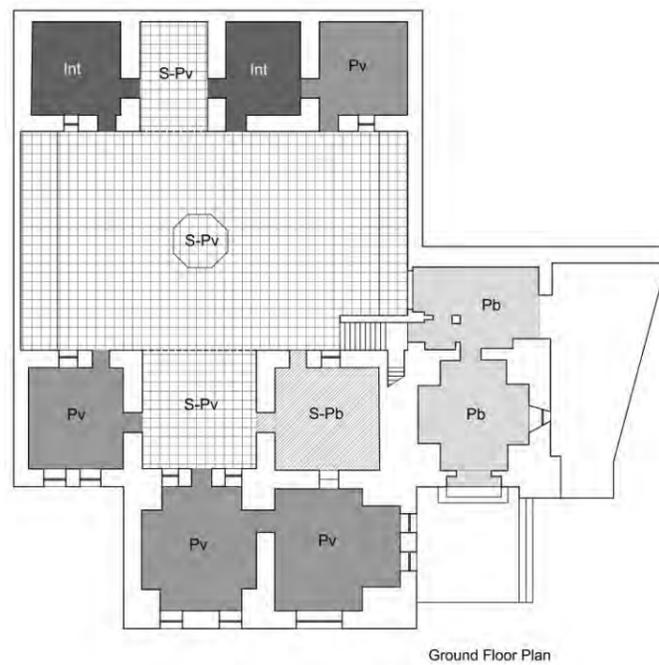
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|--------|-------------|---------|---------|----------|--------|
| Region | Middle East | Country | Lebanon | Case No. | ME-L-2 |
|--------|-------------|---------|---------|----------|--------|

## Architectural Plans for a Courtyard House, Lebanon (Redrawn by Researcher, after (Ragette, 2016, 172))

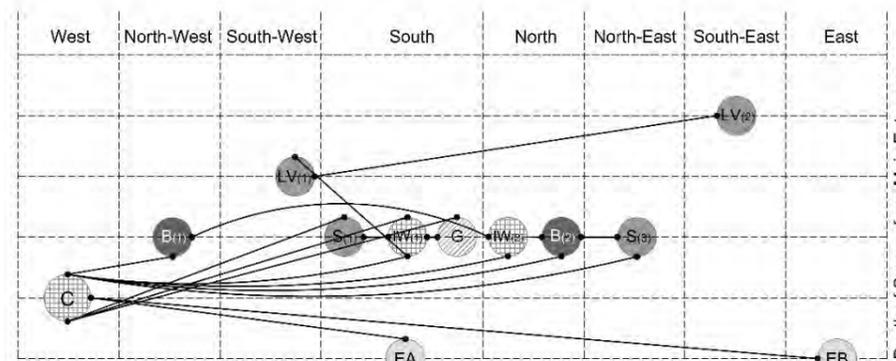


- EA: Main Entrance Hall/Corridor
- EB: Services Entrance
- C : Courtyard
- IW: Iwan
- GL : Gallery
- T : Roof Terrace / Balcony
- G : Guest Room (Reception)
- LV: Family Living Room
- B : Intimate Spaces (Bedrooms)
- S : Services (Kitchen, Toilets, Storage)
- P : Passage / Transitional Space
- DV: Double Volume

## Hierarchy and Depth of Spaces (according to the orientation, and type of spaces) (Researcher)



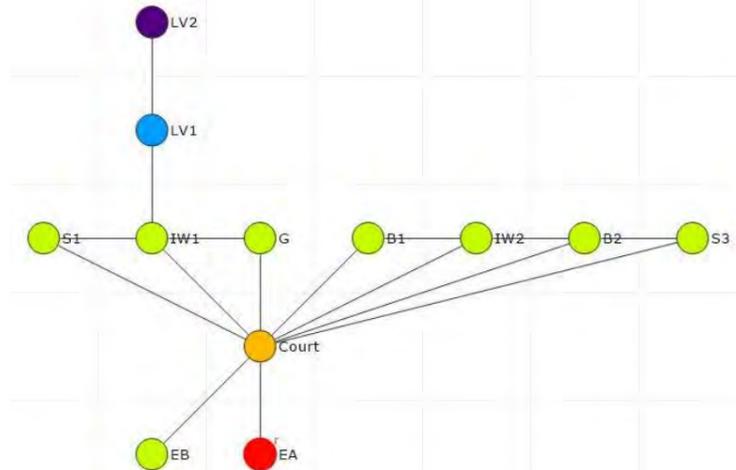
- Pb** Public Zone  
Main Entrance
- S-Pb** Semi-Public Zone  
(Reception / Men Guest Room)
- S-Pv** Semi-Private Zone  
(Courtyard, Iwan)
- Pv** Private Zone  
(Family Rooms, Services)
- Int** Intimate Zone  
(Bedrooms)
- Cir** Vertical Circulation  
(Stairs to roof / upper floors)



- Spaces located on the Ground Floor
- Direction of Surface Interaction between Spaces

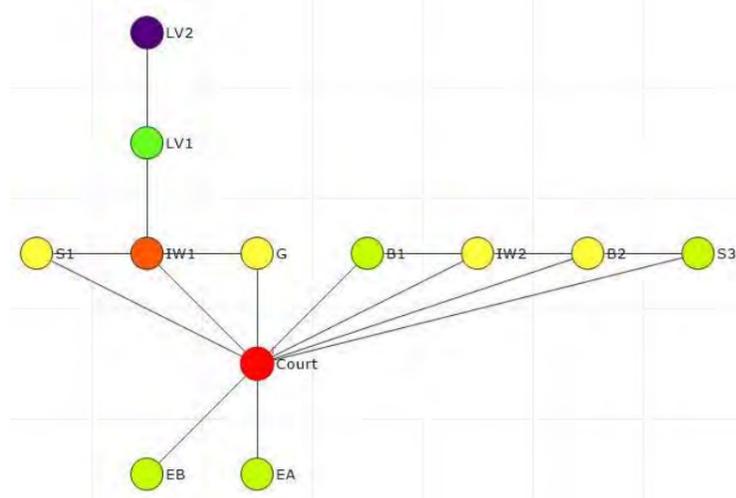
## Space Syntax Analysis

Diagrams produced by Researcher using AGRAPH Online software  
(<https://www.ntnu.no/ab/spacesyntax>)



### Depth of Spaces from the Main Entrance

Shallow Deep Spaces



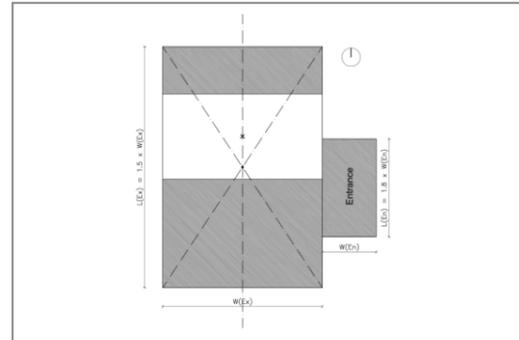
### Integration of Spaces with the Courtyard (the courtyard has the greatest control value)

High Low Integration

## The Social Logic of the Spatial Arrangement of a Courtyard House in Lebanon

|        |             |         |         |          |        |
|--------|-------------|---------|---------|----------|--------|
| Region | Middle East | Country | Lebanon | Case No. | ME-L-2 |
|--------|-------------|---------|---------|----------|--------|

### Typology and Geometric Properties of the House (Researcher)



|   |  |
|---|--|
| <b>Typology</b>   | Rectangular layout with one courtyard adjacent to the East and West sides of the house |
| <b>Exterior layout</b>  | 1 : 1.50   |
| <b>Courtyard</b>  | 1 : 1.75<br>37 % of the total area of the house  |
| <b>Distance (D) between the center of the exterior layout (●) and the center of the courtyard (x)</b> | Dx = 0<br>Dy = 1/5 W(Ex)   |
| <b>Thickness of exterior walls</b>  | 80 cm  |
| <b>Height of spaces located on the ground floor</b>   | 510 – 635 cm   |

### Integration of Spaces using Space Syntax Theory (Calculations produced by AGRAPH Online software) <https://www.ntnu.no/ab/spacesyntax>

#### Control and Integration Values for each space

TDn Total Depth (TD) for actual node      RA Relative Asymmetry = 2\*(MD-1)/(K-2)  
 MDn Mean Depth (MD) for actual node = TD/(K-1)      I Integration Value = 1/RA  
 K Number of Nodes      CV Control Value  
 NCn Number of Connections from Node

| Spaces       | TDn          | MDn         | RA          | i            | CV          | NCn         |
|--------------|--------------|-------------|-------------|--------------|-------------|-------------|
| EB           | 24           | 2.18        | 0.23        | 4.23         | 0.11        | 1.00        |
| EA           | 24           | 2.18        | 0.23        | 4.23         | 0.11        | 1.00        |
| <b>Court</b> | 14           | 1.27        | 0.05        | <b>18.33</b> | <b>4.91</b> | <b>9.00</b> |
| B1           | 23           | 2.09        | 0.21        | 4.58         | 0.44        | 2.00        |
| S1           | 21           | 1.90        | 0.18        | 5.50         | 0.36        | 2.00        |
| <b>IW1</b>   | 18           | 1.63        | 0.12        | <b>7.85</b>  | <b>1.61</b> | <b>4.00</b> |
| G            | 21           | 1.90        | 0.18        | 5.50         | 0.36        | 2.00        |
| IW2          | 22           | 2.00        | 0.20        | 5.00         | 0.94        | 3.00        |
| B2           | 22           | 2.00        | 0.20        | 5.00         | 0.94        | 3.00        |
| S3           | 23           | 2.09        | 0.21        | 4.58         | 0.44        | 2.00        |
| LV1          | 26           | 2.36        | 0.27        | 3.66         | 1.25        | 2.00        |
| LV2          | 36           | 3.27        | 0.45        | 2.20         | 0.50        | 1.00        |
| <b>Min</b>   | 14.00        | 1.27        | 0.05        | 2.20         | 0.11        |             |
| <b>Mean</b>  | <b>22.83</b> | <b>2.07</b> | <b>0.21</b> | <b>5.89</b>  | <b>1.00</b> |             |
| <b>Max</b>   | 36.00        | 3.27        | 0.45        | 18.33        | 4.91        |             |

|   | Dominant Users (Male / Female) | Percentage of area of this space related to the total area of the house | Percentage of area of this space related to the floor area where it is located | Proportion of the area of this space, to the area of the courtyard | Proportion of Spaces |
|---|--------------------------------|---|--|--|----------------------|
| <b>Courtyard</b>                                | M+F                            | 37 %  | 37 %   | 1 : 1  | 1 : 1.75             |
| <b>Iwan</b>                                     | M+F                            | 9 %   | 9 %  | 0.25 : 1   | 1 : 1.05 , 1 : 1.62  |
| <b>Guest Room</b>                               | M                              | 5 %   | 5 %  | 0.13 : 1   | 1 : 1.25             |
| <b>Living Rooms</b>                             | M+F                            | 12 %  | 12 %   | 0.32 : 1   | 1 : 1.03 , 1 : 1.08  |
| <b>Bedrooms</b>                                 | M+F                            | 7 %   | 7 %  | 0.20 : 1   | 1 : 1.25 , 1 : 1.05  |
| <b>Services (kitchen and storage) (Toilets)</b> | F<br>M+F                       | 8 %   | 8 %  | 0.22 : 1   |                      |

#### Integration Values:

Courtyard > Iwan > Guest Room > Services > Bedrooms > Living Rooms

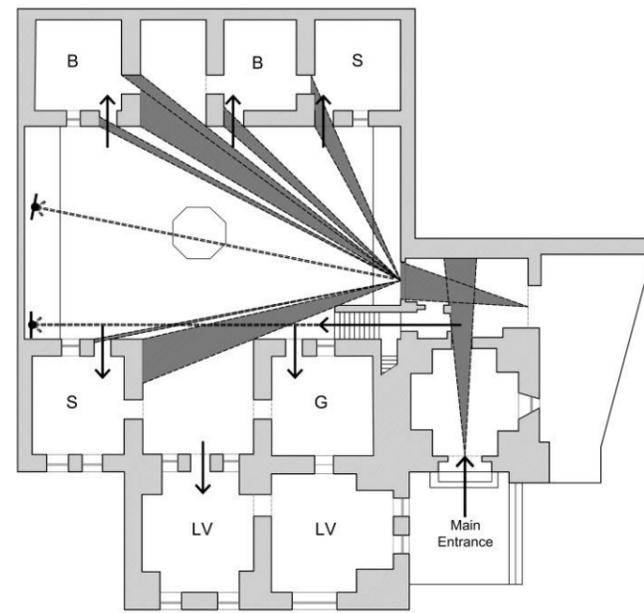
#### Lowest Integration Values:

- Living areas (private zones)

#### Highest Integration and Control Values:

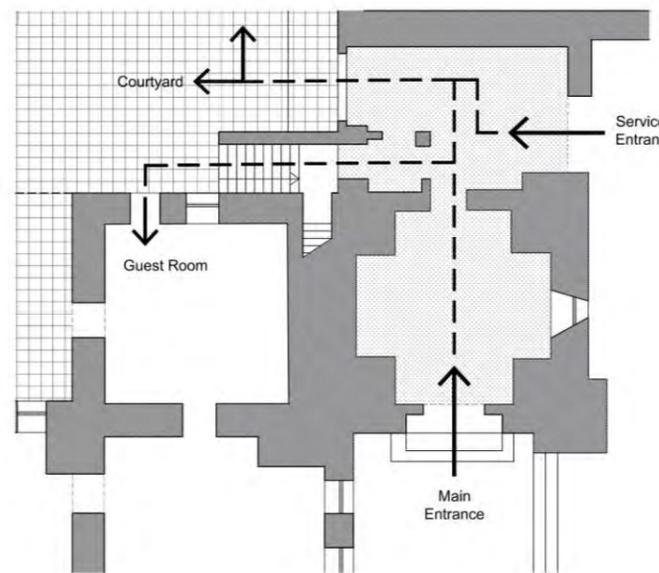
- Courtyard
- Iwan

### Visual Analysis from the Main Entrance towards inside the House (Researcher)



■ Visual access from the main entrance towards guest rooms, and from guest rooms towards living areas and intimate spaces  
 ← Entry points for spaces  
 \*--- Continuity of the visual axis, with no access at the end

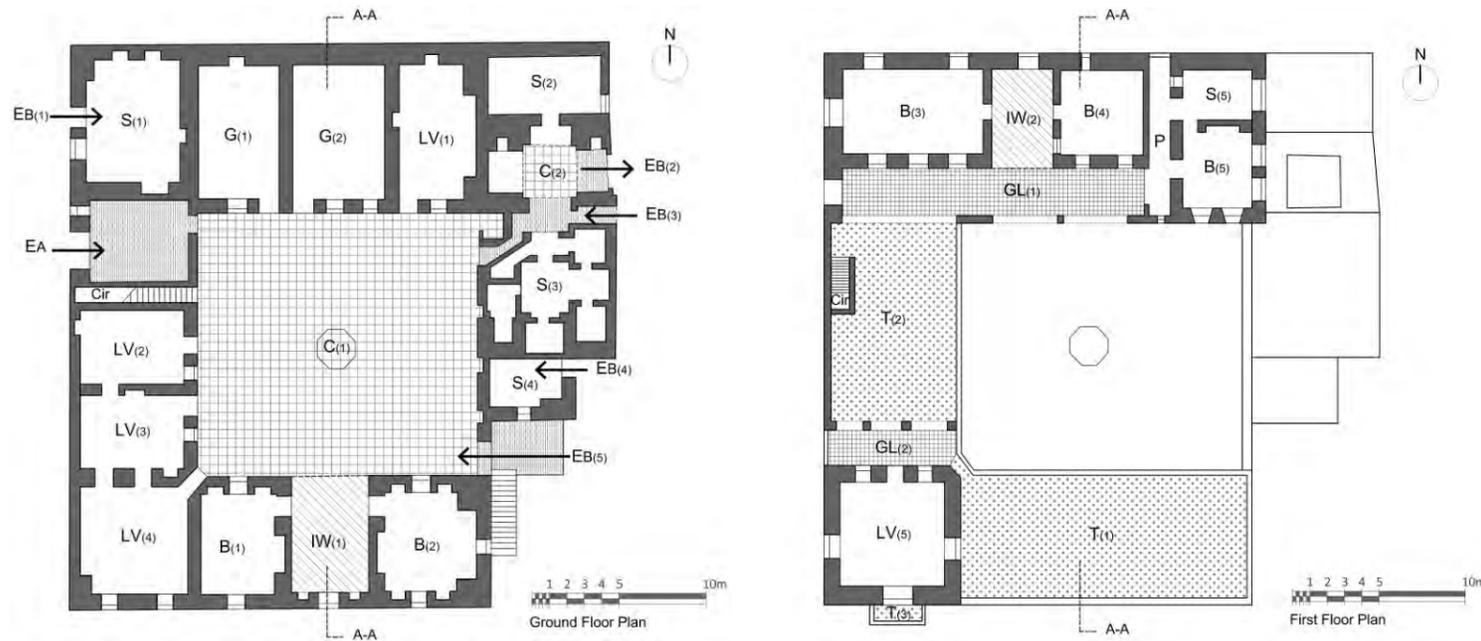
### Strategies for achieving Visual Privacy between the Main Entrance and inside the House (Researcher)



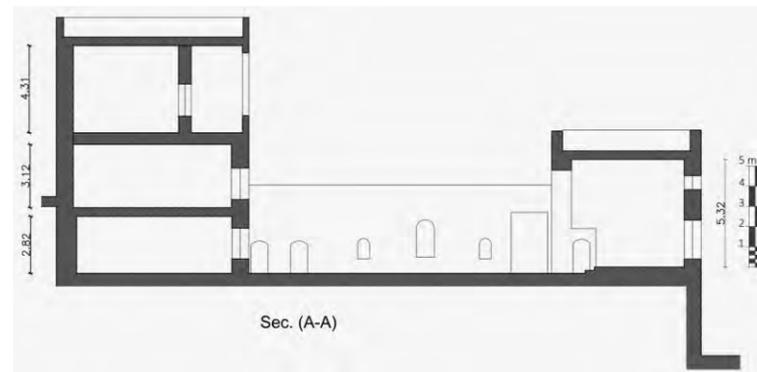
There are two entrances: one for guests, which leads directly to the guest room; and the other is for family members, which is connected with the courtyard. The entrance hall is separated by a wall that preserves the privacy of the family from guests.

# The Social Logic of the Spatial Arrangement of a Courtyard House in Lebanon

## Architectural Plans for a Courtyard House, Lebanon (Redrawn by Researcher, after (Ragette, 2016, 173))



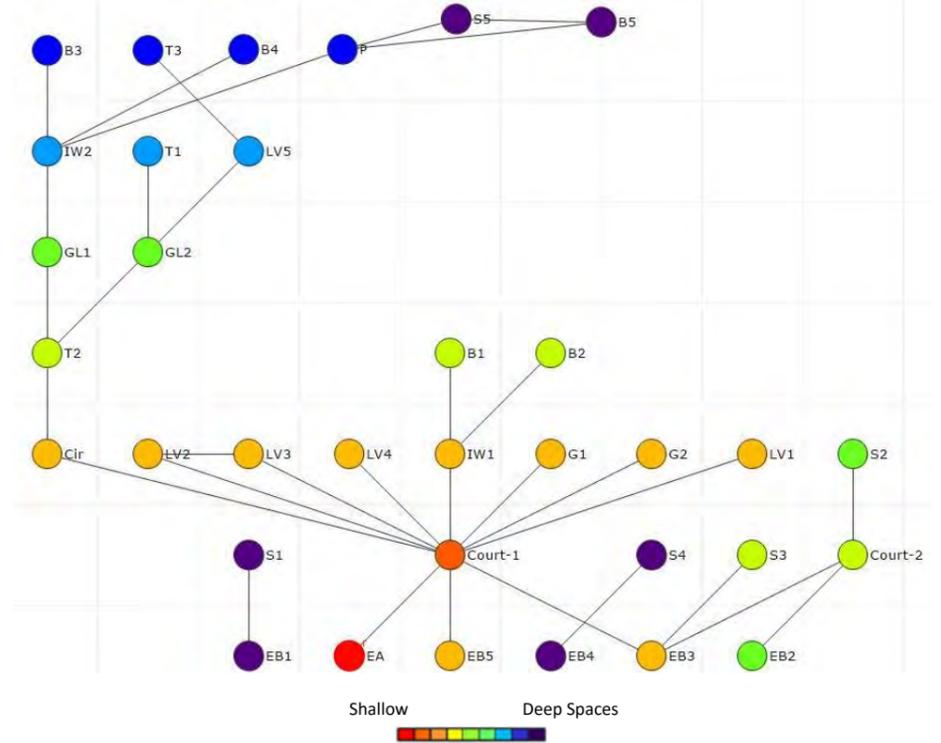
- EA: Main Entrance Hall/Corridor
- EB: Services Entrance
- C : Courtyard
- IW: Iwan
- GL : Gallery
- T : Roof Terrace / Balcony
- G : Guest Room (Reception)
- LV: Family Living Room
- B : Intimate Spaces (Bedrooms)
- S : Services (Kitchen, Toilets, Storage)
- P : Passage / Transitional Space
- DV: Double Volume



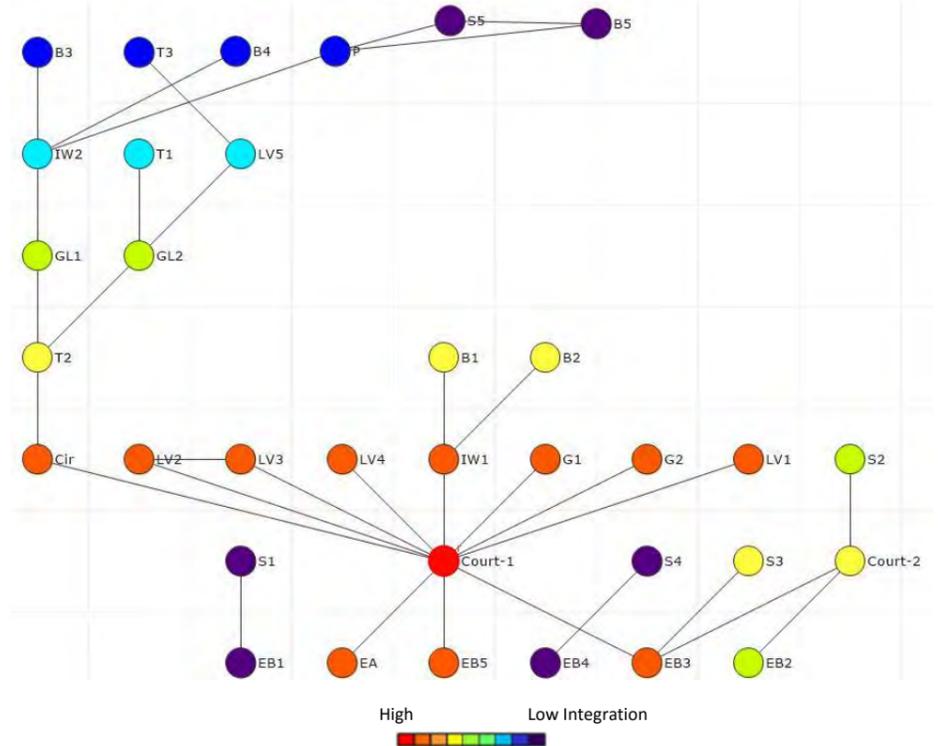
| Region | Middle East | Country | Syria | Case No. | ME-L-3 |
|--------|-------------|---------|-------|----------|--------|
|--------|-------------|---------|-------|----------|--------|

## Space Syntax Analysis Diagrams produced by Researcher using AGRAPH Online software (<https://www.ntnu.no/ab/spacesyntax>)

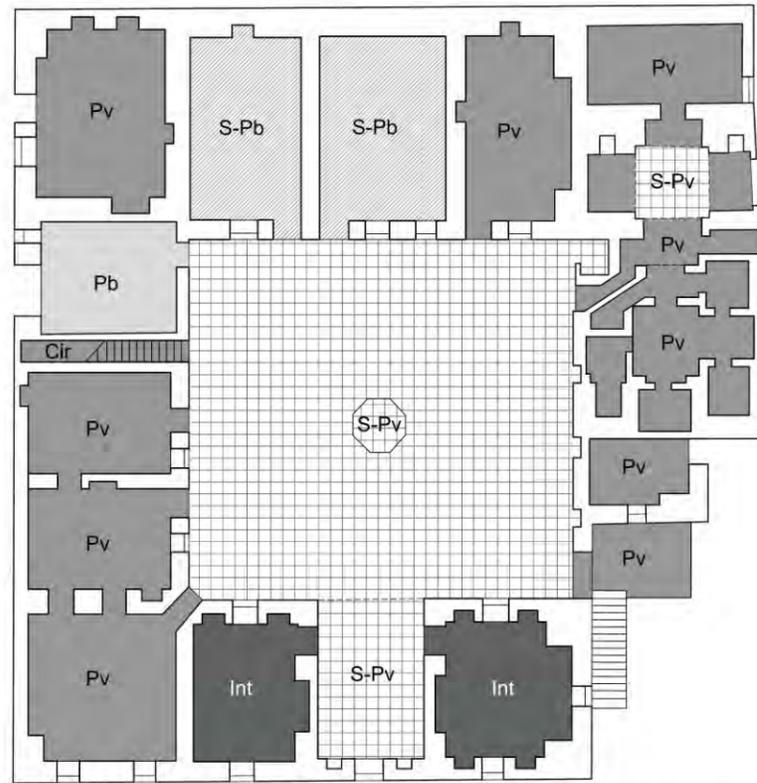
### Depth of Spaces from the Main Entrance



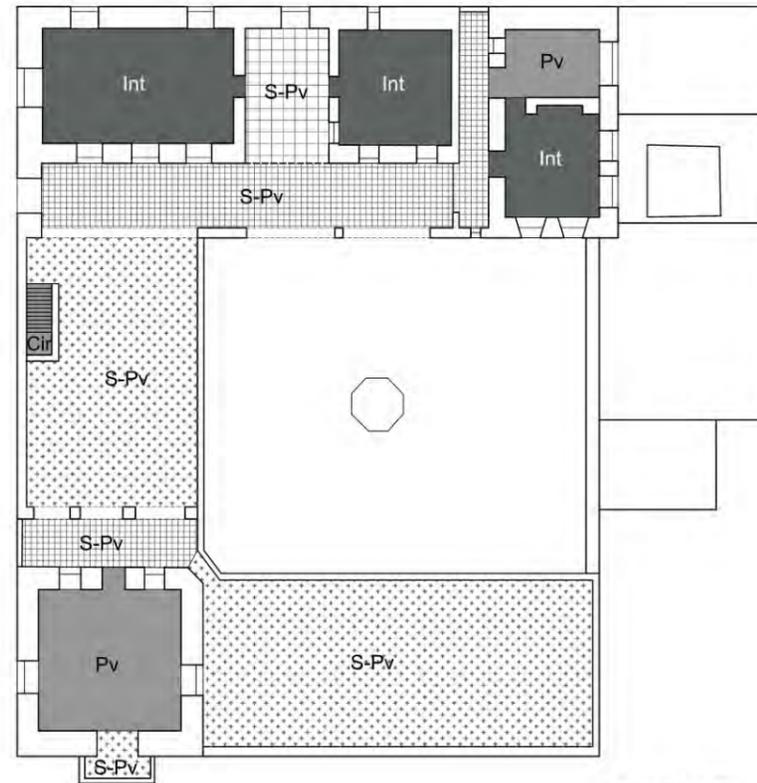
### Integration of Spaces with the Courtyard (the courtyard has the greatest control value)



Hierarchy and Depth of Spaces (according to the orientation, and type of spaces)  
(Researcher)

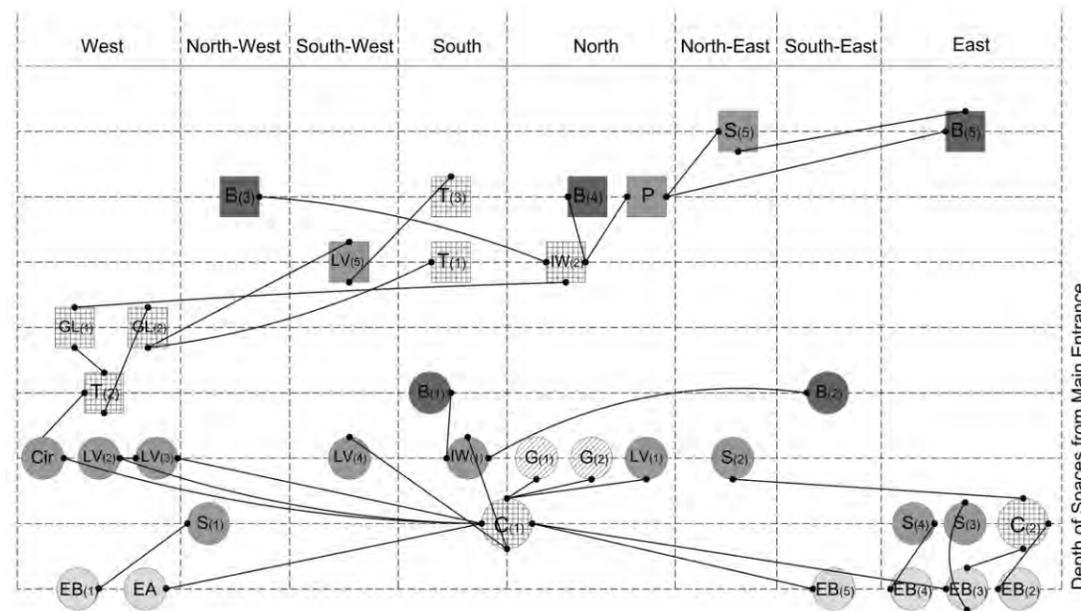


Ground Floor Plan



First Floor Plan

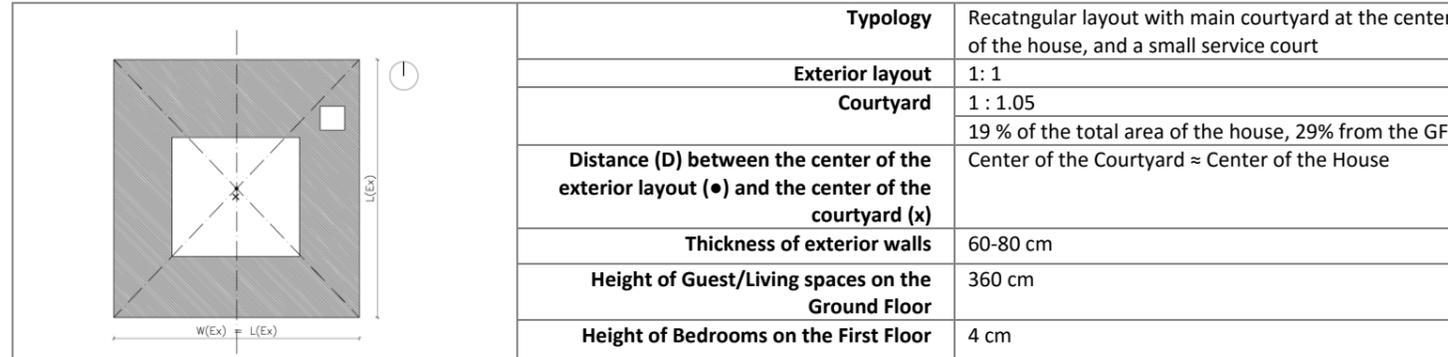
- Pb Public Zone (Main Entrance)
- S-Pb Semi-Public Zone (Reception / Men Guest Room)
- S-Pv Semi-Private Zone (Courtyard, Iwan)
- Pv Private Zone (Family Rooms, Services)
- Int Intimate Zone (Bedrooms)
- Cir Vertical Circulation (Stairs to roof / upper floors)



- Spaces located on the Ground Floor
- Spaces located on the First Floor
- Direction of Surface Interaction between Spaces

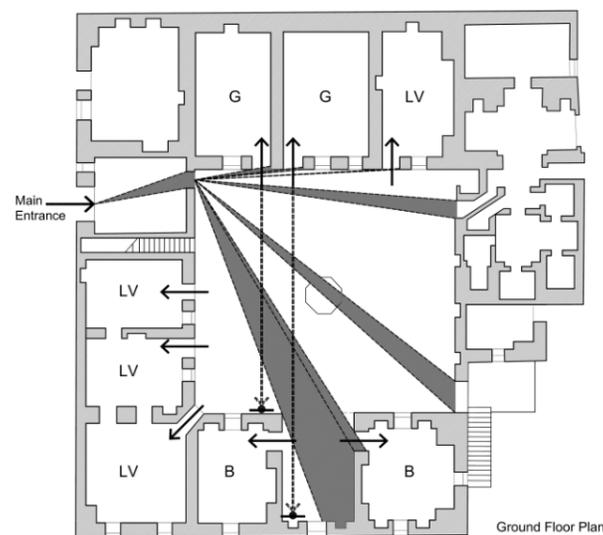
# The Social Logic of the Spatial Arrangement of a Courtyard House in Lebanon

## Typology and Geometric Properties of the House (Researcher)



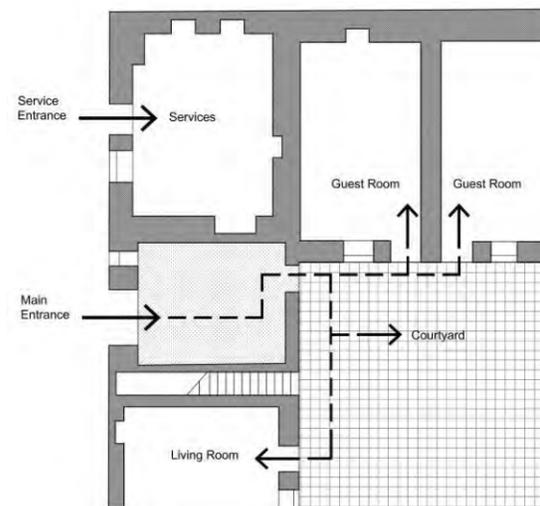
|  | Dominant Users (Male / Female) | Percentage of area of this space related to the total area of the house | Percentage of area of this space related to the floor area where it is located |                 | Proportion of the area of this space, to the area of the courtyard | Proportion of Spaces                   |
|--|--------------------------------|---|--|-----------------|--|--|
|  |                                |   | G  | 1 <sup>st</sup> |  |  |
| Main Courtyard                           | M+F                            | 19 %  | 29 %   | -               | 1 : 1  | 1 : 1.05                               |
| Service Court                            | F                              | 0.8 %   | 1 %  | -               | 0.04 : 1   | 1 : 1                                  |
| Iwan                                     | M+F                            | 2 %   | 3 %  | 5 %             | 0.21 : 1   | 1 : 1.5                                |
| Gallery                                  | M+F                            | 5 %   | -  | 14 %            | 0.26 : 1   |  |
| Terraces                                 | M+F                            | 15 %  | -  | 43 %            | 0.83 : 1   |  |
| Guest Rooms                              | M                              | 6 %   | 10 %   | -               | 0.33 : 1   | 1 : 1.65 , 1 : 1.45                    |
| Living Rooms                             | M+F                            | 10 %  | 15 %   | 8 %             | 0.69 : 1   | 1 : 1.75 , 1 : 1 , 1 : 1.4             |
| Bedrooms                                 | M+F                            | 5 %   | 7 %  | 18 %            | 0.60 : 1   | 1 : 1.35 , 1 : 1.05 , 1 : 1.66 , 1 : 1 |
| Services (kitchen and storage) (Toilets) | F<br>M+F                       | 9 %   | 14 %   | 3 %             | 0.53 : 1   |  |

### Visual analysis from the main entrance towards guest rooms and private/intimate spaces (Researcher)



Visual access from the main entrance towards guest rooms, and from guest rooms towards living areas and intimate spaces  
 Entry points for spaces  
 Continuity of the visual axis, with no access at the end

### Strategies for achieving visual privacy between the entrance and semi-public spaces (Researcher)



The use of 'bent entrance', and a hall which is near guest rooms. There are two entrances: one for guests and family members, and the other is for services.

| Region | Middle East | Country | Syria | Case No. | ME-L-3 |
|--------|-------------|---------|-------|----------|--------|
|--------|-------------|---------|-------|----------|--------|

### Integration of Spaces using Space Syntax Theory

(Calculations produced by AGRAPH Online software)  
<https://www.ntnu.no/ab/spacesyntax>

#### Control and Integration Values for each space

TDn Total Depth (TD) for actual node      RA Relative Asymmetry = 2\*(MD-1)/(K-2)  
 MDn Mean Depth (MD) for actual node = TD/(K-1)      I Integration Value = 1/RA  
 K Number of Nodes      CV Control Value  
 NCn Number of Connections from Node

| Spaces  | TDn     | MDn   | RA   | i    | CV   | NCn   |
|---------|---------|-------|------|------|------|-------|
| EA      | 241     | 7.30  | 0.39 | 2.53 | 0.09 | 1.00  |
| Court-1 | 213     | 6.45  | 0.34 | 2.93 | 8.16 | 11.00 |
| EB5     | 241     | 7.30  | 0.39 | 2.53 | 0.09 | 1.00  |
| EB4     | 1089    | 33.00 | 2.00 | 0.50 | 1.00 | 1.00  |
| EB3     | 233     | 7.06  | 0.37 | 2.64 | 1.42 | 3.00  |
| EB2     | 285     | 8.63  | 0.47 | 2.09 | 0.33 | 1.00  |
| EB1     | 1089    | 33.00 | 2.00 | 0.50 | 1.00 | 1.00  |
| S4      | 1089    | 33.00 | 2.00 | 0.50 | 1.00 | 1.00  |
| S3      | 261     | 7.90  | 0.43 | 2.31 | 0.33 | 1.00  |
| Court-2 | 257     | 7.78  | 0.42 | 2.35 | 2.33 | 3.00  |
| S1      | 1089    | 33.00 | 2.00 | 0.50 | 1.00 | 1.00  |
| IW1     | 237     | 7.18  | 0.38 | 2.58 | 2.09 | 3.00  |
| G1      | 241     | 7.30  | 0.39 | 2.53 | 0.09 | 1.00  |
| G2      | 241     | 7.30  | 0.39 | 2.53 | 0.09 | 1.00  |
| LV1     | 241     | 7.30  | 0.39 | 2.53 | 0.09 | 1.00  |
| S2      | 285     | 8.63  | 0.47 | 2.09 | 0.33 | 1.00  |
| LV4     | 241     | 7.30  | 0.39 | 2.53 | 0.09 | 1.00  |
| LV3     | 240     | 7.27  | 0.39 | 2.55 | 0.59 | 2.00  |
| LV2     | 240     | 7.27  | 0.39 | 2.55 | 0.59 | 2.00  |
| Cir     | 217     | 6.57  | 0.34 | 2.86 | 0.42 | 2.00  |
| B1      | 265     | 8.03  | 0.43 | 2.27 | 0.33 | 1.00  |
| B2      | 265     | 8.03  | 0.43 | 2.27 | 0.33 | 1.00  |
| T2      | 223     | 6.75  | 0.35 | 2.77 | 1.33 | 3.00  |
| GL1     | 239     | 7.24  | 0.39 | 2.56 | 0.58 | 2.00  |
| GL2     | 245     | 7.42  | 0.40 | 2.49 | 1.83 | 3.00  |
| IW2     | 257     | 7.78  | 0.42 | 2.35 | 2.83 | 4.00  |
| T1      | 273     | 8.27  | 0.45 | 2.20 | 0.33 | 1.00  |
| LV5     | 271     | 8.21  | 0.45 | 2.21 | 1.33 | 2.00  |
| B3      | 285     | 8.63  | 0.47 | 2.09 | 0.25 | 1.00  |
| T3      | 299     | 9.06  | 0.50 | 1.98 | 0.50 | 1.00  |
| B4      | 285     | 8.63  | 0.47 | 2.09 | 0.25 | 1.00  |
| P       | 281     | 8.51  | 0.46 | 2.12 | 1.25 | 3.00  |
| S5      | 308     | 9.33  | 0.52 | 1.92 | 0.83 | 2.00  |
| B5      | 308     | 9.33  | 0.52 | 1.92 | 0.83 | 2.00  |
| Min     | 213.00  | 6.45  | 0.34 | 0.50 | 0.09 |       |
| Mean    | 355.11  | 10.76 | 0.61 | 2.16 | 1.00 |       |
| Max     | 1089.00 | 33.00 | 2.00 | 2.93 | 8.16 |       |

#### Integration Values:

Main Courtyard > Main Entrance and Service Entrance > Gallery and Iwan > Living Rooms > Guest Room > Bedrooms > Services (Kitchen, Storage, and Toilets) > Terraces

#### Lowest Integration Values:

- Terraces
- Intimate spaces (bedrooms)
- Services

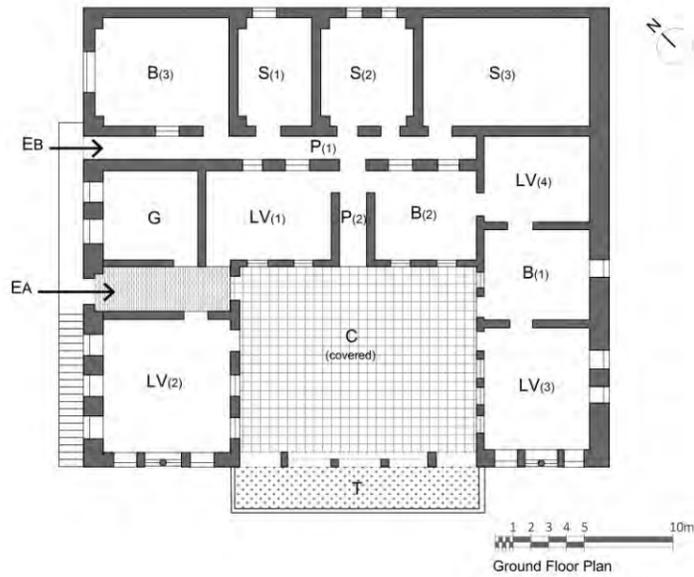
#### Highest Integration and Control Values:

- Courtyard
- Iwan and Gallery (as a semi-open living area)
- Stairs

# The Social Logic of the Spatial Arrangement of a Courtyard House in Lebanon

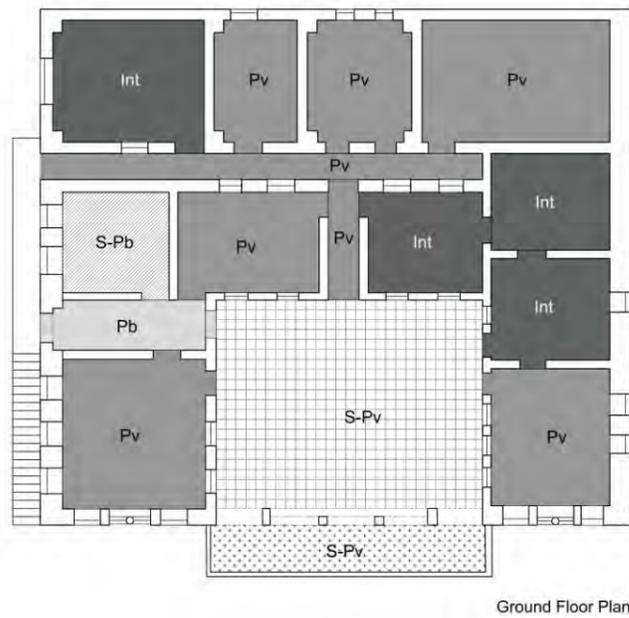
|        |             |         |         |          |        |
|--------|-------------|---------|---------|----------|--------|
| Region | Middle East | Country | Lebanon | Case No. | ME-L-4 |
|--------|-------------|---------|---------|----------|--------|

## Architectural Plans for a Courtyard House, Lebanon (Redrawn by Researcher, after (Ragette, 2016, 175))

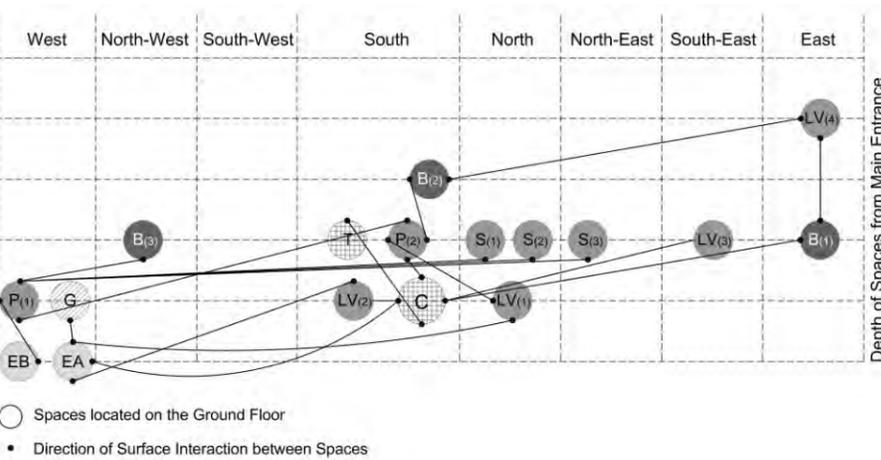


- EA: Main Entrance Hall/Corridor
- EB: Services Entrance
- C : Courtyard
- IW: Iwan
- GL : Gallery
- T : Roof Terrace / Balcony
- G : Guest Room (Reception)
- LV: Family Living Room
- B : Intimate Spaces (Bedrooms)
- S : Services (Kitchen, Toilets, Storage)
- P : Passage / Transitional Space
- DV: Double Volume

## Hierarchy and Depth of Spaces (according to the orientation, and type of spaces) (Researcher)



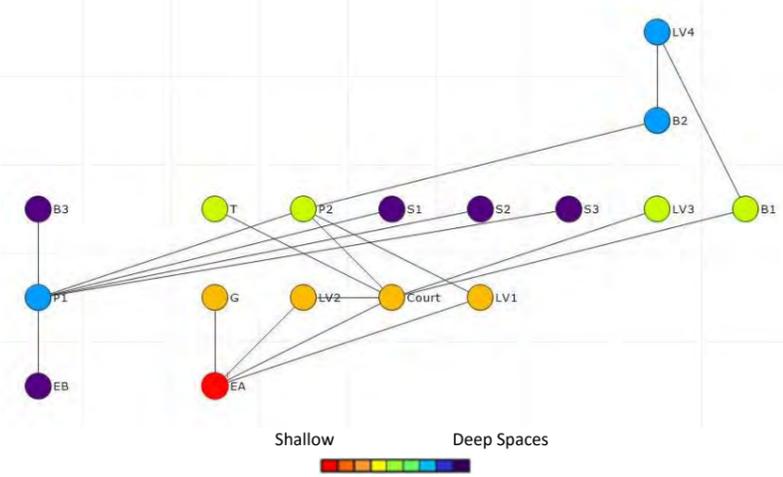
- Pb Public Zone  
Main Entrance
- S-Pb Semi-Public Zone  
(Reception / Men Guest Room)
- S-Pv Semi-Private Zone  
(Courtyard, Iwan)
- Pv Private Zone  
(Family Rooms, Services)
- Int Intimate Zone  
(Bedrooms)
- Cir Vertical Circulation  
(Stairs to roof / upper floors)



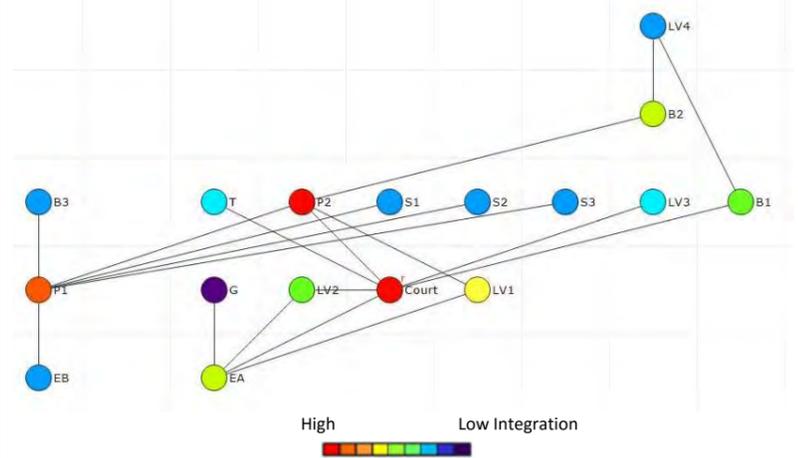
## Space Syntax Analysis

Diagrams produced by Researcher using AGRAPH Online software  
(<https://www.ntnu.no/ab/spacesyntax>)

### Depth of Spaces from the Main Entrance



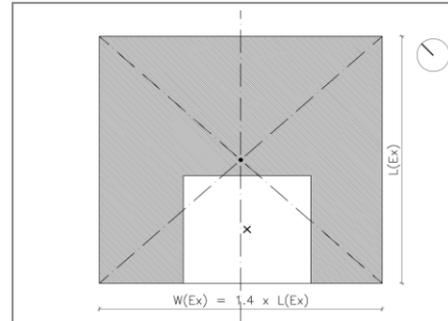
### Integration of Spaces with the Courtyard (the courtyard has the greatest control value)



## The Social Logic of the Spatial Arrangement of a Courtyard House in Lebanon

|        |             |         |         |          |        |
|--------|-------------|---------|---------|----------|--------|
| Region | Middle East | Country | Lebanon | Case No. | ME-L-4 |
|--------|-------------|---------|---------|----------|--------|

### Typology and Geometric Properties of the House (Researcher)



|   |   |
|---|---|
| <b>Typology</b>   | Rectangular layout with one courtyard adjacent to the south side of the house |
| <b>Exterior layout</b>  | 1 : 1.4   |
| <b>Courtyard</b>  | 1 : 1.28<br>20 % of the total area of the house                               |
| <b>Distance (D) between the center of the exterior layout (●) and the center of the courtyard (x)</b> | Dx = 0<br>Dy = - (1/4 W(Ex))  |
| <b>Thickness of exterior walls</b>  | 55-100 cm   |
| <b>Height of spaces located on the ground floor</b>   | 625 cm  |

|   | Dominant Users (Male / Female) | Percentage of area of this space related to the total area of the house | Percentage of area of this space related to the floor area where it is located | Proportion of the area of this space, to the area of the courtyard | Proportion of Spaces                  |
|---|--------------------------------|---|--|--|---------------------------------------|
| <b>Courtyard</b>                                | M+F                            | 20 %  | 20 %   | 1 : 1  | 1 : 1.28                              |
| <b>Terraces</b>                                 | M+F                            | 5 %   | 5 %  | 0.24 : 1   |                                       |
| <b>Guest Room</b>                               | M                              | 4 %   | 4 %  | 0.20 : 1   | 1 : 1.08                              |
| <b>Living Rooms</b>                             | M+F                            | 23 %  | 23 %   | 1.17 : 1   | 1 : 1.05, 1 : 1.22, 1 : 1.15, 1 : 1.4 |
| <b>Bedrooms</b>                                 | M+F                            | 15 %  | 15 %   | 0.76 : 1   | 1 : 1.15, 1 : 1.22                    |
| <b>Services (kitchen and storage) (Toilets)</b> | F<br>M+F                       | 8 %   | 8 %  | 0.40 : 1   |                                       |

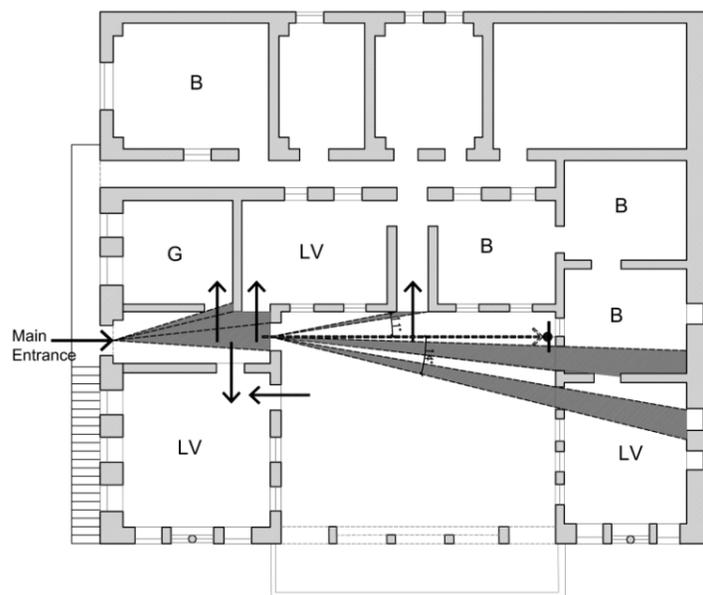
### Integration of Spaces using Space Syntax Theory (Calculations produced by AGRAPH Online software) (<https://www.ntnu.no/ab/spacesyntax>)

#### Control and Integration Values for each space

|     |  |    |   |
|-----|--|----|---|
| TDn | Total Depth (TD) for actual node               | RA | Relative Asymmetry = $2 * (MD-1) / (K-2)$ |
| MDn | Mean Depth (MD) for actual node = $TD / (K-1)$ | i  | Integration Value = $1/RA$                |
| K   | Number of Nodes                                | CV | Control Value                             |
| NCn | Number of Connections from Node                |    |   |

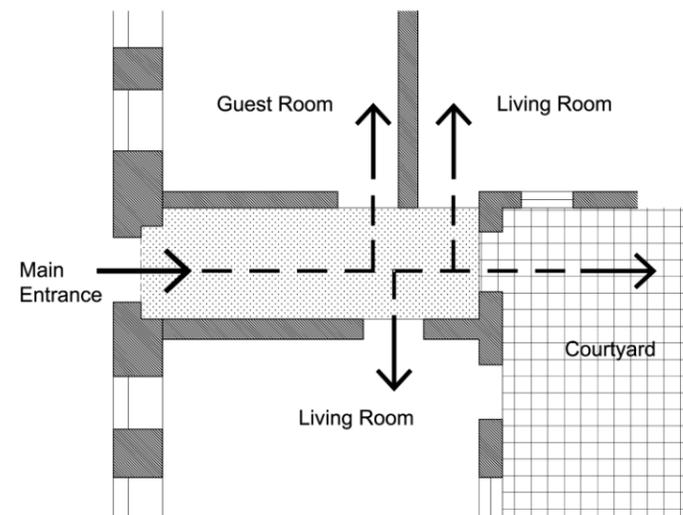
| Spaces | TDn   | MDn  | RA   | i    | CV   | NCn  |
|--------|-------|------|------|------|------|------|
| EA     | 41    | 2.56 | 0.20 | 4.80 | 2.16 | 4.00 |
| EB     | 49    | 3.06 | 0.27 | 3.63 | 0.16 | 1.00 |
| G      | 56    | 3.50 | 0.33 | 3.00 | 0.25 | 1.00 |
| P1     | 34    | 2.12 | 0.15 | 6.66 | 5.25 | 6.00 |
| B3     | 49    | 3.06 | 0.27 | 3.63 | 0.16 | 1.00 |
| LV2    | 43    | 2.68 | 0.22 | 4.44 | 0.41 | 2.00 |
| Court  | 31    | 1.93 | 0.12 | 8.00 | 3.50 | 6.00 |
| LV1    | 39    | 2.43 | 0.19 | 5.21 | 0.50 | 2.00 |
| T      | 46    | 2.87 | 0.25 | 4.00 | 0.16 | 1.00 |
| P2     | 29    | 1.81 | 0.10 | 9.23 | 1.33 | 4.00 |
| S1     | 49    | 3.06 | 0.27 | 3.63 | 0.16 | 1.00 |
| S2     | 49    | 3.06 | 0.27 | 3.63 | 0.16 | 1.00 |
| S3     | 49    | 3.06 | 0.27 | 3.63 | 0.16 | 1.00 |
| LV3    | 46    | 2.87 | 0.25 | 4.00 | 0.16 | 1.00 |
| B1     | 43    | 2.68 | 0.22 | 4.44 | 0.66 | 2.00 |
| B2     | 41    | 2.56 | 0.20 | 4.80 | 0.75 | 2.00 |
| LV4    | 48    | 3.00 | 0.26 | 3.75 | 1.00 | 2.00 |
| Min    | 29.00 | 1.81 | 0.10 | 3.00 | 0.16 |      |
| Mean   | 43.64 | 2.72 | 0.23 | 4.73 | 1.00 |      |
| Max    | 56.00 | 3.50 | 0.33 | 9.23 | 5.25 |      |

### Visual Analysis from the Main Entrance towards inside the House (Researcher)



- Visual access from the main entrance towards guest rooms, and from guest rooms towards living areas and intimate spaces
- ← Entry points for spaces
- ⋆--- Continuity of the visual axis, with no access at the end

### Strategies for achieving Visual Privacy between the Main Entrance and inside the House (Researcher)



Entry hall for guests, separated visually from the courtyard

#### Integration Values:

Passage (corridor) > Courtyard > Living Room > Entrance > Bedrooms > Services (Kitchen, Storage, and Toilets) > Guest Room

#### Lowest Integration Values:

- Guest room
- Services

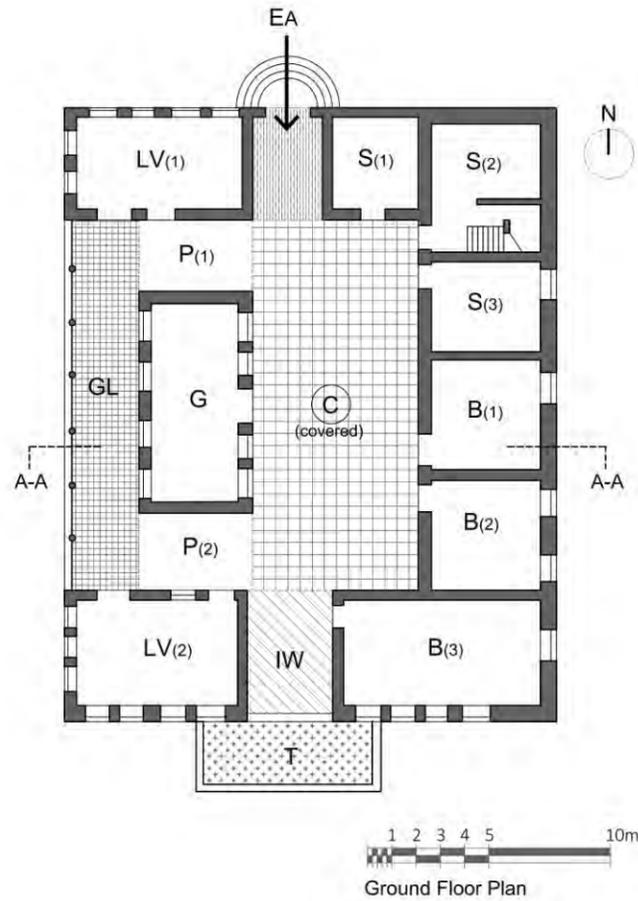
#### Highest Integration and Control Values:

- Courtyard
- Passage (corridors) as transitional spaces
- Living room

# The Social Logic of the Spatial Arrangement of a Courtyard House in Lebanon

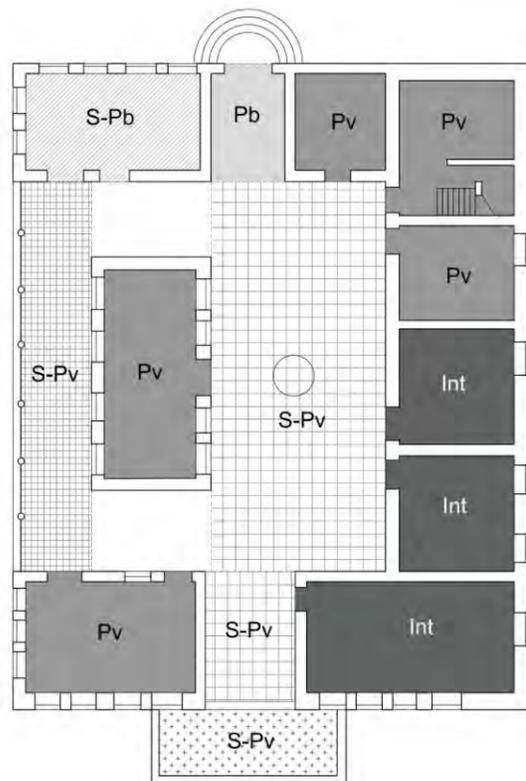
|        |             |         |         |          |        |
|--------|-------------|---------|---------|----------|--------|
| Region | Middle East | Country | Lebanon | Case No. | ME-L-5 |
|--------|-------------|---------|---------|----------|--------|

## Architectural Plans for a Courtyard House, Lebanon (Redrawn by Researcher, after (Ragette, 2016, 177))

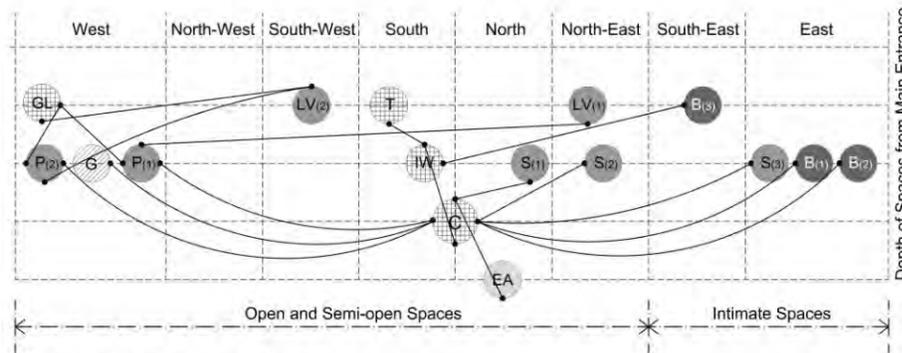


- EA: Main Entrance Hall/Corridor
- EB: Services Entrance
- C : Courtyard
- IW: Iwan
- GL : Gallery
- T : Roof Terrace / Balcony
- G : Guest Room (Reception)
- LV: Family Living Room
- B : Intimate Spaces (Bedrooms)
- S : Services (Kitchen, Toilets, Storage)
- P : Passage / Transitional Space
- DV: Double Volume

## Hierarchy and Depth of Spaces (according to the orientation, and type of spaces) (Researcher)



Ground Floor Plan

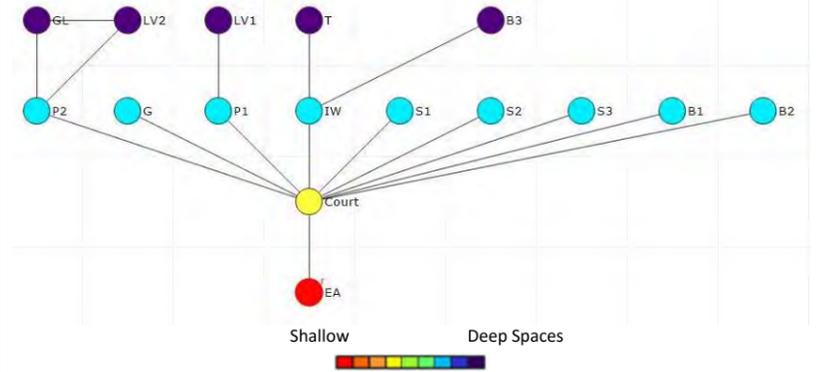


- Spaces located on the Ground Floor
- Direction of Surface Interaction between Spaces

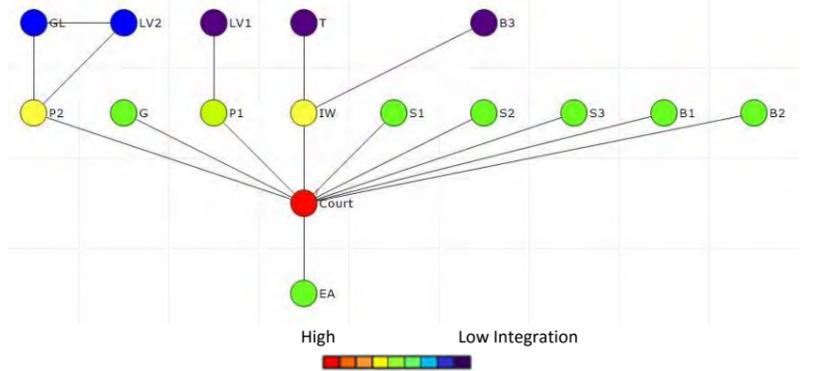
## Space Syntax Analysis

Diagrams produced by Researcher using AGRAPH Online software  
(<https://www.ntnu.no/ab/spacesyntax>)

### Depth of Spaces from the Main Entrance



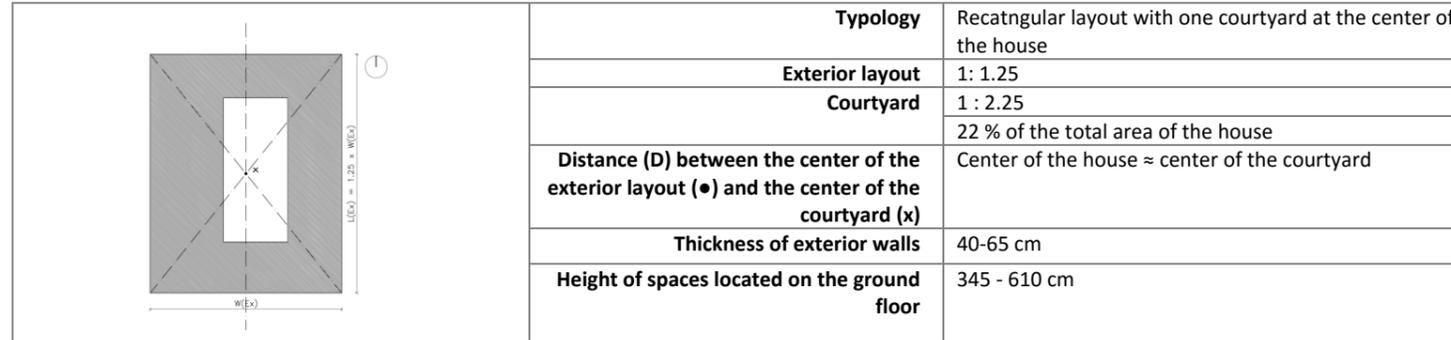
### Integration of Spaces with the Courtyard (the courtyard has the greatest control value)



## The Social Logic of the Spatial Arrangement of a Courtyard House in Lebanon

|        |             |         |         |          |        |
|--------|-------------|---------|---------|----------|--------|
| Region | Middle East | Country | Lebanon | Case No. | ME-L-5 |
|--------|-------------|---------|---------|----------|--------|

### Typology and Geometric Properties of the House (Researcher)



|   | Dominant Users (Male / Female) | Percentage of area of this space related to the total area of the house | Percentage of area of this space related to the floor area where it is located | Proportion of the area of this space, to the area of the courtyard | Proportion of Spaces |
|---|--------------------------------|---|--|--|----------------------|
| <b>Courtyard</b>                                | M+F                            | 22 %  | 22 %   | 1 : 1  | 1 : 2.25             |
| <b>Iwan</b>                                     | M+F                            | 4 %   | 4 %  | 0.17 : 1   | 1 : 1.45             |
| <b>Gallery</b>                                  | M+F                            | 9 %   | 9 %  | 0.40 : 1   |                      |
| <b>Terrace</b>                                  | M+F                            | 5 %   | 5 %  | 0.21 : 1   | 1 : 2.15             |
| <b>Guest Room</b>                               | M                              | 6 %   | 6 %  | 0.29 : 1   | 1 : 2.25             |
| <b>Living Rooms</b>                             | M+F                            | 12 %  | 12 %   | 0.55 : 1   | 1 : 1.5 , 1 : 1.8    |
| <b>Bedrooms</b>                                 | M+F                            | 16 %  | 16 %   | 0.74 : 1   | 1 : 1.87 , 1 : 1     |
| <b>Services (kitchen and storage) (Toilets)</b> | F<br>M+F                       | 9 %   | 9 %  | 0.43 : 1   |                      |

### Integration of Spaces using Space Syntax Theory

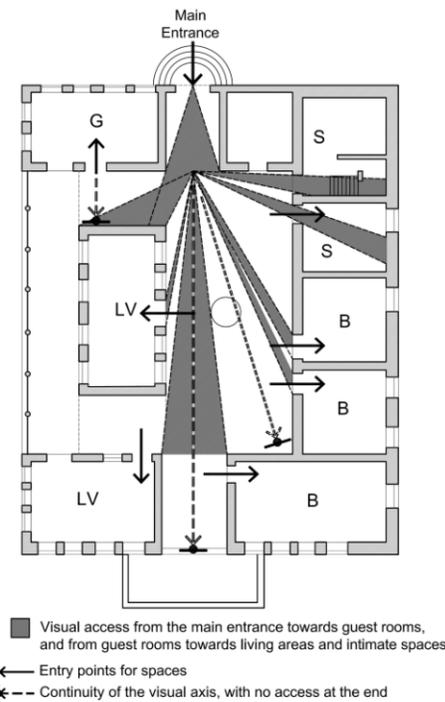
(Calculations produced by AGRAPH Online software)  
(<https://www.ntnu.no/ab/spacesyntax>)

#### Control and Integration Values for each space

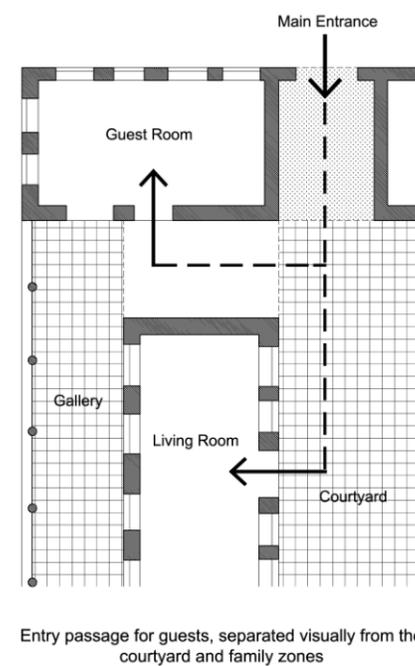
TDn Total Depth (TD) for actual node      RA Relative Asymmetry = 2\*(MD-1)/(K-2)  
 MDn Mean Depth (MD) for actual node = TD/(K-1)      I Integration Value = 1/RA  
 K Number of Nodes      CV Control Value  
 NCn Number of Connections from Node

| Spaces       | TDn          | MDn         | RA          | i            | CV          | NCn   |
|--------------|--------------|-------------|-------------|--------------|-------------|-------|
| EA           | 34           | 2.26        | 0.18        | 5.52         | 0.10        | 1.00  |
| <b>Court</b> | 20           | 1.33        | 0.04        | <b>21.00</b> | <b>8.16</b> | 10.00 |
| <b>P1</b>    | 32           | 2.13        | 0.16        | <b>6.17</b>  | <b>1.10</b> | 2.00  |
| G            | 34           | 2.26        | 0.18        | 5.52         | 0.10        | 1.00  |
| <b>P2</b>    | 30           | 2.00        | 0.14        | <b>7.00</b>  | <b>1.10</b> | 3.00  |
| GL           | 43           | 2.86        | 0.26        | 3.75         | 0.83        | 2.00  |
| LV2          | 43           | 2.86        | 0.26        | 3.75         | 0.83        | 2.00  |
| <b>IW</b>    | 30           | 2.00        | 0.14        | <b>7.00</b>  | <b>2.10</b> | 3.00  |
| <b>T</b>     | 44           | 2.93        | 0.27        | <b>3.62</b>  | 0.33        | 1.00  |
| S1           | 34           | 2.26        | 0.18        | 5.52         | 0.10        | 1.00  |
| S2           | 34           | 2.26        | 0.18        | 5.52         | 0.10        | 1.00  |
| S3           | 34           | 2.26        | 0.18        | 5.52         | 0.10        | 1.00  |
| B1           | 34           | 2.26        | 0.18        | 5.52         | 0.10        | 1.00  |
| B2           | 34           | 2.26        | 0.18        | 5.52         | 0.10        | 1.00  |
| LV1          | 46           | 3.06        | 0.29        | 3.38         | 0.50        | 1.00  |
| B3           | 44           | 2.93        | 0.27        | 3.62         | 0.33        | 1.00  |
| <b>Min</b>   | 20.00        | 1.33        | 0.04        | 3.38         | 0.10        |       |
| <b>Mean</b>  | <b>35.62</b> | <b>2.37</b> | <b>0.19</b> | <b>6.12</b>  | <b>1.00</b> |       |
| <b>Max</b>   | 46.00        | 3.06        | 0.29        | 21.00        | 8.16        |       |

### Visual Analysis from the Main Entrance towards inside the House (Researcher)



### Strategies for achieving Visual Privacy between the Main Entrance and inside the House (Researcher)



#### Integration Values:

Courtyard > Passage (corridor) > Iwan > Guest Room, Entrance, Services, Gallery > Living Rooms > Bedrooms

#### Lowest Integration Values:

- Living room
- Bedrooms
- Gallery and Terraces

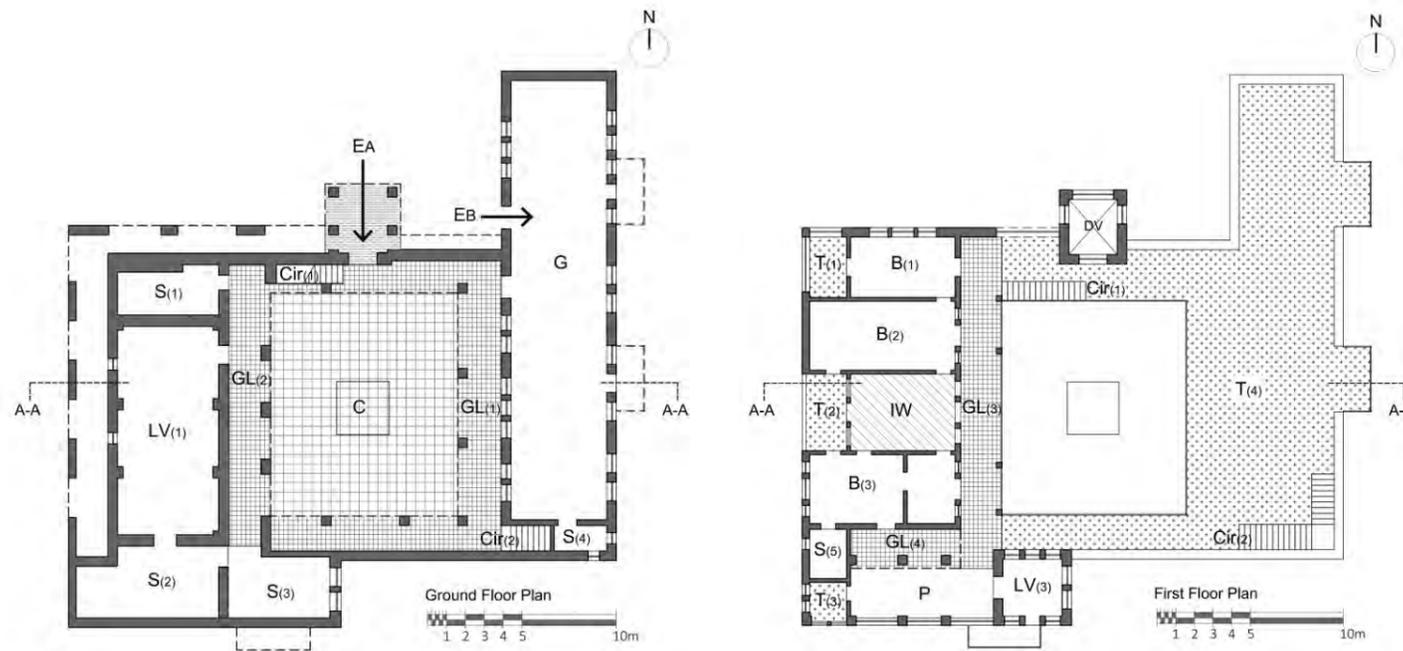
#### Highest Integration and Control Values:

- Courtyard
- Passage (corridors) as transitional spaces
- Iwan (semi-open spaces)

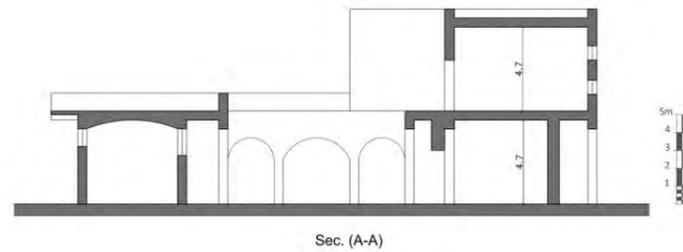
# The Social Logic of the Spatial Arrangement of a Courtyard House in Jerash, Jordan

|        |             |         |        |          |        |
|--------|-------------|---------|--------|----------|--------|
| Region | Middle East | Country | Jordan | Case No. | ME-J-1 |
|--------|-------------|---------|--------|----------|--------|

## Architectural Plans for a Courtyard House, Jordan (Redrawn by Researcher, after (??????))



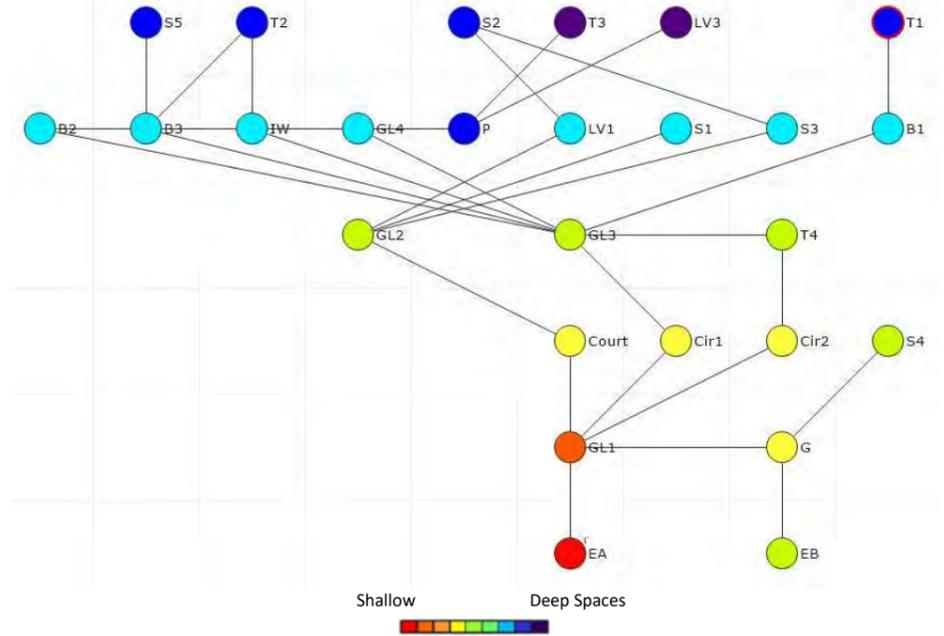
- EA: Main Entrance Hall/Corridor
- EB: Services Entrance
- C : Courtyard
- IW: Iwan
- GL : Gallery
- T : Roof Terrace / Balcony
- G : Guest Room (Reception)
- LV: Family Living Room
- B : Intimate Spaces (Bedrooms)
- S : Services (Kitchen, Toilets, Storage)
- P : Passage / Transitional Space
- DV: Double Volume



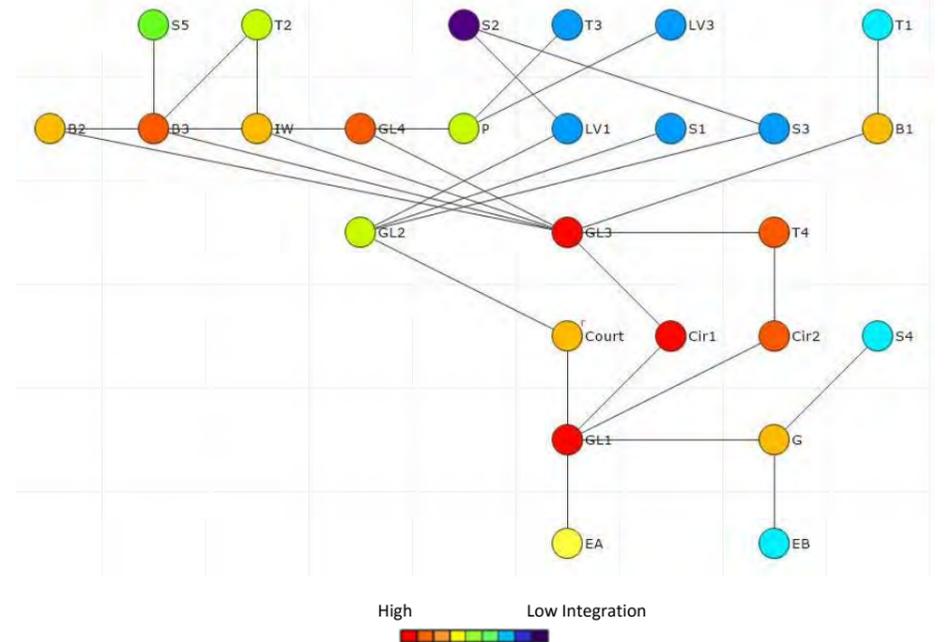
## Space Syntax Analysis

Diagrams produced by Researcher using AGRAPH Online software  
(<https://www.ntnu.no/ab/spacesyntax>)

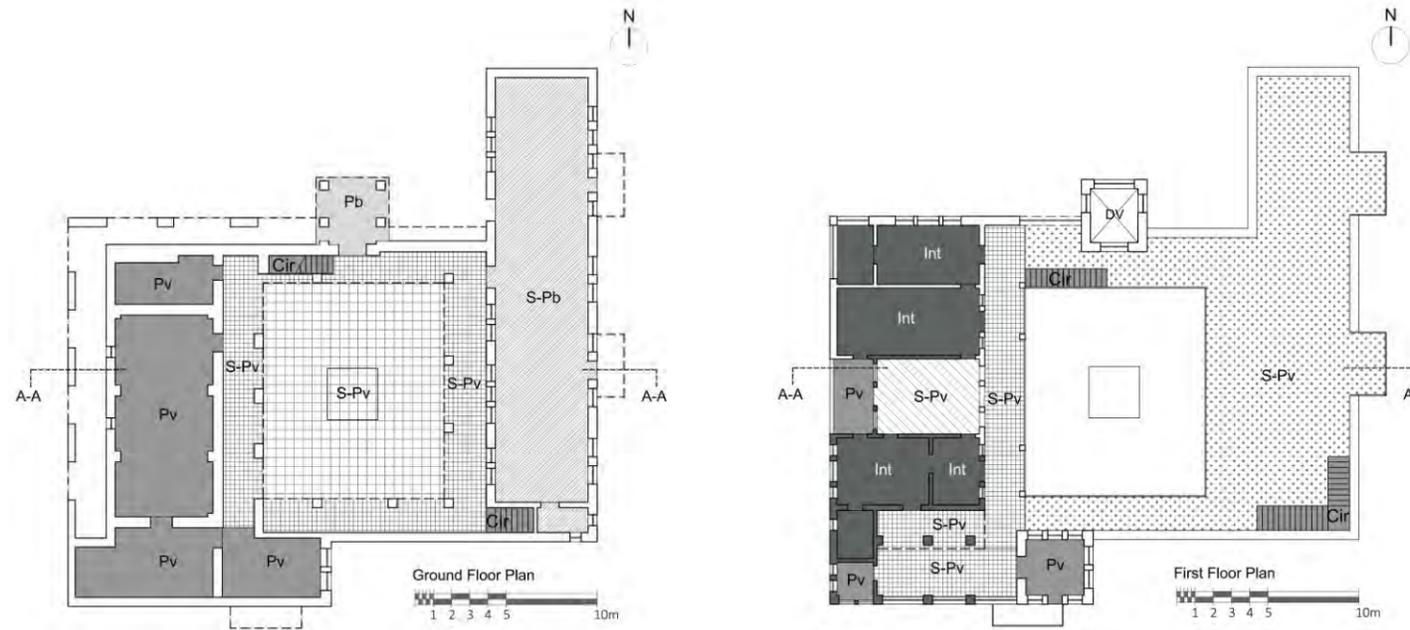
### Depth of Spaces from the Main Entrance



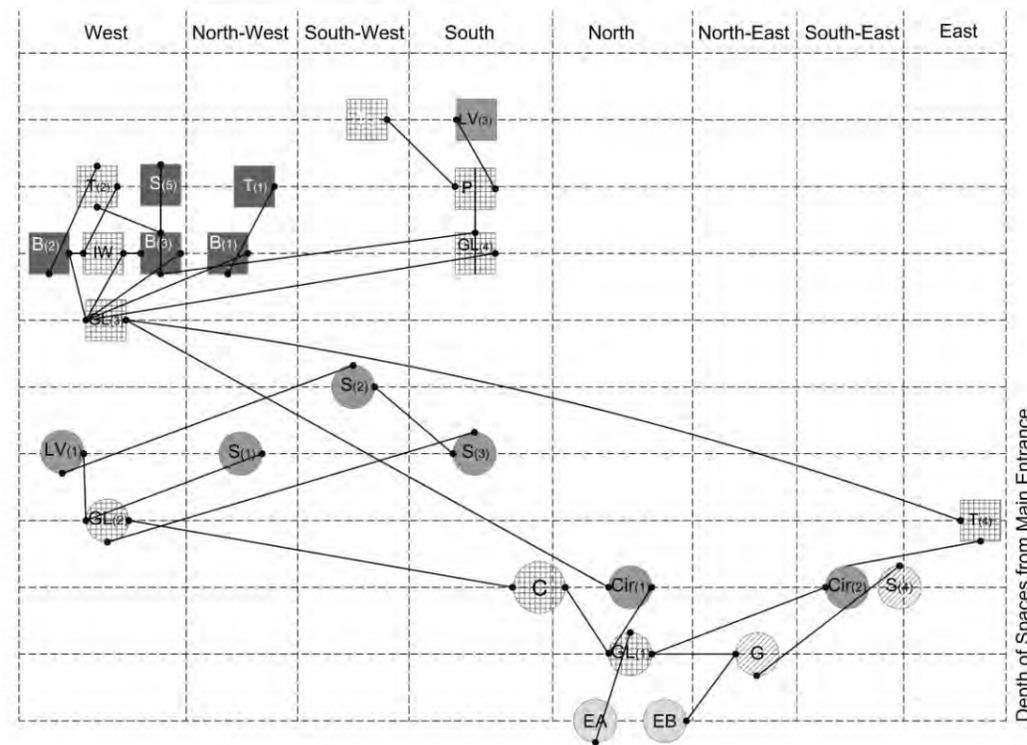
### Integration of Spaces with the Courtyard (the courtyard has the greatest control value)



Hierarchy and Depth of Spaces (according to the orientation, and type of spaces)  
(Researcher)



- Pb Public Zone (Main Entrance)
- S-Pb Semi-Public Zone (Reception / Men Guest Room)
- S-Pv Semi-Private Zone (Courtyard, Iwan)
- Pv Private Zone (Family Rooms, Services)
- Int Intimate Zone (Bedrooms)
- Cir Vertical Circulation (Stairs to roof / upper floors)

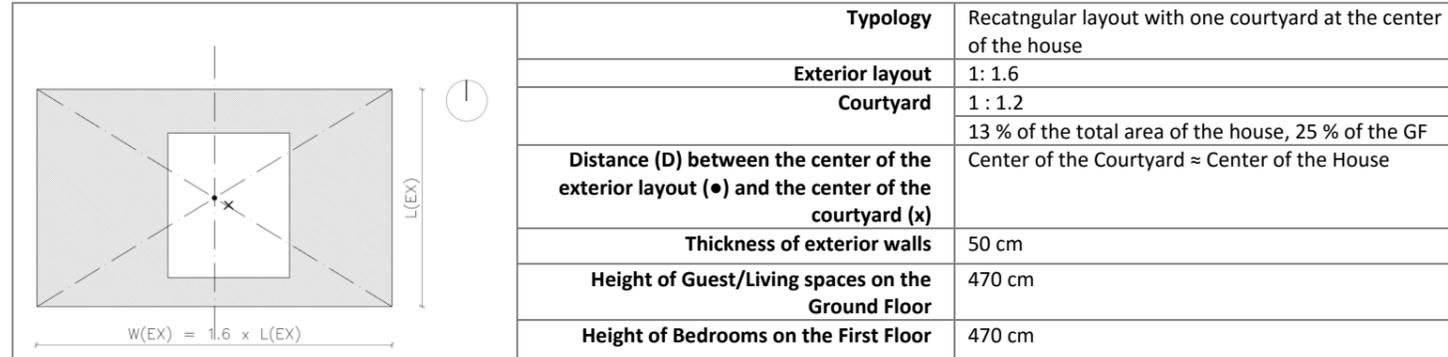


- Spaces located on the Ground Floor
- Spaces located on the First Floor
- Direction of Surface Interaction between Spaces

# The Social Logic of the Spatial Arrangement of a Courtyard House in Jerash, Jordan

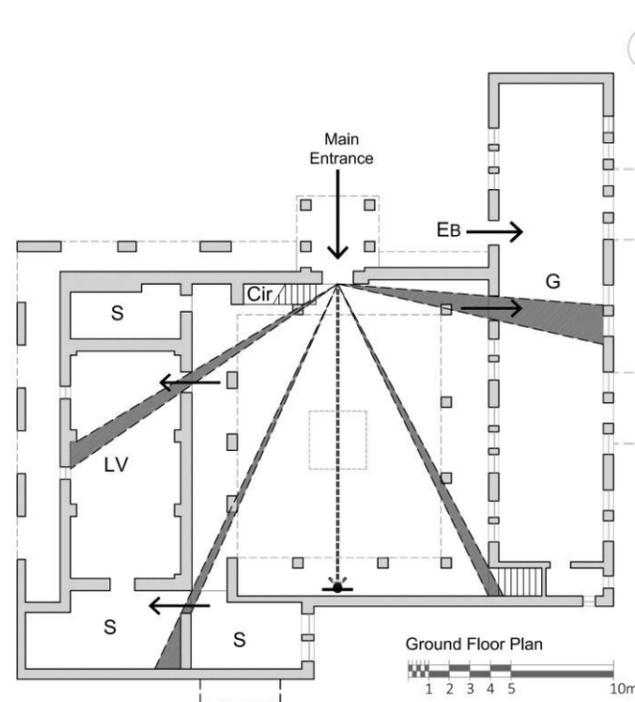
|        |             |         |        |          |        |
|--------|-------------|---------|--------|----------|--------|
| Region | Middle East | Country | Jordan | Case No. | ME-J-1 |
|--------|-------------|---------|--------|----------|--------|

## Typology and Geometric Properties of the House (Researcher)

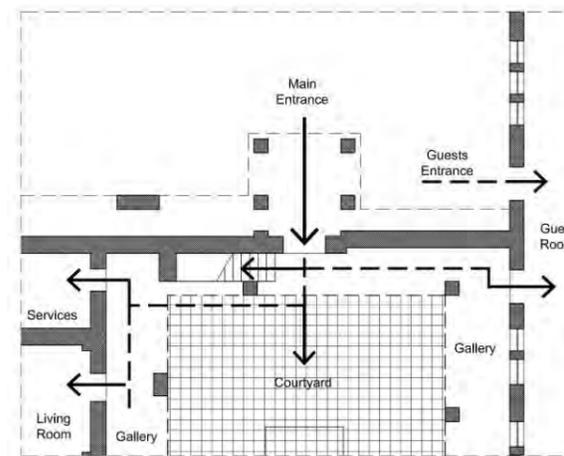


|   | Dominant Users (Male / Female) | Percentage of area of this space related to the total area of the house | Percentage of area of this space related to the floor area where it is located |                 | Proportion of the area of this space, to the area of the courtyard | Proportion of Spaces        |
|---|--------------------------------|---|--|-----------------|--|-----------------------------|
|   |                                |   | G  | 1 <sup>st</sup> |  |                             |
| <b>Courtyard</b>                                | M+F                            | 13 %  | 25 %   | -               | 1 : 1  | 1 : 1.2                     |
| <b>Iwan</b>                                     | M+F                            | 3 %   | -  | 7 %             | 0.25 : 1   | 1 : 1.3                     |
| <b>Gallery</b>                                  | M+F                            | 16 %  | 20 %   | 12 %            | 1.23 : 1   |                             |
| <b>Terraces</b>                                 | M+F                            | 26 %  | -  | 56 %            | 2 : 1  |                             |
| <b>Guest Rooms</b>                              | M                              | 14 %  | 26 %   | -               | 1.05 : 1   | 1 : 4.6                     |
| <b>Living Rooms</b>                             | M+F                            | 8 %   | 13 %   | 3 %             | 0.60 : 1   | 1 : 2                       |
| <b>Bedrooms</b>                                 | M+F                            | 9 %   | -  | 18 %            | 0.66 : 1   | 1 : 1.3 , 1 : 1.8 , 1 : 2.2 |
| <b>Services (kitchen and storage) (Toilets)</b> | F<br>M+F                       | 7 %   | 13 %   | 3 %             | 0.51 : 1   |                             |

### Visual analysis from the main entrance towards guest rooms and private/intimate spaces (Researcher)



### Strategies for achieving visual privacy between the entrance and semi-public spaces (Researcher)



The main entrance, which is for family members, is connected directly with the courtyard and with a gallery lead to living area and services. There is a separate entrance for guests adjacent to the main entrance. This preserves the privacy of the family

## Integration of Spaces using Space Syntax Theory

(Calculations produced by AGRAPH Online software)  
<https://www.ntnu.no/ab/spacesyntax>

### Control and Integration Values for each space

TDn Total Depth (TD) for actual node  
 MDn Mean Depth (MD) for actual node = TD/(K-1)  
 K Number of Nodes  
 NCn Number of Connections from Node  
 RA Relative Asymmetry = 2\*(MD-1)/(K-2)  
 i Integration Value = 1/RA  
 CV Control Value

| Spaces | TDn    | MDn  | RA   | i    | CV   | NCn  |
|--------|--------|------|------|------|------|------|
| EB     | 113    | 4.52 | 0.29 | 3.40 | 0.33 | 1.00 |
| EA     | 93     | 3.72 | 0.22 | 4.41 | 0.20 | 1.00 |
| GL1    | 69     | 2.76 | 0.14 | 6.81 | 2.83 | 5.00 |
| G      | 89     | 3.56 | 0.21 | 4.68 | 2.20 | 3.00 |
| Cir2   | 79     | 3.16 | 0.18 | 5.55 | 0.70 | 2.00 |
| S4     | 113    | 4.52 | 0.29 | 3.40 | 0.33 | 1.00 |
| Cir1   | 68     | 2.72 | 0.14 | 6.97 | 0.34 | 2.00 |
| Court  | 83     | 3.32 | 0.19 | 5.17 | 0.45 | 2.00 |
| T4     | 78     | 3.12 | 0.17 | 5.66 | 0.64 | 2.00 |
| GL3    | 67     | 2.68 | 0.14 | 7.14 | 2.78 | 7.00 |
| GL2    | 99     | 3.96 | 0.24 | 4.05 | 2.50 | 4.00 |
| B2     | 89     | 3.56 | 0.21 | 4.68 | 0.39 | 2.00 |
| B3     | 82     | 3.28 | 0.19 | 5.26 | 2.22 | 5.00 |
| LV1    | 121    | 4.84 | 0.32 | 3.12 | 0.75 | 2.00 |
| IW     | 86     | 3.44 | 0.20 | 4.91 | 1.34 | 4.00 |
| S1     | 123    | 4.92 | 0.32 | 3.06 | 0.25 | 1.00 |
| B1     | 89     | 3.56 | 0.21 | 4.68 | 1.14 | 2.00 |
| S3     | 121    | 4.84 | 0.32 | 3.12 | 0.75 | 2.00 |
| GL4    | 82     | 3.28 | 0.19 | 5.26 | 0.67 | 3.00 |
| P      | 102    | 4.08 | 0.25 | 3.89 | 2.33 | 3.00 |
| S5     | 106    | 4.24 | 0.27 | 3.70 | 0.20 | 1.00 |
| T2     | 104    | 4.16 | 0.26 | 3.79 | 0.45 | 2.00 |
| T1     | 113    | 4.52 | 0.29 | 3.40 | 0.50 | 1.00 |
| S2     | 143    | 5.72 | 0.39 | 2.54 | 1.00 | 2.00 |
| T3     | 126    | 5.04 | 0.33 | 2.97 | 0.33 | 1.00 |
| LV3    | 126    | 5.04 | 0.33 | 2.97 | 0.33 | 1.00 |
| Min    | 67.00  | 2.68 | 0.14 | 2.54 | 0.20 |      |
| Mean   | 98.61  | 3.94 | 0.24 | 4.41 | 1.00 |      |
| Max    | 143.00 | 5.72 | 0.39 | 7.14 | 2.83 |      |

### Integration Values:

Gallery > Vertical Circulation > Courtyard > Living Rooms, Iwan > Guest Room > Bedrooms, Terraces > Services (Kitchen, Storage, and Toilets)

### Lowest Integration Values:

- Terrace adjacent to bedroom on the first floor
- Living room and services adjacent to bedrooms on the first floor

### Highest Integration and Control Values:

- Gallery surrounded the courtyard
- Vertical circulation (stairs)

Appendix (4-B-8)

**Spatial and Geometric Calculations for the Selected  
Vernacular Houses**

### Data extracted from Traditional Houses located in the Middle East

| Case       | Area (G)   | Area (1st) | Area (2nd) | Area (3rd) | Area (4th) | Total excluding terraces | Total with terraces | Covered    |            | Open       |            | Total (covered+open) |
|------------|------------|------------|------------|------------|------------|--------------------------|---------------------|------------|------------|------------|------------|----------------------|
| SYR-1      | 474        | 170        |            |            |            | 644                      | 781                 | 493        | 77%        | 151        | 23%        | 644                  |
| SYR-2      | 730        | 208        | 250        |            |            | 1188                     | 1288                | 991        | 83%        | 197        | 17%        | 1188                 |
| SYR-3      | 1090       |            |            |            |            | 1090                     | 1090                | 626        | 57%        | 464        | 43%        | 1090                 |
| <b>AVG</b> | <b>765</b> | <b>189</b> | <b>250</b> |            |            | <b>974</b>               | <b>1093</b>         | <b>798</b> | <b>82%</b> | <b>176</b> | <b>18%</b> | <b>974</b>           |
| LBN-1      | 841        |            |            |            |            | 841                      | 841                 | 693        | 82%        | 148        | 18%        | 841                  |
| LBN-2      | 803        |            |            |            |            | 803                      | 803                 | 556        | 69%        | 247        | 31%        | 803                  |
| LBN-3      | 949        | 348        |            |            |            | 1297                     | 1489                | 1042       | 80%        | 255        | 20%        | 1297                 |
| LBN-4      | 800        |            |            |            |            | 800                      | 833                 | 661        | 83%        | 139        | 17%        | 800                  |
| LBN-5      | 536        |            |            |            |            | 536                      | 554                 | 432        | 81%        | 104        | 19%        | 536                  |
| <b>AVG</b> | <b>786</b> | <b>348</b> |            |            |            | <b>855</b>               | <b>936</b>          | <b>669</b> | <b>78%</b> | <b>187</b> | <b>22%</b> | <b>855</b>           |
| PAL-1      | 361        |            |            |            |            | 361                      | 525                 | 310        | 86%        | 51         | 14%        | 361                  |
| PAL-2      | 649        |            |            |            |            | 649                      | 649                 | 504        | 78%        | 145        | 22%        | 649                  |
| PAL-3      | 369        |            |            |            |            | 369                      | 393                 | 332        | 90%        | 37         | 10%        | 369                  |
| <b>AVG</b> | <b>460</b> |            |            |            |            | <b>460</b>               | <b>554</b>          | <b>382</b> | <b>83%</b> | <b>78</b>  | <b>17%</b> | <b>460</b>           |
| JOR-1      | 566        | 258        |            |            |            | 824                      | 1060                | 706        | 86%        | 118        | 14%        | 824                  |
| <b>AVG</b> | <b>566</b> | <b>258</b> |            |            |            | <b>824</b>               | <b>1060</b>         | <b>706</b> | <b>47%</b> | <b>784</b> | <b>53%</b> | <b>1490</b>          |
| IRQ-1      | 258        | 167        |            |            |            | 425                      | 465                 | 369        | 87%        | 56         | 13%        | 425                  |
| IRQ-2      | 349        | 350        |            |            |            | 699                      | 723                 | 619        | 89%        | 80         | 11%        | 699                  |
| IRQ-3      | 507        | 471        |            |            |            | 978                      | 991                 | 900        | 92%        | 78         | 8%         | 978                  |
| IRQ-4      | 367        | 292        | 221        |            |            | 880                      | 880                 | 809        | 92%        | 71         | 8%         | 880                  |
| IRQ-5      | 525        | 402        | 156        |            |            | 1083                     | 1083                | 965        | 89%        | 118        | 11%        | 1083                 |
| <b>AVG</b> | <b>401</b> | <b>336</b> | <b>189</b> |            |            | <b>813</b>               | <b>839</b>          | <b>725</b> | <b>89%</b> | <b>88</b>  | <b>11%</b> | <b>813</b>           |
| <b>AVG</b> | <b>598</b> | <b>296</b> | <b>209</b> |            |            | <b>785</b>               | <b>896</b>          | <b>649</b> | <b>83%</b> | <b>136</b> | <b>17%</b> | <b>785</b>           |

| EXCLUDING TERRACES |           |     |             |     |             |     |           |     |            |     |                  |       |     |                |     |              |     |              |     |
|--------------------|-----------|-----|-------------|-----|-------------|-----|-----------|-----|------------|-----|------------------|-------|-----|----------------|-----|--------------|-----|--------------|-----|
| Case               | Area (Pb) |     | Area (S-Pb) |     | Area (S-Pv) |     | Area (Pv) |     | Area (Int) |     | Sum of Hierarchy | Guest |     | Living covered |     | Main Court 1 |     | Main Court 2 |     |
| SYR-1              | 4         | 1%  | 50          | 11% | 193         | 42% | 134       | 29% | 76         | 17% | 457              | 50    | 8%  | 64             | 10% | 151          | 25% |              | 0%  |
| SYR-2              | 17        | 2%  | 71          | 8%  | 310         | 35% | 343       | 39% | 134        | 15% | 875              | 71    | 8%  | 183            | 19% | 197          | 21% |              | 0%  |
| SYR-3              | 9         | 1%  | 56          | 6%  | 550         | 63% | 202       | 23% | 57         | 7%  | 874              | 33    | 4%  | 143            | 17% | 181          | 21% | 283          | 33% |
| AVG                | 10        | 1%  | 59          | 8%  | 351         | 48% | 226       | 31% | 89         | 12% | 735              | 51    | 5%  | 130            | 12% | 176          | 17% | 283          | 27% |
| LBN-1              | 10        | 1%  | 21          | 3%  | 292         | 42% | 278       | 40% | 99         | 14% | 700              | 21    | 3%  | 134            | 19% | 148          | 21% |              | 0%  |
| LBN-2              | 63        | 11% | 33          | 6%  | 310         | 52% | 138       | 23% | 50         | 8%  | 594              | 33    | 5%  | 89             | 15% | 247          | 40% |              | 0%  |
| LBN-3              | 27        | 3%  | 79          | 8%  | 380         | 40% | 325       | 34% | 143        | 15% | 954              | 79    | 7%  | 166            | 14% | 245          | 21% |              | 0%  |
| LBN-4              | 19        | 3%  | 27          | 4%  | 171         | 27% | 324       | 51% | 100        | 16% | 641              | 27    | 4%  | 123            | 19% | 139          | 21% |              | 0%  |
| LBN-5              | 13        | 3%  | 41          | 9%  | 197         | 45% | 113       | 26% | 78         | 18% | 442              | 27    | 6%  | 60             | 14% | 104          | 24% |              | 0%  |
| AVG                | 26        | 4%  | 40          | 6%  | 270         | 41% | 236       | 35% | 94         | 14% | 666              | 37    | 5%  | 114            | 14% | 177          | 22% |              | 0%  |
| PAL-1              | 10        | 4%  | 57          | 20% | 51          | 18% | 75        | 27% | 90         | 32% | 283              | 33    | 7%  | 40             | 9%  | 51           | 11% |              | 0%  |
| PAL-2              | 18        | 4%  | 52          | 10% | 260         | 52% | 72        | 14% | 98         | 20% | 500              | 49    | 10% | 25             | 5%  | 145          | 29% |              | 0%  |
| PAL-3              | 7         | 3%  | 16          | 6%  | 89          | 33% | 68        | 25% | 90         | 33% | 270              | 16    | 5%  | 23             | 7%  | 37           | 12% |              | 0%  |
| AVG                | 12        | 3%  | 42          | 12% | 133         | 38% | 72        | 20% | 93         | 26% | 351              | 33    | 6%  | 29             | 6%  | 78           | 15% |              | 0%  |
| JOR-1              | 15        | 2%  | 124         | 18% | 307         | 44% | 165       | 24% | 90         | 13% | 701              | 120   | 13% | 70             | 8%  | 118          | 13% |              | 0%  |
| AVG                | 15        | 2%  | 124         | 18% | 307         | 44% | 165       | 24% | 90         | 13% | 701              | 120   | 13% | 70             | 8%  | 118          | 13% |              | 0%  |
| IRQ-1              | 8         | 3%  | 17          | 5%  | 122         | 38% | 106       | 33% | 64         | 20% | 317              | 17    | 5%  | 26             | 7%  | 56           | 16% |              | 0%  |
| IRQ-2              | 17        | 4%  | 24          | 5%  | 232         | 50% | 92        | 20% | 101        | 22% | 466              | 24    | 5%  | 38             | 8%  | 80           | 16% |              | 0%  |
| IRQ-3              | 23        | 3%  | 37          | 5%  | 237         | 35% | 306       | 45% | 70         | 10% | 673              | 37    | 5%  | 70             | 10% | 70           | 10% |              | 0%  |
| IRQ-4              | 20        | 3%  | 33          | 5%  | 302         | 44% | 213       | 31% | 123        | 18% | 691              | 30    | 5%  | 125            | 20% | 53           | 8%  |              | 0%  |
| IRQ-5              | 17        | 2%  | 25          | 3%  | 330         | 42% | 306       | 39% | 114        | 14% | 792              | 22    | 3%  | 160            | 20% | 118          | 15% | 21           | 3%  |
| AVG                | 17        | 3%  | 27          | 5%  | 245         | 42% | 205       | 35% | 94         | 16% | 588              | 26    | 4%  | 84             | 13% | 75           | 12% | 21           | 3%  |
| AVG                | 16        | 3%  | 58          | 10% | 261         | 43% | 181       | 30% | 92         | 15% | 608              | 53    | 6%  | 86             | 10% | 125          | 14% | 152          | 17% |

| Case       | Serv. Court |           | Gallery    |            | Terraces   |            | Iwan      |           | Bedrooms  |            | Services with Kitch |            | Kitchen   | Main EN   |           | Service EN |           | Corridor & Stairs |           | Total       |
|------------|-------------|-----------|------------|------------|------------|------------|-----------|-----------|-----------|------------|---------------------|------------|-----------|-----------|-----------|------------|-----------|-------------------|-----------|-------------|
|            |             |           |            |            |            |            |           |           |           |            |                     |            |           |           |           |            |           |                   |           |             |
| SYR-1      |             | 0%        | 20         | 3%         | 137        | 22%        | 22        | 4%        | 76        | 12%        | 48                  | 8%         |           | 4         | 1%        |            | 0%        | 39                | 6%        | 611         |
| SYR-2      |             | 0%        | 74         | 8%         | 100        | 11%        | 38        | 4%        | 123       | 13%        | 95                  | 10%        |           | 17        | 2%        |            | 0%        | 47                | 5%        | 945         |
| SYR-3      |             | 0%        |            | 0%         |            | 0%         | 65        | 8%        | 80        | 9%         | 39                  | 5%         |           | 9         | 1%        | 15         | 2%        | 15                | 2%        | 863         |
| <b>AVG</b> |             | <b>0%</b> | <b>47</b>  | <b>4%</b>  | <b>119</b> | <b>11%</b> | <b>42</b> | <b>4%</b> | <b>93</b> | <b>9%</b>  | <b>61</b>           | <b>6%</b>  |           | <b>10</b> | <b>1%</b> | <b>15</b>  | <b>1%</b> | <b>34</b>         | <b>3%</b> | <b>1060</b> |
| LBN-1      |             | 0%        | 53         | 8%         |            | 0%         | 72        | 10%       | 99        | 14%        | 140                 | 20%        |           | 10        | 1%        |            | 0%        | 28                | 4%        | 705         |
| LBN-2      |             | 0%        |            | 0%         |            | 0%         | 63        | 10%       | 50        | 8%         | 57                  | 9%         |           | 30        | 5%        | 31         | 5%        | 10                | 2%        | 610         |
| LBN-3      | 10          | 1%        | 63         | 5%         | 192        | 16%        | 50        | 4%        | 143       | 12%        | 123                 | 11%        |           | 27        | 2%        | 29         | 2%        | 41                | 4%        | 1168        |
| LBN-4      |             | 0%        |            | 0%         | 33         | 5%         |           | 0%        | 100       | 15%        | 167                 | 26%        |           | 19        | 3%        | 3          | 0%        | 38                | 6%        | 649         |
| LBN-5      |             | 0%        | 42         | 10%        | 18         | 4%         | 18        | 4%        | 78        | 18%        | 53                  | 12%        |           | 13        | 3%        |            | 0%        | 29                | 7%        | 442         |
| <b>AVG</b> | <b>10</b>   | <b>1%</b> | <b>53</b>  | <b>7%</b>  | <b>81</b>  | <b>10%</b> | <b>51</b> | <b>6%</b> | <b>94</b> | <b>12%</b> | <b>108</b>          | <b>14%</b> |           | <b>20</b> | <b>2%</b> | <b>21</b>  | <b>3%</b> | <b>29</b>         | <b>4%</b> | <b>795</b>  |
| PAL-1      |             | 0%        |            | 0%         | 164        | 37%        |           | 0%        | 82        | 18%        | 36                  | 8%         | 28        | 10        | 2%        |            | 0%        | 31                | 7%        | 447         |
| PAL-2      |             | 0%        | 95         | 19%        |            | 0%         | 17        | 3%        | 98        | 20%        | 43                  | 9%         | 23        | 17        | 3%        | 6          | 1%        | 7                 | 1%        | 502         |
| PAL-3      |             | 0%        |            | 0%         | 24         | 8%         |           | 0%        | 90        | 29%        | 41                  | 13%        | 16        | 7         | 2%        | 4          | 1%        | 67                | 22%       | 309         |
| <b>AVG</b> |             | <b>0%</b> | <b>95</b>  | <b>18%</b> | <b>94</b>  | <b>18%</b> | <b>17</b> | <b>3%</b> | <b>90</b> | <b>17%</b> | <b>40</b>           | <b>8%</b>  | <b>22</b> | <b>11</b> | <b>2%</b> | <b>5</b>   | <b>1%</b> | <b>35</b>         | <b>7%</b> | <b>527</b>  |
| JOR-1      |             | 0%        | 145        | 16%        | 236        | 26%        | 23        | 3%        | 78        | 9%         | 69                  | 8%         |           | 15        | 2%        |            | 0%        | 42                | 5%        | 916         |
| <b>AVG</b> |             | <b>0%</b> | <b>145</b> | <b>16%</b> | <b>236</b> | <b>26%</b> | <b>23</b> | <b>3%</b> | <b>78</b> | <b>9%</b>  | <b>69</b>           | <b>8%</b>  |           | <b>15</b> | <b>2%</b> |            | <b>0%</b> | <b>42</b>         | <b>5%</b> | <b>916</b>  |
| IRQ-1      |             | 0%        | 31         | 9%         | 40         | 11%        | 48        | 13%       | 64        | 18%        | 36                  | 10%        | 6         | 8         | 2%        |            | 0%        | 30                | 8%        | 356         |
| IRQ-2      |             | 0%        | 92         | 19%        | 24         | 5%         | 60        | 12%       | 101       | 21%        | 42                  | 9%         | 22        | 17        | 3%        |            | 0%        | 12                | 2%        | 490         |
| IRQ-3      | 8           | 1%        | 91         | 13%        | 13         | 2%         | 69        | 10%       | 70        | 10%        | 155                 | 23%        |           | 23        | 3%        |            | 0%        | 71                | 10%       | 677         |
| IRQ-4      | 18          | 3%        | 109        | 17%        |            | 0%         | 15        | 2%        | 117       | 18%        | 63                  | 10%        | 20        | 20        | 3%        | 3          | 0%        | 81                | 13%       | 634         |
| IRQ-5      |             | 0%        | 171        | 22%        |            | 0%         | 9         | 1%        | 114       | 14%        | 101                 | 13%        |           | 17        | 2%        |            | 0%        | 61                | 8%        | 794         |
| <b>AVG</b> | <b>13</b>   | <b>2%</b> | <b>99</b>  | <b>16%</b> | <b>26</b>  | <b>4%</b>  | <b>40</b> | <b>6%</b> | <b>93</b> | <b>15%</b> | <b>79</b>           | <b>13%</b> | <b>16</b> | <b>17</b> | <b>3%</b> | <b>3</b>   | <b>0%</b> | <b>51</b>         | <b>8%</b> | <b>627</b>  |
| <b>AVG</b> | <b>12</b>   | <b>1%</b> | <b>88</b>  | <b>10%</b> | <b>111</b> | <b>13%</b> | <b>35</b> | <b>4%</b> | <b>90</b> | <b>10%</b> | <b>71</b>           | <b>8%</b>  | <b>19</b> | <b>15</b> | <b>2%</b> | <b>11</b>  | <b>1%</b> | <b>38</b>         | <b>4%</b> | <b>885</b>  |

| Case  | Distance (Court - Center)<br>x , y |              | Distance (Court2 - Center)<br>x , y |             | Thick. Of Walls | Main Court   |              |             |           | Service Court |              |             |           | Iwan-1      |             |             |           |             |
|-------|------------------------------------|--------------|-------------------------------------|-------------|-----------------|--------------|--------------|-------------|-----------|---------------|--------------|-------------|-----------|-------------|-------------|-------------|-----------|-------------|
|       | x                                  | y            | x                                   | y           |                 | x            | y            | prop.       | direction | x             | y            | prop.       | direction | Y           | X           | prop.       | direction | X(Iw):X(C)  |
| SYR-1 | 1.40                               | -1.47        |                                     |             | 70              | 12.7         | 11.9         | 1.07        | S         |               |              |             |           | 5           | 4.25        | 1.18        | E         |             |
| SYR-2 | 1.14                               | 0.24         |                                     |             | 95              | 11.5         | 46           | 0.25        | CEN.      |               |              |             |           | 6.65        | 5.8         | 1.15        | S         | 0.50        |
| SYR-3 | 2.00                               | 3.65         | 2.20                                | 0.15        | 80              | 11.7         | 15.7         | 0.75        | N         | 18.2          | 15           | 1.21        | E         | 6.3         | 5.1         | 1.24        | S         | 0.44        |
| AVG   | <b>1.51</b>                        | <b>0.81</b>  | <b>2.20</b>                         | <b>0.15</b> | <b>82</b>       | <b>11.97</b> | <b>24.53</b> | <b>0.69</b> |           | <b>18.20</b>  | <b>15.00</b> | <b>1.21</b> |           | <b>5.98</b> | <b>5.05</b> | <b>1.19</b> |           | <b>0.47</b> |
| LBN-1 | 4.11                               | 0.85         |                                     |             | 95              | 13.5         | 11           | 1.23        | CEN.      |               |              |             |           | 7.5         | 5.3         | 1.42        | S         | 0.39        |
| LBN-2 | -2.38                              | 3.83         |                                     |             | 95              | 21.1         | 12           | 1.76        | W-E       |               |              |             |           | 6.5         | 6.25        | 1.04        | S         | 0.30        |
| LBN-3 | 0.73                               | -1.59        |                                     |             | 80              | 16           | 15.2         | 1.05        | CEN.      | 3             | 3            | 1.00        | E         | 6.7         | 4.45        | 1.51        | S         | 0.28        |
| LBN-4 | 0.64                               | -6.20        |                                     |             | 80              | 13.3         | 10.4         | 1.28        | W         |               |              |             |           |             |             |             |           |             |
| LBN-5 | 1.06                               | 0.97         |                                     |             | 65              | 6.85         | 15.25        | 0.45        | CEN.      |               |              |             |           | 5.1         | 3.5         | 1.46        | S         | 0.51        |
| AVG   | <b>0.83</b>                        | <b>-0.43</b> |                                     |             | <b>83</b>       | <b>14.15</b> | <b>12.77</b> | <b>1.15</b> |           | <b>3.00</b>   | <b>3.00</b>  | <b>1.00</b> |           | <b>6.45</b> | <b>4.88</b> | <b>1.35</b> |           | <b>0.37</b> |
| PAL-1 | 5.72                               | 0.00         |                                     |             | 87              | 7.15         | 7.10         | 1.01        | E         |               |              |             |           |             |             |             |           |             |
| PAL-2 | 3.77                               | 0.38         |                                     |             | 82              | 11.70        | 12.30        | 0.95        | E         |               |              |             |           | 5.40        | 3.00        | 1.80        | W         |             |
| PAL-3 | -0.83                              | -3.17        |                                     |             | 60              | 6.55         | 5.60         | 1.17        | S         |               |              |             |           |             |             |             |           |             |
| AVG   | <b>2.89</b>                        | <b>-0.93</b> |                                     |             | <b>76</b>       | <b>8.47</b>  | <b>8.33</b>  | <b>1.04</b> |           |               |              |             |           | <b>5.40</b> | <b>3.00</b> | <b>1.80</b> |           |             |
| JOR-1 | -0.28                              | -0.78        |                                     |             | 50              | 10.00        | 11.85        | 0.84        | CEN.      |               |              |             |           | 5.70        | 4.30        | 1.33        | W         |             |
| AVG   | <b>-0.28</b>                       | <b>-0.78</b> |                                     |             | <b>50</b>       | <b>10.00</b> | <b>11.85</b> | <b>0.84</b> |           |               |              |             |           | <b>5.70</b> | <b>4.30</b> | <b>1.33</b> |           |             |
| IRQ-1 | -2.33                              | 0.82         |                                     |             | 68              | 8.35         | 6.70         | 1.25        | CEN.      |               |              |             |           | 4.15        | 5.40        | 0.77        | S         | 0.65        |
| IRQ-2 | 1.10                               | 4.80         |                                     |             | 63              | 11.25        | 6.70         | 1.68        | N         |               |              |             |           | 4.88        | 3.88        | 1.26        | NW        |             |
| IRQ-3 | -1.11                              | -1.64        | 2.29                                | 11.34       | 78              | 8.55         | 8.15         | 1.05        | CEN.      | 2.75          | 2.65         | 1.04        | S         | 5.35        | 3.35        | 1.60        | E         |             |
| IRQ-4 | -1.54                              | 1.95         | 8.60                                | -5.28       | 55              | 8.15         | 6.50         | 1.25        | CEN.      | 4.35          | 3.85         | 1.13        | E         | 4.20        | 3.55        | 1.18        | N         | 0.44        |
| IRQ-5 | -1.03                              | -1.18        | 0.95                                | 10.68       | 85              | 11.75        | 10.00        | 1.18        | CEN.      | 4.65          | 4.25         | 1.09        | N         | 3.35        | 2.45        | 1.37        | S         | 0.21        |
| AVG   | <b>-0.98</b>                       | <b>0.95</b>  | <b>3.95</b>                         | <b>5.58</b> | <b>70</b>       | <b>9.61</b>  | <b>7.61</b>  | <b>1.28</b> |           | <b>3.92</b>   | <b>3.58</b>  | <b>1.09</b> |           | <b>4.39</b> | <b>3.73</b> | <b>1.23</b> |           | <b>0.43</b> |
| AVG   | <b>0.79</b>                        | <b>-0.08</b> | <b>3.07</b>                         | <b>2.87</b> | <b>72</b>       | <b>10.84</b> | <b>13.02</b> | <b>1.20</b> |           | <b>8.37</b>   | <b>7.19</b>  | <b>1.16</b> |           | <b>5.58</b> | <b>4.19</b> | <b>1.33</b> |           | <b>1.27</b> |

| Case  | Iwan-2      |             |             |             |             |             |           | Main Liv     |             |             |           |
|-------|-------------|-------------|-------------|-------------|-------------|-------------|-----------|--------------|-------------|-------------|-----------|
|       | Y(IW):Y(C)  | Y           | X           | prop.       | X(Iw):X(C)  | Y(IW):Y(C)  | direction | x            | y           | prop.       | direction |
| SYR-1 | 0.42        |             |             |             |             |             |           | 10.25        | 3.5         | 2.93        | N         |
| SYR-2 |             |             |             |             |             |             |           | 8.2          | 4.9         | 1.67        | W         |
| SYR-3 |             | 4.7         | 4.9         | 1.04        | 0.27        |             | S         | 7.5          | 4.5         | 1.67        | SE        |
| AVG   | <b>0.42</b> | <b>4.70</b> | <b>4.90</b> | <b>1.04</b> | <b>0.27</b> |             |           | <b>8.65</b>  | <b>4.30</b> | <b>2.09</b> |           |
| LBN-1 |             | 6.85        | 4.5         | 1.52        | 0.33        |             | N         | 7            | 6.7         | 1.04        | SE        |
| LBN-2 |             | 6           | 3.7         | 1.62        | 0.18        |             | N         | 6.8          | 6.25        | 1.09        | S         |
| LBN-3 |             | 5.75        | 3.55        | 1.62        | 0.22        |             | N         | 6.15         | 6.15        | 1.00        | SW        |
| LBN-4 |             |             |             |             |             |             |           | 7.5          | 7.15        | 1.05        | N         |
| LBN-5 |             |             |             |             |             |             |           | 8.15         | 3.6         | 2.26        | W         |
| AVG   |             | <b>6.20</b> | <b>3.92</b> | <b>1.59</b> | <b>0.24</b> |             |           | <b>7.12</b>  | <b>5.97</b> | <b>1.29</b> |           |
| PAL-1 |             |             |             |             |             |             |           | 6.10         | 4.25        | 1.44        | E         |
| PAL-2 | 0.44        |             |             |             |             |             |           | 4.70         | 4.65        | 1.01        | W         |
| PAL-3 |             |             |             |             |             |             |           | 4.75         | 4.45        | 1.07        | N         |
| AVG   | <b>0.44</b> |             |             |             |             |             |           | <b>5.18</b>  | <b>4.45</b> | <b>1.17</b> |           |
| JOR-1 | 0.48        |             |             |             |             |             |           | 11.05        | 5.40        | 2.05        | W         |
| AVG   | <b>0.48</b> |             |             |             |             |             |           | <b>11.05</b> | <b>5.40</b> | <b>2.05</b> |           |
| IRQ-1 |             | 2.45        | 5.25        | 2.14        | 0.63        |             | N         | 8.15         | 3.20        | 2.55        | NE        |
| IRQ-2 | 0.73        | 4.60        | 4.10        | 1.12        |             | 0.69        | W         | 11.80        | 3.30        | 3.58        | SW        |
| IRQ-3 | 0.66        | 5.55        | 6.55        | 1.18        | 0.77        |             | E         | 6.75         | 3.35        | 2.01        | S         |
| IRQ-4 |             |             |             |             |             |             |           | 5.27         | 2.68        | 1.97        | W         |
| IRQ-5 |             |             |             |             |             |             |           | 7.15         | 4.30        | 1.66        | S         |
| AVG   | <b>0.69</b> | <b>4.20</b> | <b>5.30</b> | <b>1.48</b> | <b>0.70</b> | <b>0.69</b> |           | <b>7.82</b>  | <b>3.37</b> | <b>2.35</b> |           |
| AVG   | <b>2.03</b> | <b>5.03</b> | <b>4.71</b> | <b>1.07</b> | <b>1.21</b> | <b>0.69</b> |           | <b>7.97</b>  | <b>4.70</b> | <b>1.70</b> |           |

| Case       | Guest        |             |             |           |         |                    | Rooms       |             |             |             | X(Rooms) / X(Court) |             | Y(Rooms) / Y(Court) |             | x(court)/X(L) |
|------------|--------------|-------------|-------------|-----------|---------|--------------------|-------------|-------------|-------------|-------------|---------------------|-------------|---------------------|-------------|---------------|
|            | x            | y           | prop.       | direction | M/F/M+F | No. of Guest Rooms | E           | W           | N           | S           | E                   | W           | N                   | S           |               |
| SYR-1      | 7.25         | 4.1         | 1.77        | W         | M+F     | 1                  | 5.2         | 8.9         | 5.3         | 1.5         | 0.41                | 0.70        | 0.45                | 0.13        | 0.47          |
| SYR-2      | 5.8          | 5.4         | 1.07        | S         | M       | 2                  | 5.15        | 6.5         | 7.15        | 7.5         | 0.45                | 0.57        | 0.16                | 0.16        | 0.50          |
| SYR-3      | 6.5          | 5           | 1.30        | NW        | M+F     | 1                  | 3.5         | 4           | 0           | 8.9         | 0.30                | 0.34        | 0.00                | 0.57        | 0.61          |
| <b>AVG</b> | <b>6.52</b>  | <b>4.83</b> | <b>1.38</b> |           |         |                    | <b>4.62</b> | <b>6.47</b> | <b>4.15</b> | <b>5.97</b> | <b>0.39</b>         | <b>0.54</b> | <b>0.20</b>         | <b>0.29</b> | <b>0.52</b>   |
| LBN-1      | 5.8          | 3.65        | 1.59        | E         | M+F     | 1                  | 5           | 11.8        | 7.75        | 7.3         | 0.37                | 0.87        | 0.70                | 0.66        | 0.45          |
| LBN-2      | 5.75         | 5.6         | 1.03        | SE        | M+F     | 1                  | 0           | 0           | 6           | 15.25       | 0.00                | 0.00        | 0.50                | 1.27        | 1.00          |
| LBN-3      | 7.75         | 5.25        | 1.48        | N         | M       | 2                  | 8           | 7.25        | 9.75        | 8           | 0.50                | 0.45        | 0.64                | 0.53        | 0.51          |
| LBN-4      | 5.3          | 5           | 1.06        | N         | M+F     | 1                  | 7.5         | 8.85        | 14.5        | 0           | 0.56                | 0.67        | 1.39                | 0.00        | 0.45          |
| LBN-5      | 6.85         | 3.8         | 1.80        | NW        | M+F     | 1                  | 5.7         | 7.75        | 4.65        | 5.15        | 0.83                | 1.13        | 0.30                | 0.34        | 0.34          |
| <b>AVG</b> | <b>6.29</b>  | <b>4.66</b> | <b>1.39</b> |           |         |                    | <b>5.24</b> | <b>7.13</b> | <b>8.53</b> | <b>7.14</b> | <b>0.45</b>         | <b>0.62</b> | <b>0.71</b>         | <b>0.56</b> | <b>0.53</b>   |
| PAL-1      | 5.50         | 5.10        | 1.08        | NE        | M+F     | 1                  | 0           | 10.85       | 6           | 6.8         | 0.00                | 1.52        | 0.85                | 0.96        | 0.40          |
| PAL-2      | 4.70         | 4.70        | 1.00        | NW        | M       | 2                  | 0           | 9.6         | 8.5         | 9.35        | 0.00                | 0.82        | 0.69                | 0.76        | 0.55          |
| PAL-3      | 4.60         | 3.20        | 1.44        | W         | M+F     | 1                  | 6.05        | 7.65        | 9.55        | 0           | 0.92                | 1.17        | 1.71                | 0.00        | 0.32          |
| <b>AVG</b> | <b>4.93</b>  | <b>4.33</b> | <b>1.17</b> |           |         |                    | <b>2.02</b> | <b>9.37</b> | <b>8.02</b> | <b>5.38</b> | <b>0.31</b>         | <b>1.17</b> | <b>1.08</b>         | <b>0.57</b> | <b>0.43</b>   |
| JOR-1      | 23.30        | 5.10        | 4.57        | E         | M+F     | 1                  | 9.4         | 8.65        | 2.3         | 2.3         | 0.94                | 0.87        | 0.19                | 0.19        | 0.36          |
| <b>AVG</b> | <b>23.30</b> | <b>5.10</b> | <b>4.57</b> |           |         |                    | <b>9.40</b> | <b>8.65</b> | <b>2.30</b> | <b>2.30</b> | <b>0.94</b>         | <b>0.87</b> | <b>0.19</b>         | <b>0.19</b> | <b>0.36</b>   |
| IRQ-1      | 5.20         | 3.20        | 1.63        | SE        | M+F     | 1                  | 9.8         | 2.15        | 3.05        | 4.7         | 1.17                | 0.26        | 0.46                | 0.70        | 0.41          |
| IRQ-2      | 5.95         | 3.85        | 1.55        | S         | M+F     | 1                  | 0           | 4.55        | 0           | 10.3        | 0.00                | 0.40        | 0.00                | 1.54        | 0.71          |
| IRQ-3      | 8.65         | 3.45        | 2.51        | S         | M+F     | 1                  | 7.85        | 3.35        | 12.3        | 8.3         | 0.92                | 0.39        | 1.51                | 1.02        | 0.43          |
| IRQ-4      | 5.75         | 2.75        | 2.09        | S         | M       | 2                  | 2.55        | 7.35        | 4.55        | 5           | 0.31                | 0.90        | 0.70                | 0.77        | 0.45          |
| IRQ-5      | 6.35         | 3.45        | 1.84        | E         | M+F     | 1                  | 7.45        | 4           | 6.3         | 4.15        | 0.63                | 0.34        | 0.63                | 0.42        | 0.51          |
| <b>AVG</b> | <b>6.38</b>  | <b>3.34</b> | <b>1.92</b> |           |         |                    | <b>5.53</b> | <b>4.28</b> | <b>5.24</b> | <b>6.49</b> | <b>0.61</b>         | <b>0.46</b> | <b>0.66</b>         | <b>0.89</b> | <b>0.49</b>   |
| <b>AVG</b> | <b>9.48</b>  | <b>4.45</b> | <b>2.13</b> |           |         |                    | <b>5.36</b> | <b>7.18</b> | <b>5.65</b> | <b>5.46</b> | <b>0.54</b>         | <b>0.73</b> | <b>0.57</b>         | <b>0.50</b> | <b>0.47</b>   |

## Spatial Data extracted from Traditional Houses located in North Africa

| Case       | Area (G)   | Area (1st) | Area (2nd)  | Area (3rd) | Area (4th) | Total without terraces | Total with terraces | Covered     |            | Open       |            | Total (covered+open) |
|------------|------------|------------|-------------|------------|------------|------------------------|---------------------|-------------|------------|------------|------------|----------------------|
|            |            |            |             |            |            |                        |                     |             |            |            |            |                      |
| EGY-1      | 363        |            |             |            |            | 363                    | 363                 | 325         | 90%        | 38         | 10%        | 363                  |
| EGY-2      | 533        | 503        | 140         |            |            | 1176                   | 1253                | 1075        | 91%        | 101        | 9%         | 1176                 |
| EGY-3      | 419        |            |             |            |            | 419                    | 454                 | 358         | 85%        | 61         | 15%        | 419                  |
| EGY-4      | 187        | 183        |             |            |            | 370                    | 373                 | 325         | 88%        | 45         | 12%        | 370                  |
| <b>AVG</b> | <b>376</b> | <b>343</b> | <b>140</b>  |            |            | <b>582</b>             | <b>620</b>          | <b>525</b>  | <b>90%</b> | <b>57</b>  | <b>10%</b> | <b>582</b>           |
| TUN-1      | 906        | 132        |             |            |            | 1038                   | 1038                | 797         | 77%        | 241        | 23%        | 1038                 |
| TUN-2      | 475        | 246        |             |            |            | 721                    | 777                 | 623         | 86%        | 98         | 14%        | 721                  |
| TUN-3      | 446        |            |             |            |            | 446                    | 446                 | 343         | 77%        | 103        | 23%        | 446                  |
| TUN-4-A    | 215        |            |             |            |            | 215                    | 215                 | 178         | 83%        | 37         | 17%        | 215                  |
| TUN-4-B    | 358        |            |             |            |            | 358                    | 358                 | 225         | 63%        | 133        | 37%        | 358                  |
| TUN-5-A    | 304        |            |             |            |            | 304                    | 304                 | 210         | 69%        | 94         | 31%        | 304                  |
| TUN-5-B    | 215        |            |             |            |            | 215                    | 215                 | 166         | 77%        | 49         | 23%        | 215                  |
| TUN-5-C    | 311        |            |             |            |            | 311                    | 311                 | 237         | 76%        | 74         | 24%        | 311                  |
| TUN-6      | 530        |            |             |            |            | 530                    | 530                 | 447         | 84%        | 83         | 16%        | 530                  |
| TUN-7      | 253        |            |             |            |            | 253                    | 253                 | 200         | 79%        | 53         | 21%        | 253                  |
| <b>AVG</b> | <b>401</b> | <b>189</b> |             |            |            | <b>439</b>             | <b>495</b>          | <b>343</b>  | <b>78%</b> | <b>97</b>  | <b>22%</b> | <b>439</b>           |
| MOR-1      | 925        | 798        |             |            |            | 1723                   | 1723                | 1586        | 92%        | 137        | 8%         | 1723                 |
| MOR-2      | 162        | 162        | 120         |            |            | 444                    | 486                 | 409         | 92%        | 35         | 8%         | 444                  |
| <b>AVG</b> | <b>544</b> |            |             |            |            | <b>1084</b>            | <b>1126</b>         | <b>998</b>  | <b>92%</b> | <b>86</b>  | <b>8%</b>  | <b>1084</b>          |
| ALG-1      | 1188       | 1089       | 1045        |            |            | 3322                   | 3322                | 3040        | 92%        | 282        | 8%         | 3322                 |
| ALG-2      | 65         | 48         |             |            |            | 113                    | 128                 | 106         | 94%        | 7          | 6%         | 113                  |
| <b>AVG</b> | <b>627</b> | <b>569</b> | <b>1045</b> |            |            | <b>1718</b>            | <b>1733</b>         | <b>1573</b> | <b>92%</b> | <b>145</b> | <b>8%</b>  | <b>1718</b>          |
| <b>AVG</b> | <b>487</b> | <b>367</b> | <b>593</b>  |            |            | <b>956</b>             | <b>993</b>          | <b>859</b>  | <b>88%</b> | <b>96</b>  | <b>12%</b> | <b>956</b>           |

| EXCLUDING TERRACES |           |     |             |     |             |     |           |     |            |     |                  |       |     |                |     |              |     |              |    |
|--------------------|-----------|-----|-------------|-----|-------------|-----|-----------|-----|------------|-----|------------------|-------|-----|----------------|-----|--------------|-----|--------------|----|
| Case               | Area (Pb) |     | Area (S-Pb) |     | Area (S-Pv) |     | Area (Pv) |     | Area (Int) |     | Sum of Hierarchy | Guest |     | Living covered |     | Main Court 1 |     | Main Court 2 |    |
| EGY-1              | 24        | 9%  | 77          | 30% | 38          | 15% | 71        | 27% | 50         | 19% | 260              | 73    | 28% | 16             | 6%  | 38           | 14% |              | 0% |
| EGY-2              | 24        | 3%  | 53          | 6%  | 182         | 20% | 507       | 55% | 162        | 17% | 928              | 53    | 6%  | 158            | 17% | 85           | 9%  | 21           | 2% |
| EGY-3              | 10        | 3%  | 58          | 19% | 121         | 39% | 57        | 18% | 67         | 21% | 313              | 23    | 7%  | 22             | 7%  | 61           | 18% |              | 0% |
| EGY-4              | 10        | 4%  | 20          | 8%  | 25          | 10% | 116       | 47% | 76         | 31% | 247              | 20    | 7%  | 15             | 5%  | 45           | 15% |              | 0% |
| AVG                | 17        | 4%  | 52          | 12% | 92          | 21% | 188       | 43% | 89         | 20% | 437              | 42    | 8%  | 53             | 10% | 57           | 11% | 21           | 4% |
| TUN-1              | 32        | 4%  | 58          | 7%  | 394         | 48% | 206       | 25% | 129        | 16% | 819              | 58    | 7%  | 109            | 13% | 241          | 29% |              | 0% |
| TUN-2              | 39        | 8%  | 28          | 6%  | 224         | 45% | 120       | 24% | 90         | 18% | 501              | 28    | 5%  | 50             | 9%  | 98           | 18% |              | 0% |
| TUN-3              | 38        | 11% | 13          | 4%  | 121         | 35% | 136       | 39% | 39         | 11% | 347              | 13    | 4%  | 81             | 24% | 103          | 30% |              | 0% |
| TUN-4-A            | 8         | 5%  | 20          | 12% | 52          | 31% | 55        | 33% | 31         | 19% | 166              | 20    | 13% | 43             | 28% | 37           | 24% |              | 0% |
| TUN-4-B            | 8         | 3%  | 10          | 3%  | 133         | 46% | 106       | 36% | 34         | 12% | 291              | 10    | 3%  | 70             | 24% | 133          | 46% |              | 0% |
| TUN-5-A            | 10        | 4%  |             | 0%  | 94          | 38% | 116       | 46% | 30         | 12% | 250              |       | 0%  | 75             | 30% | 94           | 38% |              | 0% |
| TUN-5-B            | 15        | 9%  |             | 0%  | 59          | 34% | 80        | 47% | 18         | 10% | 172              |       | 0%  | 26             | 15% | 49           | 28% |              | 0% |
| TUN-5-C            | 21        | 9%  |             | 0%  | 94          | 39% | 112       | 46% | 17         | 7%  | 244              |       | 0%  | 51             | 21% | 74           | 30% |              | 0% |
| TUN-6              | 37        | 10% | 39          | 11% | 112         | 31% | 158       | 43% | 20         | 5%  | 366              | 28    | 8%  | 75             | 20% | 83           | 23% |              | 0% |
| TUN-7              | 20        | 11% | 12          | 7%  | 61          | 34% | 60        | 34% | 24         | 14% | 177              | 10    | 6%  | 36             | 22% | 53           | 33% |              | 0% |
| AVG                | 23        | 7%  | 26          | 8%  | 134         | 39% | 115       | 34% | 43         | 13% | 341              | 24    | 5%  | 62             | 21% | 97           | 30% |              | 0  |
| MOR-1              | 27        | 2%  | 132         | 10% | 318         | 24% | 482       | 36% | 370        | 28% | 1329             | 132   | 10% | 170            | 12% | 137          | 10% |              | 0% |
| MOR-2              | 11        | 3%  | 19          | 6%  | 70          | 21% | 186       | 55% | 50         | 15% | 336              | 16    | 5%  | 11             | 3%  | 35           | 11% |              | 0% |
| AVG                | 19        | 2%  | 76          | 9%  | 194         | 23% | 334       | 40% | 210        | 25% | 832              | 74    | 7%  | 91             | 8%  | 86           | 10% |              | 0% |
| ALG-1              | 58        | 2%  | 148         | 6%  | 638         | 26% | 1251      | 51% | 367        | 15% | 2462             | 119   | 5%  | 156            | 7%  | 282          | 12% |              | 0% |
| ALG-2              | 13        | 0%  | 13          | 15% | 22          | 25% | 30        | 34% | 9          | 10% | 87               | 12    | 12% | 17             | 17% | 7            | 7%  |              | 0% |
| AVG                | 36        | 3%  | 81          | 6%  | 330         | 26% | 641       | 50% | 188        | 15% | 1275             | 66    | 8%  | 87             | 12% | 145          | 9%  |              | 0% |
| AVG                | 24        | 4%  | 58          | 9%  | 187         | 27% | 319       | 42% | 132        | 18% | 721              | 51    | 7%  | 73             | 13% | 96           | 15% | 21           | 1% |

| Case       | Serv. Court |           | Gallery    |            | Terraces  |           | Iwan      |           | Bedrooms   |            | Services with Kitch |            | Kitchen   | Main EN   |           | Service EN |           |
|------------|-------------|-----------|------------|------------|-----------|-----------|-----------|-----------|------------|------------|---------------------|------------|-----------|-----------|-----------|------------|-----------|
|            |             |           |            |            |           |           |           |           |            |            |                     |            |           |           |           |            |           |
| EGY-1      |             | 0%        |            | 0%         |           | 0%        |           | 0%        | 50         | 19%        | 35                  | 13%        | 17        | 24        | 9%        | 5          | 2%        |
| EGY-2      | 16          | 2%        |            | 0%         | 77        | 8%        |           | 0%        | 149        | 16%        | 154                 | 17%        |           | 24        | 3%        | 16         | 2%        |
| EGY-3      |             | 0%        |            | 0%         | 35        | 11%       | 42        | 13%       | 68         | 20%        | 40                  | 12%        | 14        | 10        | 3%        |            | 0%        |
| EGY-4      |             | 0%        |            | 0%         | 3         | 1%        |           | 0%        | 76         | 25%        | 70                  | 23%        | 14        | 10        | 3%        |            | 0%        |
| <b>AVG</b> |             | <b>0%</b> |            | <b>0%</b>  | <b>38</b> | <b>8%</b> | <b>42</b> | <b>8%</b> | <b>86</b>  | <b>17%</b> | <b>75</b>           | <b>15%</b> |           | <b>17</b> | <b>3%</b> | <b>11</b>  | <b>2%</b> |
| TUN-1      |             | 0%        | 34         | 4%         |           | 0%        |           | 0%        | 129        | 16%        | 54                  | 7%         | 40        | 32        | 4%        |            | 0%        |
| TUN-2      |             | 0%        | 105        | 19%        | 56        | 10%       | 21        | 4%        | 90         | 16%        | 53                  | 10%        | 27        | 39        | 7%        |            | 0%        |
| TUN-3      |             | 0%        |            | 0%         |           | 0%        |           | 0%        | 39         | 11%        | 55                  | 16%        | 18        | 30        | 9%        |            | 0%        |
| TUN-4-A    |             | 0%        |            | 0%         |           | 0%        |           | 0%        | 31         | 20%        | 13                  | 8%         | 9         | 8         | 5%        |            | 0%        |
| TUN-4-B    |             | 0%        |            | 0%         |           | 0%        |           | 0%        | 34         | 12%        | 36                  | 12%        | 8         | 8         | 3%        |            | 0%        |
| TUN-5-A    |             | 0%        |            | 0%         |           | 0%        |           | 0%        | 30         | 12%        | 41                  | 16%        | 16        | 10        | 4%        |            | 0%        |
| TUN-5-B    |             | 0%        |            | 0%         |           | 0%        | 10        | 6%        | 18         | 10%        | 54                  | 31%        | 10        | 15        | 9%        |            | 0%        |
| TUN-5-C    |             | 0%        |            | 0%         |           | 0%        | 20        | 8%        | 17         | 7%         | 60                  | 25%        | 14        | 21        | 9%        |            | 0%        |
| TUN-6      |             | 0%        | 10         | 3%         |           | 0%        |           | 0%        | 20         | 5%         | 70                  | 19%        | 27        | 37        | 10%       | 8          | 2%        |
| TUN-7      |             | 0%        | 8          | 5%         |           | 0%        |           | 0%        | 24         | 15%        | 13                  | 8%         | 7         | 9         | 6%        |            | 0%        |
| <b>AVG</b> |             | <b>0%</b> | <b>39</b>  | <b>3%</b>  | <b>56</b> | <b>1%</b> | <b>17</b> | <b>2%</b> | <b>43</b>  | <b>12%</b> | <b>45</b>           | <b>15%</b> | <b>18</b> | <b>21</b> | <b>6%</b> | <b>8</b>   | <b>0%</b> |
| MOR-1      |             | 0%        | 401        | 29%        |           | 0%        |           | 0%        | 370        | 27%        | 64                  | 5%         | 44        | 27        | 2%        |            | 0%        |
| MOR-2      |             | 0%        |            | 0%         | 42        | 13%       |           | 0%        | 50         | 16%        | 132                 | 41%        |           | 11        | 3%        | 4          | 1%        |
| <b>AVG</b> |             | <b>0%</b> | <b>401</b> | <b>15%</b> | <b>42</b> | <b>7%</b> | <b>0%</b> | <b>0%</b> | <b>210</b> | <b>21%</b> | <b>98</b>           | <b>23%</b> | <b>44</b> | <b>19</b> | <b>3%</b> | <b>4</b>   | <b>1%</b> |
| ALG-1      |             | 0%        | 182        | 8%         |           | 0%        |           | 0%        | 324        | 14%        | 931                 | 39%        |           | 58        | 2%        |            | 0%        |
| ALG-2      |             | 0%        | 10         | 10%        | 15        | 15%       |           | 0%        | 9          | 9%         | 14                  | 14%        | 6         | 13        | 13%       |            | 0%        |
| <b>AVG</b> |             | <b>0%</b> | <b>96</b>  | <b>9%</b>  | <b>15</b> | <b>7%</b> | <b>0%</b> | <b>0%</b> | <b>167</b> | <b>11%</b> | <b>473</b>          | <b>26%</b> | <b>6</b>  | <b>36</b> | <b>8%</b> |            | <b>0%</b> |
| <b>AVG</b> |             | <b>0%</b> | <b>179</b> | <b>7%</b>  | <b>38</b> | <b>6%</b> | <b>30</b> | <b>3%</b> | <b>126</b> | <b>15%</b> | <b>173</b>          | <b>20%</b> | <b>23</b> | <b>23</b> | <b>5%</b> | <b>8</b>   | <b>1%</b> |

| Case       | Corridor & Stairs |            | Total       | Distance (Court - Center) |              | Distance (Court2 - Center) |              | Thick. Of Walls | Main Court   |              |             |           | Service Court |             |             |           |  |
|------------|-------------------|------------|-------------|---------------------------|--------------|----------------------------|--------------|-----------------|--------------|--------------|-------------|-----------|---------------|-------------|-------------|-----------|--|
|            |                   |            |             | x                         | y            | x                          | y            |                 | x            | y            | prop.       | direction | x             | y           | prop.       | direction |  |
| EGY-1      | 23                | 9%         | 264         | 2.45                      | -0.63        |                            |              | 65              | 6.8          | 5.55         | 1.23        |           |               |             |             |           |  |
| EGY-2      | 158               | 17%        | 911         | -0.23                     | -4.25        | -8.83                      | 3.71         | 85              | 9.5          | 9.5          | 1.00        | CEN.      | 3.85          | 4.5         | 0.86        | NE        |  |
| EGY-3      | 31                | 9%         | 332         | -2.66                     | -4.02        |                            |              | 55              | 6.6          | 9.1          | 0.73        | SE        |               |             |             |           |  |
| EGY-4      | 62                | 21%        | 301         | -1.19                     | -2.21        |                            |              | 35              | 9            | 5            | 1.80        | S         |               |             |             |           |  |
| <b>AVG</b> | <b>69</b>         | <b>13%</b> | <b>510</b>  | <b>-0.41</b>              | <b>-2.78</b> | <b>-8.83</b>               | <b>3.71</b>  | <b>60</b>       | <b>7.98</b>  | <b>7.29</b>  | <b>1.19</b> |           | <b>3.85</b>   | <b>4.50</b> | <b>0.86</b> |           |  |
| TUN-1      | 163               | 20%        | 820         | 3.85                      | 1.19         |                            |              | 80              | 14.35        | 9.35         | 1.53        | E         |               |             |             |           |  |
| TUN-2      | 14                | 3%         | 554         | 1.16                      | 3.97         |                            |              | 120             | 8            | 11.85        | 0.68        | E         |               |             |             |           |  |
| TUN-3      | 22                | 6%         | 343         | 0.25                      | 0.49         |                            |              | 67              | 10.4         | 10.3         | 1.01        | CEN.      |               |             |             |           |  |
| TUN-4-A    | 2                 | 1%         | 154         | 6.35                      | 8.80         | 0.00                       | -0.50        | 50              | 6.35         | 8.8          | 0.72        | CEN.      |               |             |             |           |  |
| TUN-4-B    |                   | 0%         | 291         | 0.00                      | 0.00         |                            |              | 50              | 11.7         | 11.05        | 1.06        | CEN.      |               |             |             |           |  |
| TUN-5-A    |                   | 0%         | 250         | 0.00                      | 0.00         |                            |              | 50              | 13.65        | 6.95         | 1.96        | CEN.      |               |             |             |           |  |
| TUN-5-B    |                   | 0%         | 172         | 0.00                      | 0.00         |                            |              | 50              | 9.75         | 4.6          | 2.12        | CEN.      |               |             |             |           |  |
| TUN-5-C    |                   | 0%         | 243         | -1.35                     | 0.28         |                            |              | 50              | 13.15        | 5.55         | 2.37        | CEN.      |               |             |             |           |  |
| TUN-6      | 37                | 10%        | 368         | 0.96                      | -0.28        |                            |              | 75              | 9.1          | 9.05         | 1.01        | CEN.      |               |             |             |           |  |
| TUN-7      | 10                | 6%         | 163         | 0.65                      | 1.05         |                            |              | 70              | 7            | 7.4          | 0.95        | CEN.      |               |             |             |           |  |
| <b>AVG</b> | <b>41</b>         | <b>5%</b>  | <b>336</b>  | <b>1</b>                  | <b>1.55</b>  | <b>0</b>                   | <b>-0.50</b> | <b>66</b>       | <b>10.35</b> | <b>8.49</b>  | <b>1.34</b> |           |               |             |             |           |  |
| MOR-1      | 71                | 5%         | 1372        | 0.00                      | 0.00         |                            |              | 100             | 16.75        | 18.75        | 0.89        |           |               |             |             |           |  |
| MOR-2      | 21                | 7%         | 322         | 0.40                      | -0.91        |                            |              | 50              | 5.80         | 6.10         | 0.95        | CEN.      | 8.20          | 1.90        | 4.32        | NE        |  |
| <b>AVG</b> | <b>46</b>         | <b>6%</b>  | <b>847</b>  | <b>0</b>                  | <b>0</b>     |                            |              | <b>75</b>       | <b>11.28</b> | <b>12.43</b> | <b>0.92</b> |           | <b>8.20</b>   | <b>1.90</b> | <b>4.32</b> |           |  |
| ALG-1      | 334               | 14%        | 2386        | -0.60                     | 0.60         |                            |              | 85              | 11.35        | 10.90        | 1.04        |           |               |             |             |           |  |
| ALG-2      | 4                 | 4%         | 101         | 1.85                      | -0.17        |                            |              | 25              | 2.40         | 2.90         | 0.83        | W         |               |             |             |           |  |
| <b>AVG</b> | <b>169</b>        | <b>9%</b>  | <b>1244</b> | <b>0.63</b>               | <b>0.22</b>  |                            |              | <b>55</b>       | <b>6.88</b>  | <b>6.90</b>  | <b>0.93</b> |           |               |             |             |           |  |
| <b>AVG</b> | <b>81</b>         | <b>8%</b>  | <b>734</b>  | <b>1.60</b>               | <b>-1.47</b> | <b>-8.83</b>               | <b>3.21</b>  | <b>64.05</b>    | <b>9.12</b>  | <b>8.78</b>  | <b>1.10</b> |           | <b>6.03</b>   | <b>3.20</b> | <b>2.59</b> |           |  |

| Case    | Iwan-1      |             |             |             |             |           | Iwan-2      |             |             |            |             |           | Main Liv     |             |             |           |
|---------|-------------|-------------|-------------|-------------|-------------|-----------|-------------|-------------|-------------|------------|-------------|-----------|--------------|-------------|-------------|-----------|
|         | Y           | X           | prop.       | X(IW):X(C)  | Y(IW):Y(C)  | direction | Y           | X           | prop.       | X(IW):X(C) | Y(IW):Y(C)  | direction | x            | y           | prop.       | direction |
| EGY-1   |             |             |             |             |             |           |             |             |             |            |             |           | 4.9          | 3.17        | 1.55        |           |
| EGY-2   |             |             |             |             |             |           |             |             |             |            |             |           | 5.7          | 5.65        | 1.01        | E         |
| EGY-3   | 4.2         | 4.2         | 1.00        | 0.64        |             | S         | 5.2         | 2.45        | 2.12        |            | 0.57        | E         | 4.85         | 4.15        | 1.17        | E         |
| EGY-4   |             |             |             |             |             |           |             |             |             |            |             |           |              |             |             |           |
| AVG     | <b>4.20</b> | <b>4.20</b> | <b>1.00</b> | <b>0.64</b> |             |           | <b>5.20</b> | <b>2.45</b> | <b>2.12</b> |            | <b>0.57</b> |           | <b>5.15</b>  | <b>4.32</b> | <b>1.24</b> |           |
| TUN-1   |             |             |             |             |             |           |             |             |             |            |             |           | 13.8         | 3.75        | 3.68        | S         |
| TUN-2   | 3.25        | 6.4         | 0.51        | 0.80        |             | N         |             |             |             |            |             |           | 11.65        | 3.3         | 3.53        | W         |
| TUN-3   |             |             |             |             |             |           |             |             |             |            |             |           | 9.45         | 4.1         | 2.30        | N         |
| TUN-4-A |             |             |             |             |             |           |             |             |             |            |             |           | 6.35         | 2.85        | 2.23        | N         |
| TUN-4-B |             |             |             |             |             |           |             |             |             |            |             |           | 6.35         | 3           | 2.12        | N         |
| TUN-5-A |             |             |             |             |             |           |             |             |             |            |             |           | 9.75         | 3.2         | 3.05        | S         |
| TUN-5-B | 3.5         | 2.85        | 1.23        | 0.29        |             | S         |             |             |             |            |             |           | 4.6          | 2.75        | 1.67        | W         |
| TUN-5-C | 7.45        | 3.35        | 2.22        |             | 1.34        | E         |             |             |             |            |             |           | 2.85         | 5.6         | 0.51        | W         |
| TUN-6   |             |             |             |             |             |           |             |             |             |            |             |           | 9.9          | 2.6         | 3.81        | E         |
| TUN-7   |             |             |             |             |             |           |             |             |             |            |             |           | 8.25         | 2.85        | 2.89        | N         |
| AVG     | <b>4.73</b> | <b>4.20</b> | <b>1.32</b> | <b>0.55</b> | <b>1.34</b> |           |             |             |             |            |             |           | <b>8.30</b>  | <b>3.40</b> | <b>2.58</b> |           |
| MOR-1   |             |             |             |             |             |           |             |             |             |            |             |           | 19.60        | 5.35        | 3.66        | E         |
| MOR-2   |             |             |             |             |             |           |             |             |             |            |             |           | 5.40         | 1.90        | 2.84        | N         |
| AVG     |             |             |             |             |             |           |             |             |             |            |             |           | <b>12.50</b> | <b>3.63</b> | <b>3.25</b> |           |
| ALG-1   |             |             |             |             |             |           |             |             |             |            |             |           | 11.10        | 7.40        | 1.50        | N         |
| ALG-2   |             |             |             |             |             |           |             |             |             |            |             |           | 4.25         | 2.20        | 1.93        | E         |
| AVG     |             |             |             |             |             |           |             |             |             |            |             |           | <b>7.68</b>  | <b>4.80</b> | <b>1.72</b> |           |
| AVG     | <b>4.47</b> | <b>4.20</b> | <b>1.16</b> | <b>0.59</b> | <b>1.34</b> |           | <b>5.20</b> | <b>2.45</b> | <b>2.12</b> |            | <b>0.57</b> |           | <b>8.41</b>  | <b>4.04</b> | <b>2.20</b> |           |

| Case       | Guest        |             |             |           |         |                    | Rooms       |             |             |             | X(Rooms)/X(Main-Court) |             | Y(Rooms)/Y(Main-Court) |             | x(MC) / X(L) |
|------------|--------------|-------------|-------------|-----------|---------|--------------------|-------------|-------------|-------------|-------------|------------------------|-------------|------------------------|-------------|--------------|
|            | x            | y           | prop.       | direction | M/F/M+F | No. of Guest Rooms | E           | W           | N           | S           | E                      | W           | N                      | S           |              |
| EGY-1      | 10.3         | 4           | 2.58        | SW        | M       | 2                  | 4.15        | 4.2         | 8.25        | 5.25        | 0.61                   | 0.62        | 1.49                   | 0.95        | 0.45         |
| EGY-2      | 8.1          | 5           | 1.62        | S         | M       | 1                  | 13.15       | 4.25        | 7.65        | 4.7         | 1.38                   | 0.45        | 0.81                   | 0.49        | 0.35         |
| EGY-3      | 5.25         | 4.55        | 1.15        | CEN.      | M+F     | 1                  | 13.35       | 5.6         | 11.85       | 0           | 2.02                   | 0.85        | 1.30                   | 0.00        | 0.26         |
| EGY-4      | 3.25         | 3.15        | 1.03        | N         | M       | 2                  | 5.25        | 4.75        | 4.25        | 0           | 0.58                   | 0.53        | 0.85                   | 0.00        | 0.47         |
| <b>AVG</b> | <b>6.73</b>  | <b>4.18</b> | <b>1.60</b> |           |         |                    | <b>8.98</b> | <b>4.70</b> | <b>8.00</b> | <b>2.49</b> | <b>1.15</b>            | <b>0.61</b> | <b>1.11</b>            | <b>0.36</b> | <b>0.37</b>  |
| TUN-1      | 14.55        | 3.85        | 3.78        | SE        | M+F     | 1                  | 7.6         | 14          | 5.4         | 9           | 0.53                   | 0.98        | 0.58                   | 0.96        | 0.40         |
| TUN-2      | 10.1         | 3.1         | 3.26        | S         | M+F     | 1                  | 0           | 8.8         | 7.8         | 5.5         | 0.00                   | 1.10        | 0.66                   | 0.46        | 0.48         |
| TUN-3      | 4.9          | 2.5         | 1.96        | W         | M+F     | 1                  | 4.8         | 5.3         | 5.3         | 6.25        | 0.46                   | 0.51        | 0.51                   | 0.61        | 0.51         |
| TUN-4-A    | 6.35         | 2.95        | 2.15        | S         | M+F     | 1                  | 4.05        | 3.55        | 3.85        | 3.45        | 0.64                   | 0.56        | 0.44                   | 0.39        | 0.46         |
| TUN-4-B    | 3.15         | 3           | 1.05        | NE        | M+F     | 1                  | 4           | 3.55        | 4           | 3.85        | 0.34                   | 0.30        | 0.36                   | 0.35        | 0.61         |
| TUN-5-A    |              |             |             |           |         |                    | 4.1         | 3.75        | 3.75        | 3.75        | 0.30                   | 0.27        | 0.54                   | 0.54        | 0.63         |
| TUN-5-B    |              |             |             |           |         |                    | 3.9         | 3.75        | 4.25        | 3.5         | 0.40                   | 0.38        | 0.92                   | 0.76        | 0.56         |
| TUN-5-C    |              |             |             |           |         |                    | 4.15        | 3.9         | 4           | 3.9         | 0.32                   | 0.30        | 0.72                   | 0.70        | 0.62         |
| TUN-6      | 8.15         | 4.7         | 1.73        | S         | M+F     | 1                  | 8.35        | 9.5         | 7.75        | 7           | 0.92                   | 1.04        | 0.86                   | 0.77        | 0.34         |
| TUN-7      | 4.45         | 2.75        | 1.62        | E         | M+F     | 1                  | 3.4         | 4.1         | 3.4         | 7           | 0.49                   | 0.59        | 0.46                   | 0.95        | 0.48         |
| <b>AVG</b> | <b>7.38</b>  | <b>3.26</b> | <b>2.22</b> |           |         |                    | <b>4.44</b> | <b>6.02</b> | <b>4.95</b> | <b>5.32</b> | <b>0.44</b>            | <b>0.60</b> | <b>0.60</b>            | <b>0.65</b> | <b>0.50</b>  |
| MOR-1      | 16.50        | 4.85        | 3.40        | W         | M       | 2                  | 10          | 9.6         | 9.4         | 9.3         | 0.60                   | 0.57        | 0.50                   | 0.50        | 0.46         |
| MOR-2      | 8.20         | 1.90        | 4.32        | N         | M+F     | 1                  | 2.8         | 2.9         | 5.9         | 3.3         | 0.48                   | 0.50        | 0.97                   | 0.54        | 0.50         |
| <b>AVG</b> | <b>12.35</b> | <b>3.38</b> | <b>3.86</b> |           |         |                    | <b>6.40</b> | <b>6.25</b> | <b>7.65</b> | <b>6.30</b> | <b>0.54</b>            | <b>0.54</b> | <b>0.73</b>            | <b>0.52</b> | <b>0.47</b>  |
| ALG-1      | 10.95        | 3.65        | 3.00        | S         | M       | 2                  | 11.15       | 4.35        | 12.35       | 8.4         | 0.98                   | 0.38        | 1.13                   | 0.77        | 0.42         |
| ALG-2      | 6.10         | 1.90        | 3.21        | S         | M+F     | 1                  | 4           | 0           | 3.25        | 3.65        | 1.67                   | 0.00        | 1.12                   | 1.26        | 0.38         |
| <b>AVG</b> | <b>8.53</b>  | <b>2.78</b> | <b>3.11</b> |           |         |                    | <b>7.58</b> | <b>2.18</b> | <b>7.80</b> | <b>6.03</b> | <b>1.32</b>            | <b>0.19</b> | <b>1.13</b>            | <b>1.01</b> | <b>0.41</b>  |
| <b>AVG</b> | <b>8.74</b>  | <b>3.40</b> | <b>2.70</b> |           |         |                    | <b>6.85</b> | <b>4.79</b> | <b>7.10</b> | <b>5.03</b> | <b>0.86</b>            | <b>0.49</b> | <b>0.89</b>            | <b>0.64</b> | <b>0.44</b>  |

### Spatial Data extracted from Traditional Houses located in the Gulf Area

| Case       | Area (G)    | Area (1st) | Area (2nd) | Area (3rd) | Area (4th) | Area (5th) | Total excluding terraces | Total with terraces | Covered     |            | Open       |            | Total (covered+open) |
|------------|-------------|------------|------------|------------|------------|------------|--------------------------|---------------------|-------------|------------|------------|------------|----------------------|
| OMA        | 355         | 168        |            |            |            |            | 523                      | 669                 | 417         | 80%        | 106        | 20%        | 523                  |
| <b>AVG</b> | <b>355</b>  | <b>168</b> |            |            |            |            | <b>523</b>               | <b>669</b>          | <b>417</b>  | <b>80%</b> | <b>106</b> | <b>20%</b> | <b>523</b>           |
| UAE        | 1185        | 867        |            |            |            |            | 2052                     | 2060                | 1773        | 86%        | 279        | 14%        | 2052                 |
| <b>AVG</b> | <b>1185</b> | <b>867</b> |            |            |            |            | <b>2052</b>              | <b>2060</b>         | <b>1773</b> | <b>86%</b> | <b>279</b> | <b>14%</b> | <b>2052</b>          |
| KSA-1      | 364         |            |            |            |            |            | 364                      | 364                 | 317         | 87%        | 47         | 13%        | 364                  |
| KSA-2      | 687         |            |            |            |            |            | 687                      | 851                 | 627         | 91%        | 60         | 9%         | 687                  |
| KSA-3      | 464         | 192        |            |            |            |            | 656                      | 899                 | 630         | 96%        | 26         | 4%         | 656                  |
| KSA-4      | 305         | 217        |            |            |            |            | 522                      | 522                 | 433         | 83%        | 89         | 17%        | 522                  |
| KSA-5      | 153         | 165        | 150        |            |            |            | 468                      | 569                 | 423         | 90%        | 45         | 10%        | 468                  |
| <b>AVG</b> | <b>395</b>  | <b>191</b> | <b>150</b> |            |            |            | <b>539</b>               | <b>709</b>          | <b>467</b>  | <b>87%</b> | <b>72</b>  | <b>13%</b> | <b>539</b>           |
| KUW-1      | 1332        |            |            |            |            |            | 1332                     | 1530                | 1160        | 87%        | 172        | 13%        | 1332                 |
| KUW-2      | 458         |            |            |            |            |            | 458                      | 458                 | 358         | 78%        | 100        | 22%        | 458                  |
| KUW-3      | 413         |            |            |            |            |            | 413                      | 413                 | 321         | 78%        | 92         | 22%        | 413                  |
| <b>AVG</b> | <b>734</b>  |            |            |            |            |            | <b>734</b>               | <b>800</b>          | <b>613</b>  | <b>83%</b> | <b>121</b> | <b>17%</b> | <b>734</b>           |
| YEM-1      | 167         | 133        | 158        | 162        | 162        | 65         | 847                      | 984                 | 827         | 98%        | 20         | 2%         | 847                  |
| YEM-2      | 109         | 147        | 117        |            |            |            | 373                      | 405                 | 347         | 93%        | 26         | 7%         | 373                  |
| <b>AVG</b> | <b>138</b>  | <b>140</b> | <b>138</b> | <b>162</b> | <b>162</b> | <b>65</b>  | <b>610</b>               | <b>695</b>          | <b>587</b>  | <b>96%</b> | <b>23</b>  | <b>4%</b>  | <b>610</b>           |
| <b>AVG</b> | <b>561</b>  | <b>342</b> | <b>144</b> | <b>162</b> | <b>162</b> | <b>65</b>  | <b>892</b>               | <b>987</b>          | <b>771</b>  | <b>86%</b> | <b>120</b> | <b>14%</b> | <b>892</b>           |

EXCLUDING TERRACES

| Case  | Area (Pb) |           | Area (S-Pb) |            | Area (S-Pv) |            | Area (Pv)  |            | Area (Int) |            | Sum of Hierarchy | Guest     |           | Living covered |            | Main Court 1 |            | Main Court 2 |           |
|-------|-----------|-----------|-------------|------------|-------------|------------|------------|------------|------------|------------|------------------|-----------|-----------|----------------|------------|--------------|------------|--------------|-----------|
|       |           |           |             |            |             |            |            |            |            |            |                  |           |           |                |            |              |            |              |           |
| OMA   | 16        | 3%        | 53          | 10%        | 115         | 22%        | 280        | 53%        | 61         | 12%        | 525              | 53        | 8%        | 53             | 8%         | 106          | 16%        |              | 0%        |
| AVG   | <b>16</b> | <b>3%</b> | <b>53</b>   | <b>10%</b> | <b>115</b>  | <b>22%</b> | <b>280</b> | <b>53%</b> | <b>61</b>  | <b>12%</b> | <b>525</b>       | <b>53</b> | <b>8%</b> | <b>53</b>      | <b>8%</b>  | <b>106</b>   | <b>16%</b> |              | <b>0%</b> |
| UAE   | 33        | 2%        | 62          | 4%         | 440         | 28%        | 789        | 51%        | 228        | 15%        | 1552             | 53        | 3%        | 281            | 18%        | 279          | 17%        |              | 0%        |
| AVG   | <b>33</b> | <b>2%</b> | <b>62</b>   | <b>4%</b>  | <b>440</b>  | <b>28%</b> | <b>789</b> | <b>51%</b> | <b>228</b> | <b>15%</b> | <b>1552</b>      | <b>53</b> | <b>3%</b> | <b>281</b>     | <b>18%</b> | <b>279</b>   | <b>17%</b> | <b>0</b>     | <b>0%</b> |
| KSA-1 | 10        | 4%        | 52          | 19%        | 121         | 44%        | 64         | 23%        | 30         | 11%        | 277              | 42        | 16%       | 9              | 3%         | 31           | 12%        |              | 0%        |
| KSA-2 | 44        | 8%        | 104         | 19%        | 125         | 23%        | 191        | 35%        | 80         | 15%        | 544              | 46        | 7%        | 37             | 6%         | 60           | 9%         |              | 0%        |
| KSA-3 | 12        | 2%        | 85          | 17%        | 70          | 14%        | 250        | 50%        | 81         | 16%        | 498              | 72        | 9%        | 146            | 18%        | 26           | 3%         |              | 0%        |
| KSA-4 | 23        | 5%        | 62          | 15%        | 152         | 36%        | 142        | 33%        | 46         | 11%        | 425              | 52        | 14%       | 26             | 7%         | 42           | 11%        |              | 0%        |
| KSA-5 | 11        | 3%        | 18          | 4%         | 72          | 17%        | 264        | 62%        | 62         | 15%        | 427              | 18        | 3%        | 69             | 13%        | 45           | 8%         |              | 0%        |
| AVG   | <b>20</b> | <b>5%</b> | <b>64</b>   | <b>15%</b> | <b>108</b>  | <b>25%</b> | <b>182</b> | <b>42%</b> | <b>60</b>  | <b>14%</b> | <b>434</b>       | <b>46</b> | <b>9%</b> | <b>57</b>      | <b>11%</b> | <b>41</b>    | <b>8%</b>  |              | <b>0%</b> |
| KUW-1 | 53        | 5%        | 152         | 14%        | 355         | 32%        | 283        | 25%        | 269        | 24%        | 1112             | 65        | 6%        | 44             | 4%         | 104          | 9%         | 45           | 4%        |
| KUW-2 | 15        | 4%        | 50          | 13%        | 100         | 27%        | 109        | 29%        | 98         | 26%        | 372              | 46        | 12%       | 43             | 11%        | 100          | 27%        |              | 0%        |
| KUW-3 | 10        | 3%        | 35          | 9%         | 215         | 56%        | 71         | 18%        | 55         | 14%        | 386              | 35        | 10%       | 43             | 12%        | 92           | 26%        |              | 0%        |
| AVG   | <b>26</b> | <b>4%</b> | <b>79</b>   | <b>13%</b> | <b>223</b>  | <b>36%</b> | <b>154</b> | <b>25%</b> | <b>141</b> | <b>23%</b> | <b>623</b>       | <b>49</b> | <b>7%</b> | <b>43</b>      | <b>6%</b>  | <b>99</b>    | <b>13%</b> | <b>45</b>    | <b>6%</b> |
| YEM-1 | 18        | 3%        | 32          | 6%         | 75          | 13%        | 374        | 67%        | 61         | 11%        | 560              | 27        | 4%        | 64             | 9%         | 20           | 3%         |              | 0%        |
| YEM-2 | 9         | 4%        | 47          | 21%        | 30          | 13%        | 113        | 50%        | 25         | 11%        | 224              | 25        | 10%       | 31             | 12%        | 26           | 10%        |              | 0%        |
| AVG   | <b>14</b> | <b>3%</b> | <b>40</b>   | <b>10%</b> | <b>53</b>   | <b>13%</b> | <b>244</b> | <b>62%</b> | <b>43</b>  | <b>11%</b> | <b>392</b>       | <b>26</b> | <b>5%</b> | <b>48</b>      | <b>10%</b> | <b>23</b>    | <b>5%</b>  |              |           |
| AVG   | <b>22</b> | <b>3%</b> | <b>60</b>   | <b>10%</b> | <b>188</b>  | <b>25%</b> | <b>330</b> | <b>47%</b> | <b>106</b> | <b>15%</b> | <b>705</b>       | <b>45</b> | <b>6%</b> | <b>96</b>      | <b>10%</b> | <b>109</b>   | <b>12%</b> | <b>23</b>    | <b>2%</b> |

| Case  | Serv. Court |           | Gallery    |            | Terraces   |            | Iwan |           | Bedrooms   |            | Services with Kitch |            | Kitchen   | Main EN   |           | Service EN |           | Corridor & Stairs |            | Total       |
|-------|-------------|-----------|------------|------------|------------|------------|------|-----------|------------|------------|---------------------|------------|-----------|-----------|-----------|------------|-----------|-------------------|------------|-------------|
|       |             |           |            |            |            |            |      |           |            |            |                     |            |           |           |           |            |           |                   |            |             |
| OMA   |             | 0%        |            | 0%         | 146        | 22%        |      | 0%        | 61         | 9%         | 60                  | 9%         | 16        | 16        | 2%        |            | 0%        | 177               | 26%        | 672         |
| AVG   |             | <b>0%</b> |            | <b>0%</b>  | <b>146</b> | <b>22%</b> |      | <b>0%</b> | <b>61</b>  | <b>9%</b>  | <b>60</b>           | <b>9%</b>  |           | <b>16</b> | <b>2%</b> |            | <b>0%</b> | <b>177</b>        | <b>26%</b> | <b>672</b>  |
| UAE   |             | 0%        | 200        | 13%        | 8          | 1%         |      | 0%        | 203        | 13%        | 318                 | 20%        |           | 17        | 1%        | 21         | 1%        | 218               | 14%        | 1598        |
| AVG   |             | <b>0%</b> | <b>200</b> | <b>13%</b> | <b>8</b>   | <b>1%</b>  |      | <b>0%</b> | <b>203</b> | <b>13%</b> | <b>318</b>          | <b>20%</b> |           | <b>17</b> | <b>1%</b> | <b>21</b>  | <b>1%</b> | <b>218</b>        | <b>14%</b> | <b>1598</b> |
| KSA-1 | 16          | 6%        | 53         | 20%        |            | 0%         |      | 0%        | 30         | 11%        | 37                  | 14%        | 8         | 10        | 4%        | 13         | 5%        | 22                | 8%         | 263         |
| KSA-2 |             | 0%        | 65         | 10%        | 164        | 25%        |      | 0%        | 80         | 12%        | 91                  | 14%        | 37        | 36        | 6%        | 12         | 2%        | 60                | 9%         | 651         |
| KSA-3 |             | 0%        | 54         | 7%         | 243        | 31%        |      | 0%        | 82         | 10%        | 92                  | 12%        | 31        | 12        | 2%        |            | 0%        | 69                | 9%         | 796         |
| KSA-4 | 47          | 12%       | 53         | 14%        |            | 0%         |      | 0%        | 46         | 12%        | 50                  | 13%        |           | 23        | 6%        |            | 0%        | 42                | 11%        | 381         |
| KSA-5 |             | 0%        |            | 0%         | 101        | 19%        |      | 0%        | 56         | 11%        | 127                 | 24%        |           | 18        | 3%        |            | 0%        | 97                | 18%        | 531         |
| AVG   | <b>32</b>   | <b>6%</b> | <b>56</b>  | <b>11%</b> | <b>169</b> | <b>32%</b> |      | <b>0%</b> | <b>59</b>  | <b>11%</b> | <b>79</b>           | <b>15%</b> | <b>25</b> | <b>20</b> | <b>4%</b> | <b>13</b>  | <b>2%</b> | <b>58</b>         | <b>11%</b> | <b>524</b>  |
| KUW-1 | 68          | 6%        | 135        | 11%        | 198        | 17%        |      | 0%        | 193        | 16%        | 146                 | 12%        | 37        | 53        | 5%        | 12         | 1%        | 113               | 10%        | 1176        |
| KUW-2 |             | 0%        | 11         | 3%         |            | 0%         |      | 0%        | 94         | 25%        | 36                  | 10%        | 6         | 15        | 4%        |            | 0%        | 29                | 8%         | 374         |
| KUW-3 |             | 0%        | 79         | 23%        |            | 0%         |      | 0%        | 55         | 16%        | 20                  | 6%         | 20        | 10        | 3%        | 8          | 2%        | 9                 | 3%         | 351         |
| AVG   | <b>68</b>   | <b>9%</b> | <b>79</b>  | <b>11%</b> | <b>198</b> | <b>27%</b> |      | <b>0%</b> | <b>55</b>  | <b>7%</b>  | <b>20</b>           | <b>3%</b>  | <b>21</b> | <b>26</b> | <b>4%</b> | <b>10</b>  | <b>1%</b> | <b>50</b>         | <b>7%</b>  | <b>742</b>  |
| YEM-1 |             | 0%        |            | 0%         | 137        | 19%        |      | 0%        | 61         | 9%         | 212                 | 30%        | 20        | 17        | 2%        |            | 0%        | 165               | 23%        | 703         |
| YEM-2 |             | 0%        |            | 0%         | 32         | 12%        |      | 0%        | 25         | 10%        | 78                  | 30%        | 21        | 9         | 3%        |            | 0%        | 34                | 13%        | 260         |
| AVG   |             |           |            |            | <b>85</b>  | <b>18%</b> |      |           | <b>43</b>  | <b>9%</b>  | <b>145</b>          | <b>30%</b> | <b>21</b> | <b>13</b> | <b>3%</b> |            |           | <b>100</b>        | <b>21%</b> | <b>482</b>  |
| AVG   | <b>50</b>   | <b>4%</b> | <b>112</b> | <b>8%</b>  | <b>121</b> | <b>20%</b> |      |           | <b>84</b>  | <b>10%</b> | <b>124</b>          | <b>15%</b> | <b>22</b> | <b>18</b> | <b>3%</b> | <b>15</b>  | <b>1%</b> | <b>121</b>        | <b>16%</b> | <b>804</b>  |

| Case  | Distance (Court - Center)<br>x , y |              | Distance (Court2 - Center)<br>x , y |              | Thick. Of Walls | Main Court   |              |             |           | Service Court |              |             |           | Main Liv    |             |             |           |
|-------|------------------------------------|--------------|-------------------------------------|--------------|-----------------|--------------|--------------|-------------|-----------|---------------|--------------|-------------|-----------|-------------|-------------|-------------|-----------|
|       | x                                  | y            | x                                   | y            |                 | x            | y            | prop.       | direction | x             | y            | prop.       | direction | x           | y           | prop.       | direction |
| OMA   | -1.48                              | -1.48        |                                     |              | 40              | 10.25        | 11.75        | 0.87        | CEN.      |               |              |             |           | 5.1         | 3.25        | 1.57        | W         |
| AVG   | <b>-1.48</b>                       | <b>-1.48</b> |                                     |              | <b>40</b>       | <b>10.25</b> | <b>11.75</b> | <b>0.87</b> |           |               |              |             |           | <b>5.10</b> | <b>3.25</b> | <b>1.57</b> |           |
| UAE   | 1.84                               | 0.39         |                                     |              | 65              | 15.5         | 15.5         | 1.00        | CEN.      |               |              |             |           | 9.35        | 5.9         | 1.58        | W         |
| AVG   | <b>1.84</b>                        | <b>0.39</b>  |                                     |              | <b>65</b>       | <b>15.50</b> | <b>15.50</b> | <b>1.00</b> |           |               |              |             |           | <b>9.35</b> | <b>5.90</b> | <b>1.58</b> |           |
| KSA-1 | 0.89                               | 1.32         |                                     |              | 40              | 5.60         | 5.60         | 1.00        | CEN.      | 5.15          | 2.95         | 1.75        | N         | 2.85        | 2.85        | 1.00        | E         |
| KSA-2 | -0.40                              | -1.75        |                                     |              | 50              | 7.90         | 7.60         | 1.04        | CEN.      |               |              |             |           | 7.10        | 4.85        | 1.46        | S         |
| KSA-3 | 0.69                               | 4.10         |                                     |              | 55              | 4.25         | 5.95         | 0.71        | N         |               |              |             |           | 8.65        | 8.15        | 1.06        | SE        |
| KSA-4 | 3.31                               | 2.41         |                                     |              | 35              | 7.90         | 5.25         | 1.50        | E         | 10.15         | 4.55         | 2.23        | NW        | 4.75        | 2.50        | 1.90        | S         |
| KSA-5 | -1.75                              | -5.60        |                                     |              | 60              | 7.60         | 6.35         | 1.20        | SE        |               |              |             |           | 8.00        | 3.70        | 2.16        | S         |
| AVG   | <b>0.55</b>                        | <b>0.10</b>  |                                     |              | <b>48</b>       | <b>6.65</b>  | <b>6.15</b>  | <b>1.09</b> |           | <b>7.65</b>   | <b>3.75</b>  | <b>1.99</b> |           | <b>6.27</b> | <b>4.41</b> | <b>1.52</b> |           |
| KUW-1 | -3.40                              | 5.08         | 8.90                                | -7.27        | 35              | 10.10        | 10.20        | 0.99        | CEN.      | 6.60          | 10.25        | 0.64        | E         | 5.15        | 8.45        | 0.61        | S         |
| KUW-2 | 0.56                               | -1.39        |                                     |              | 40              | 10.05        | 9.85         | 1.02        | CEN.      |               |              |             |           | 7.75        | 5.25        | 1.48        | W         |
| KUW-3 | -3.45                              | 0.49         |                                     |              | 35              | 9.95         | 9.45         | 1.05        | E         |               |              |             |           | 6.50        | 4.20        | 1.55        | SE        |
| AVG   | <b>-2.10</b>                       | <b>1.39</b>  | <b>8.90</b>                         | <b>-7.27</b> | <b>37</b>       | <b>10.03</b> | <b>9.83</b>  | <b>1.02</b> |           | <b>6.60</b>   | <b>10.25</b> | <b>0.64</b> |           | <b>6.47</b> | <b>5.97</b> | <b>1.21</b> |           |
| YEM-1 | -0.38                              | 0.00         |                                     |              | 70              | 3.50         | 5.80         | 0.60        | CEN.      |               |              |             |           | 8.10        | 3.40        | 2.38        | SE        |
| YEM-2 | 0.00                               | 0.00         |                                     |              | 79              | 10.10        | 2.25         | 4.49        | CEN.      |               |              |             |           | 6.15        | 2.75        | 2.24        | NW        |
| AVG   | <b>-0.19</b>                       | <b>0.00</b>  |                                     |              | <b>75</b>       | <b>6.80</b>  | <b>4.03</b>  | <b>2.55</b> |           |               |              |             |           | <b>7.13</b> | <b>3.08</b> | <b>2.31</b> |           |
| AVG   | <b>-0.28</b>                       | <b>0.08</b>  | <b>8.90</b>                         | <b>-7.27</b> | <b>52.83</b>    | <b>9.85</b>  | <b>9.45</b>  | <b>1.31</b> |           | <b>7.13</b>   | <b>7.00</b>  | <b>1.32</b> |           | <b>6.86</b> | <b>4.52</b> | <b>1.64</b> |           |

| Case  | Guest        |             |             |           |         |                    | Rooms        |              |              |             | X(Rooms) / X(Court) |             | Y(Rooms) / Y(Court) |             | x(MC) / X(L) |
|-------|--------------|-------------|-------------|-----------|---------|--------------------|--------------|--------------|--------------|-------------|---------------------|-------------|---------------------|-------------|--------------|
|       | x            | y           | prop.       | direction | M/F/M+F | No. of Guest Rooms | E            | W            | N            | S           | E                   | W           | N                   | S           |              |
| OMA   | 10.75        | 2.85        | 3.77        | E         | M       | 2                  | 3.65         | 6.4          | 6.6          | 3.3         | 0.36                | 0.62        | 0.56                | 0.28        | 0.50         |
| AVG   | <b>10.75</b> | <b>2.85</b> | <b>3.77</b> |           |         |                    | <b>3.65</b>  | <b>6.40</b>  | <b>6.60</b>  | <b>3.30</b> | <b>0.36</b>         | <b>0.62</b> | <b>0.56</b>         | <b>0.28</b> | <b>0.50</b>  |
| UAE   | 13.1         | 3.95        | 3.32        | W         | M+F     | 1                  | 11.8         | 14.6         | 5.5          | 6.15        | 0.76                | 0.94        | 0.35                | 0.40        | 0.37         |
| AVG   | <b>13.10</b> | <b>3.95</b> | <b>3.32</b> |           |         |                    | <b>11.80</b> | <b>14.60</b> | <b>5.50</b>  | <b>6.15</b> | <b>0.76</b>         | <b>0.94</b> | <b>0.35</b>         | <b>0.40</b> | <b>0.37</b>  |
| KSA-1 | 11.45        | 3.35        | 3.42        | SE        | M+F     | 1                  | 5.5          | 7.5          | 6.6          | 7.8         | 0.98                | 1.34        | 1.18                | 1.39        | 0.30         |
| KSA-2 | 9.10         | 5.70        | 1.60        | W         | M+F     | 1                  | 10.75        | 9            | 10.3         | 8.5         | 1.36                | 1.14        | 1.36                | 1.12        | 0.29         |
| KSA-3 | 9.65         | 6.75        | 1.43        | SW        | M+F     | 1                  | 8            | 9.45         | 3.5          | 11.15       | 1.88                | 2.22        | 0.59                | 1.87        | 0.20         |
| KSA-4 | 3.65         | 7.55        | 0.48        | W         | M+F     | 2                  | 0            | 6.55         | 10.6         | 5.35        | 0.00                | 0.83        | 2.02                | 1.02        | 0.55         |
| KSA-5 | 4.60         | 3.65        | 1.26        | S         | M       | 1                  | 0            | 11.7         | 6.1          | 0           | 0.00                | 1.54        | 0.96                | 0.00        | 0.39         |
| AVG   | <b>7.69</b>  | <b>5.40</b> | <b>1.64</b> |           |         |                    | <b>4.85</b>  | <b>8.84</b>  | <b>7.42</b>  | <b>6.56</b> | <b>0.85</b>         | <b>1.41</b> | <b>1.22</b>         | <b>1.08</b> | <b>0.33</b>  |
| KUW-1 | 10.10        | 6.70        | 1.51        | E         | M+F     | 1                  | 10.75        | 7.45         | 21.1         | 14.4        | 1.06                | 0.74        | 2.07                | 1.41        | 0.36         |
| KUW-2 | 6.20         | 3.60        | 1.72        | S         | M       | 2                  | 4.95         | 6.08         | 7.3          | 4.55        | 0.49                | 0.60        | 0.74                | 0.46        | 0.48         |
| KUW-3 | 4.10         | 3.35        | 1.22        | S         | M       | 2                  | 7.5          | 0            | 6.35         | 7.35        | 0.75                | 0.00        | 0.67                | 0.78        | 0.57         |
| AVG   | <b>6.80</b>  | <b>4.55</b> | <b>1.48</b> |           |         |                    | <b>7.73</b>  | <b>4.51</b>  | <b>11.58</b> | <b>8.77</b> | <b>0.77</b>         | <b>0.45</b> | <b>1.16</b>         | <b>0.88</b> | <b>0.45</b>  |
| YEM-1 | 7.90         | 3.25        | 2.43        | SE        | M       | 1                  | 4.45         | 4.85         | 3.9          | 5           | 1.27                | 1.39        | 0.67                | 0.86        | 0.27         |
| YEM-2 | 9.00         | 2.70        | 3.33        | NW        | M+F     | 1                  | 3.45         | 3.25         | 3.3          | 3.9         | 0.34                | 0.32        | 1.47                | 1.73        | 0.60         |
| AVG   | <b>8.45</b>  | <b>2.98</b> | <b>2.88</b> |           |         |                    | <b>3.95</b>  | <b>4.05</b>  | <b>3.60</b>  | <b>4.45</b> | <b>0.81</b>         | <b>0.85</b> | <b>1.07</b>         | <b>1.30</b> | <b>0.46</b>  |
| AVG   | <b>9.36</b>  | <b>3.95</b> | <b>2.62</b> |           |         |                    | <b>6.40</b>  | <b>7.68</b>  | <b>6.94</b>  | <b>5.85</b> | <b>0.71</b>         | <b>0.86</b> | <b>0.87</b>         | <b>0.79</b> | <b>0.42</b>  |

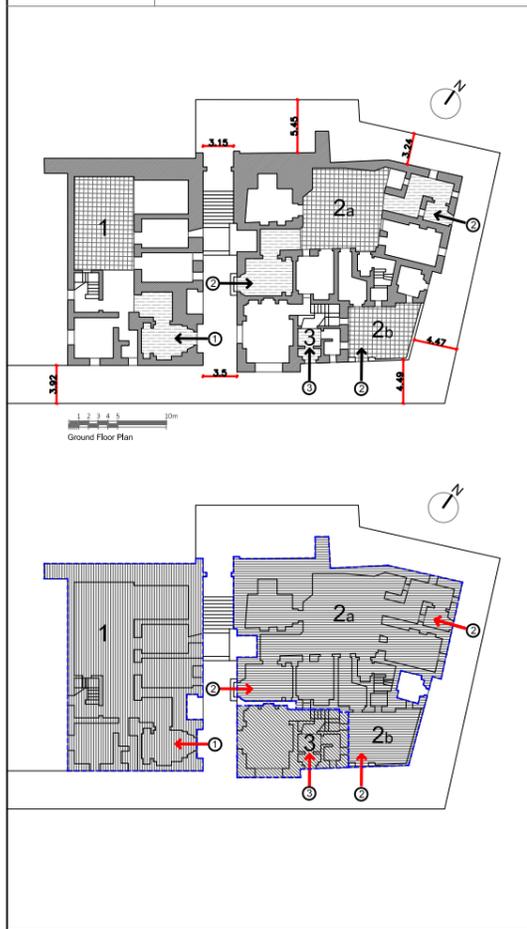
Appendix (4-B-9)

**As-built Plans for the Selected Traditional  
Neighbourhoods**

# As-Built Plans for Neighborhoods / Clusters of Houses (4 cases)

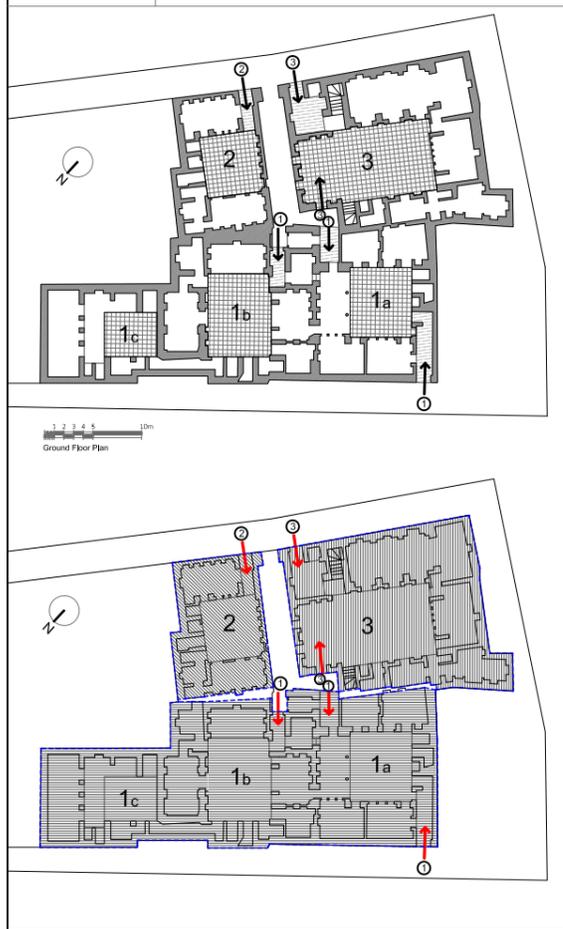
**CLUS-1**

A three-house cluster, Cairo, Egypt.  
(redrawn by the author, after Ragette, 2016, 148)



**CLUS-2**

A five-courtyard compound, Baghdad, Iraq.  
(redrawn by the author, after Ragette, 2016, 191)



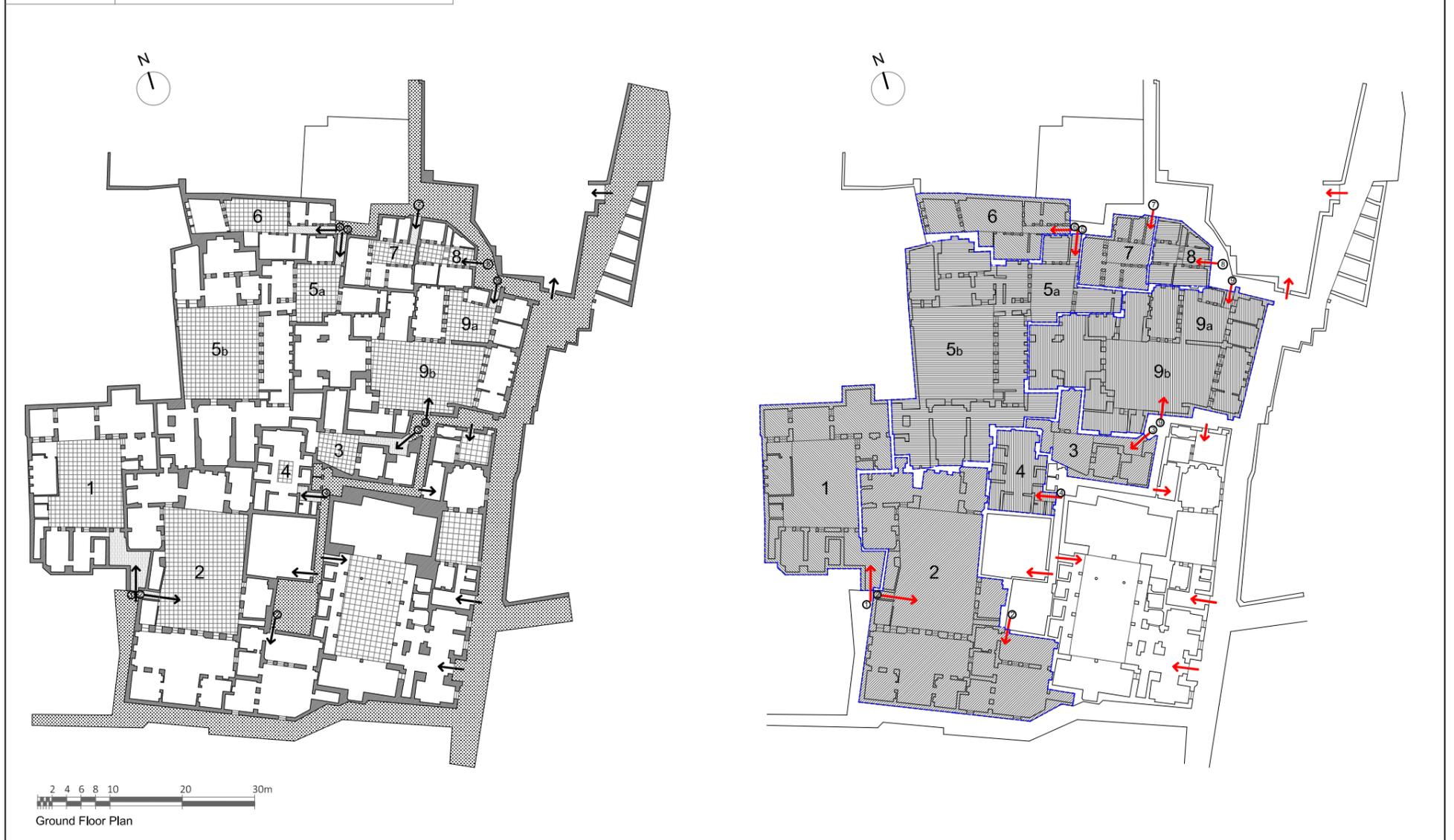
**CLUS-3**

Part of an old neighborhood, Ur, Iraq  
(redrawn by the author, after Hakim, 1986)



**CLUS-4**

Part of an old neighborhood, Aleppo, Syria  
(redrawn by the author, after Ragette, 2016)



Appendix (4-B-10)

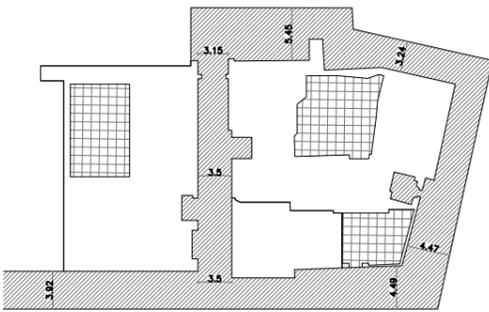
**Analysing Aspects of Social Sustainability for the  
Selected Traditional Neighbourhoods**

# Social Indicators: Hierarchy of Open Spaces / Accessibility / Safety and Security

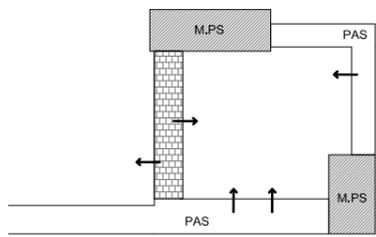
## Strategies:

- Main Public Space  $\longrightarrow$  Alleys  $\longrightarrow$  'Semi-Private' Open Space between Residential Units
- Entrances of residential units are connected with alleys or the 'semi-private' open space.
- Corners of buildings are cut at  $45^\circ$  up to shoulder height to ease people walk and movement.
- Semi-private open spaces between houses offer secure spaces for children to play in front of houses.

CLUS-1: Egypt

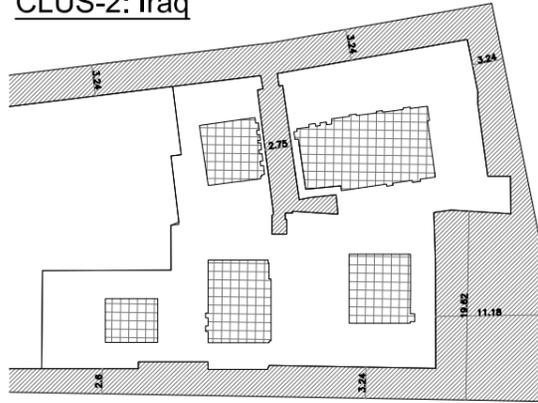


- Public Spaces
- Private Courtyards
- Built-up Area

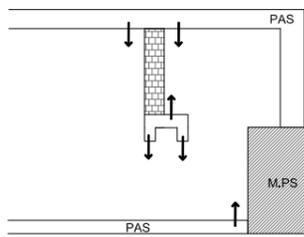


- Main Public Spaces (M.P.S) ( $3.15 \text{ m} \leq \text{width}_{(M.P.S)} \leq 3.95 \text{ m}$ )
- 'Semi-Private' Open Spaces (P.V.S) ( $\text{width}_{(P.V.S)} = 3.50 \text{ m}$ )
- Alleys and Passageways (PAS) ( $4.45 \text{ m} \leq \text{width}_{(PAS)} \leq 5.45 \text{ m}$ )
- Entrances of Residential Units

CLUS-2: Iraq

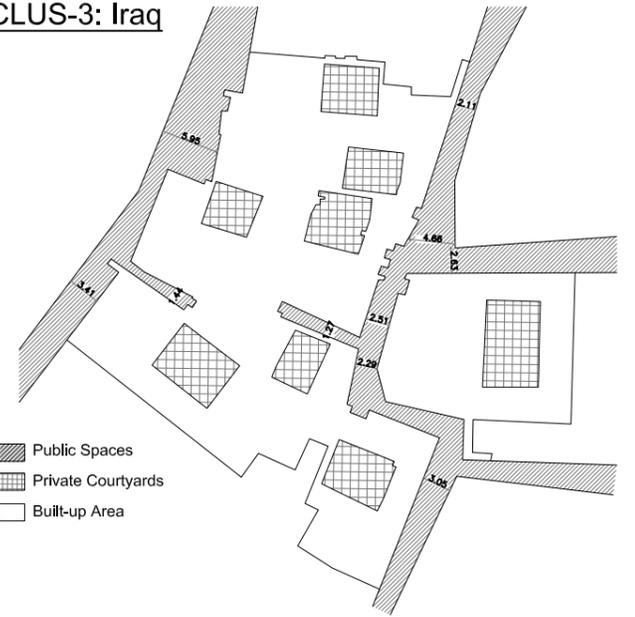


- Public Spaces
- Private Courtyards
- Built-up Area

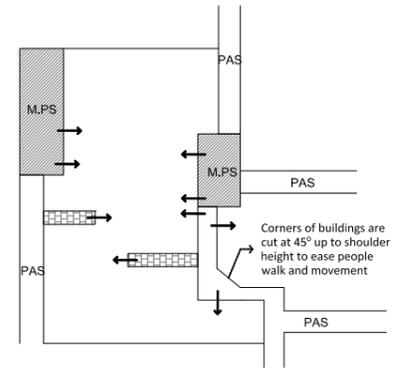


- Main Public Spaces (M.P.S) ( $\text{width}_{(M.P.S)} = 11.25 \text{ m}$ )
- 'Semi-Private' Open Spaces (P.V.S) ( $\text{width}_{(P.V.S)} = 2.75 \text{ m}$ )
- Alleys and Passageways (PAS) ( $2.60 \text{ m} \leq \text{width}_{(PAS)} \leq 3.25 \text{ m}$ )
- Entrances of Residential Units

CLUS-3: Iraq

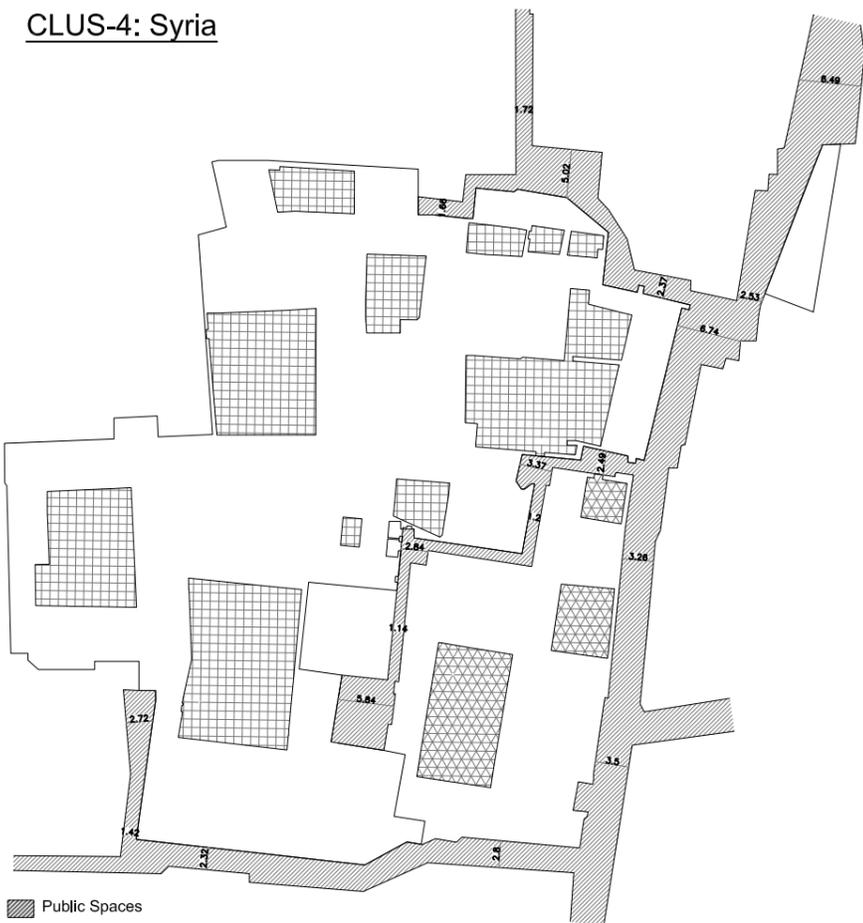


- Public Spaces
- Private Courtyards
- Built-up Area

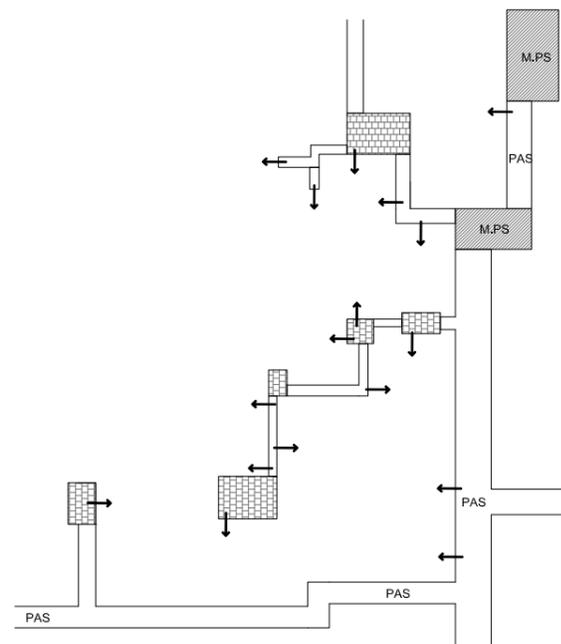


- Main Public Spaces (M.P.S) ( $4.35 \text{ m} \leq \text{width}_{(M.P.S)} \leq 5.95 \text{ m}$ )
- 'Semi-Private' Open Spaces (P.V.S) ( $1.25 \text{ m} \leq \text{width}_{(P.V.S)} \leq 1.45 \text{ m}$ )
- Alleys and Passageways (PAS) ( $2.25 \text{ m} \leq \text{width}_{(PAS)} \leq 3.40 \text{ m}$ )
- Entrances of Residential Units

CLUS-4: Syria



- Public Spaces
- Private Courtyards in Residential Buildings
- Private Courtyards in Non-Residential Buildings
- Built-up Area



- Main Public Spaces (M.P.S) ( $5.00 \text{ m} \leq \text{width}_{(M.P.S)} \leq 8.75 \text{ m}$ )
- 'Semi-Private' Open Spaces (P.V.S) ( $1.15 \text{ m} \leq \text{width}_{(P.V.S)} \leq 5.85 \text{ m}$ )
- Alleys and Passageways (PAS) ( $2.30 \text{ m} \leq \text{width}_{(PAS)} \leq 3.50 \text{ m}$ )
- Entrances of Residential Units

# Social Indicators: Density and Crowding / Social Interaction / Thermal Comfort

## Strategies:

Total area of open public spaces and alleys

(the percent of public spaces relative to the total area of the cluster = 20% to 38%)

(Higher value means that the cluster is more comfortable for people to live, and there is more potentials for social interaction between families live in the same cluster).

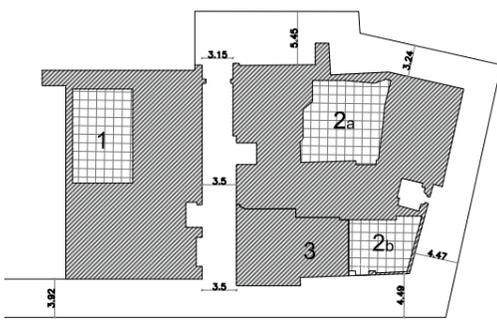
Total area of private courtyards

(the percent of private courtyards relative to the total area of houses = 18% to 28%)

(Higher value means that houses are more comfortable for people to live).

The use of covered pathways, which are gradually diminished in size and in character from public to semi-public to the cul-de-sac, as a climate comfort entrance spaces for houses

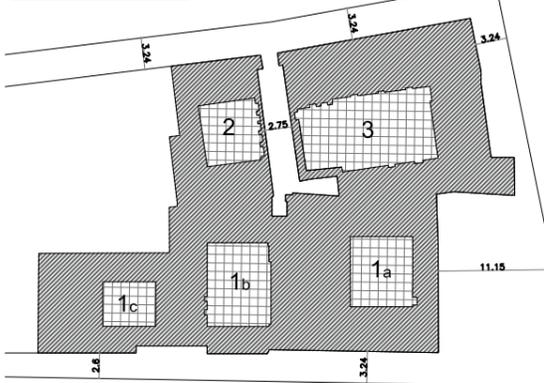
**CLUS-1: Egypt**



Total Area of the Cluster = 1185 m<sup>2</sup>  
 Total Area of Public Spaces = 454 m<sup>2</sup>  
 The Percent of Public Spaces relative to the Total Area of the Cluster = 38.3 %

Total Area of Houses = 731 m<sup>2</sup>  
 Total Area of Covered Spaces = 569 m<sup>2</sup>  
 Total Area of Private Courtyards = 162 m<sup>2</sup>  
 The Percent of Private Courtyards relative to the Total Area of Houses = 22.2 %

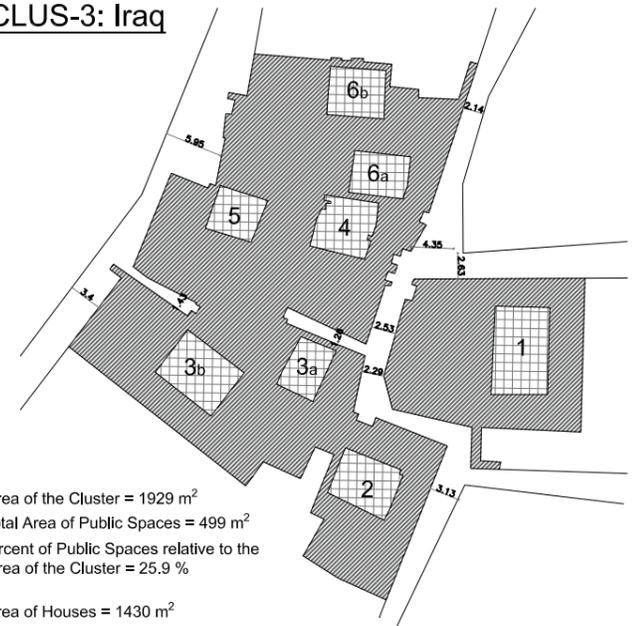
**CLUS-2: Iraq**



Total Area of the Cluster = 1642 m<sup>2</sup>  
 Total Area of Public Spaces = 622 m<sup>2</sup>  
 The Percent of Public Spaces relative to the Total Area of the Cluster = 37.9 %

Total Area of Houses = 1020 m<sup>2</sup>  
 Total Area of Covered Spaces = 757 m<sup>2</sup>  
 Total Area of Private Courtyards = 263 m<sup>2</sup>  
 The Percent of Private Courtyards relative to the Total Area of Houses = 25.8 %

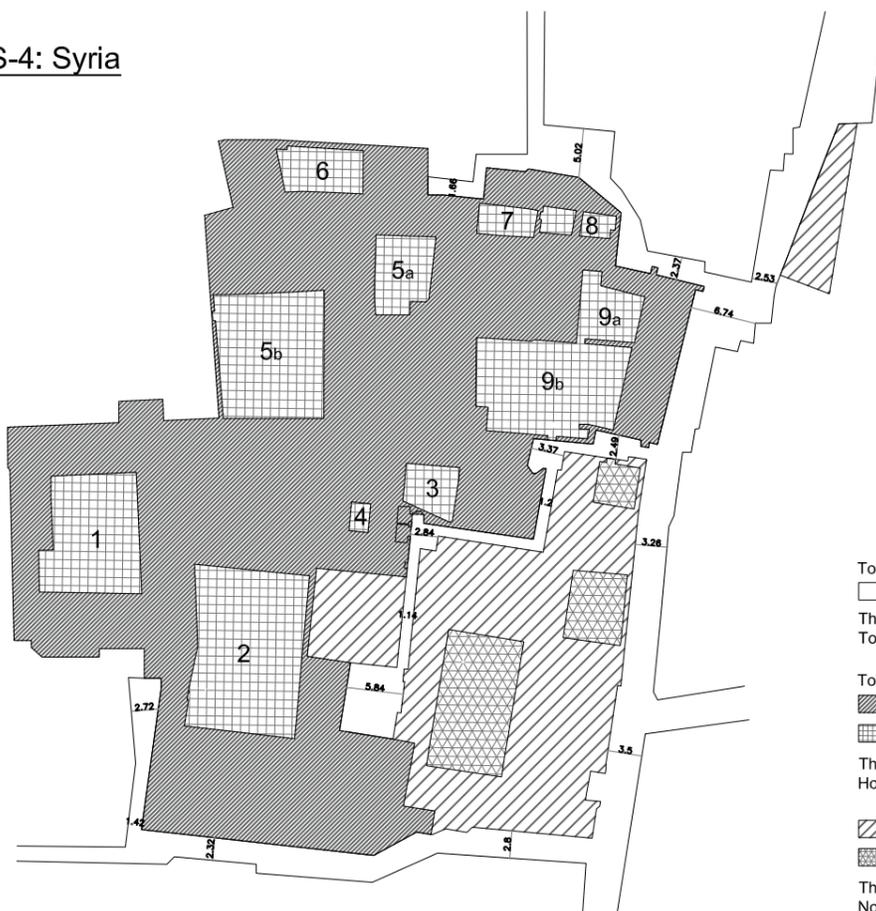
**CLUS-3: Iraq**



Total Area of the Cluster = 1929 m<sup>2</sup>  
 Total Area of Public Spaces = 499 m<sup>2</sup>  
 The Percent of Public Spaces relative to the Total Area of the Cluster = 25.9 %

Total Area of Houses = 1430 m<sup>2</sup>  
 Total Area of Covered Spaces = 1174 m<sup>2</sup>  
 Total Area of Private Courtyards = 256 m<sup>2</sup>  
 The Percent of Private Courtyards relative to the Total Area of Houses = 17.9 %

**CLUS-4: Syria**



Total Area of the Cluster = 4525 m<sup>2</sup>  
 Total Area of Public Spaces = 929 m<sup>2</sup>  
 The Percent of Public Spaces relative to the Total Area of the Cluster = 20.5 %

Total Area of Houses = 2757 m<sup>2</sup>  
 Total Area of Covered Spaces for Houses = 1998 m<sup>2</sup>  
 Total Area of Private Courtyards in Houses = 759 m<sup>2</sup>  
 The Percent of Private Courtyards relative to the Total Area of Houses = 27.5 %

Total Area of Non-Residential Activities = 839 m<sup>2</sup>  
 Total Area of Courtyards in Non-Residential Activities = 168 m<sup>2</sup>  
 The Percent of Private Courtyards relative to the Total Area of Non-Residential Activities = 20.0 %

## Social Indicator: Visual Privacy

### Strategies:

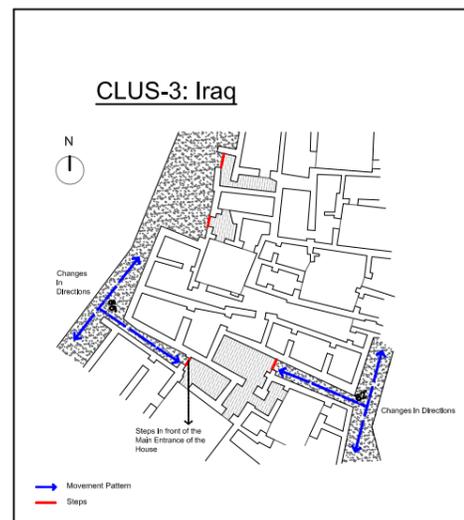
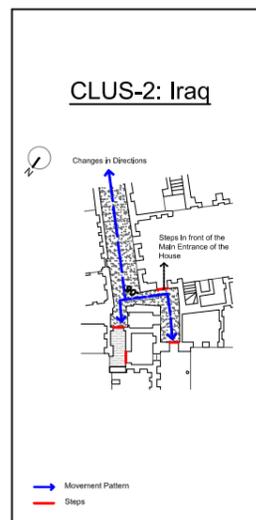
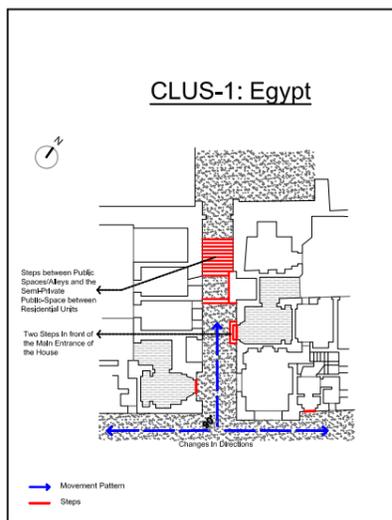
- Avoid entrances facing each other (the principle of staggered entrances)
- Walls in front of main entrances are solid walls.
- Walls in front of the entry of the semi-private spaces are solid walls.
- Apartments are connected with corridors or semi-private spaces.
- Entrances for apartments are not connected with the main public space.
- Wall that is directly located in front of the entrance of any apartment is a solid wall.
- Entrances of houses are carefully located through the principle of staggered entrances to maintain the private life, and to prevent the person standing at an entrance from looking directly into the house.



## Social Indicator: Hygiene / Accessibility

### Strategies:

- Steps between public spaces/alleys and the semi-private open space between residential units
- 1-2 Steps in front of the main entrance of house
- Changes in directions between public spaces, alleys, and entrances of houses

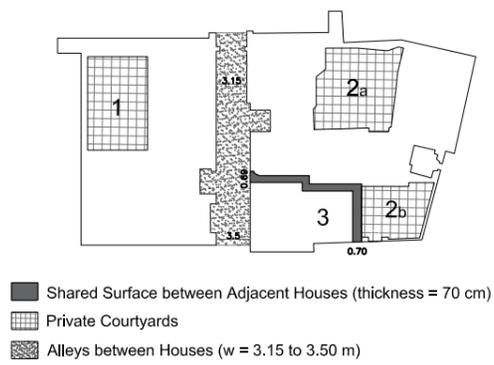


## Social Indicator: Acoustical Privacy

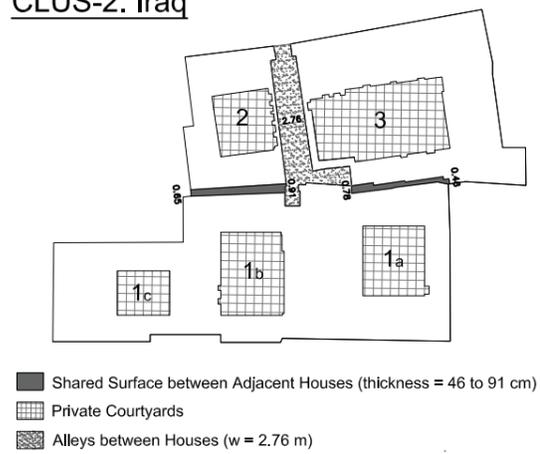
### Strategies:

- Thick walls between attached houses (40-90 cm).
- The use of introverted courtyards, and increase the width of alleys between houses decrease the transition of noise between houses.

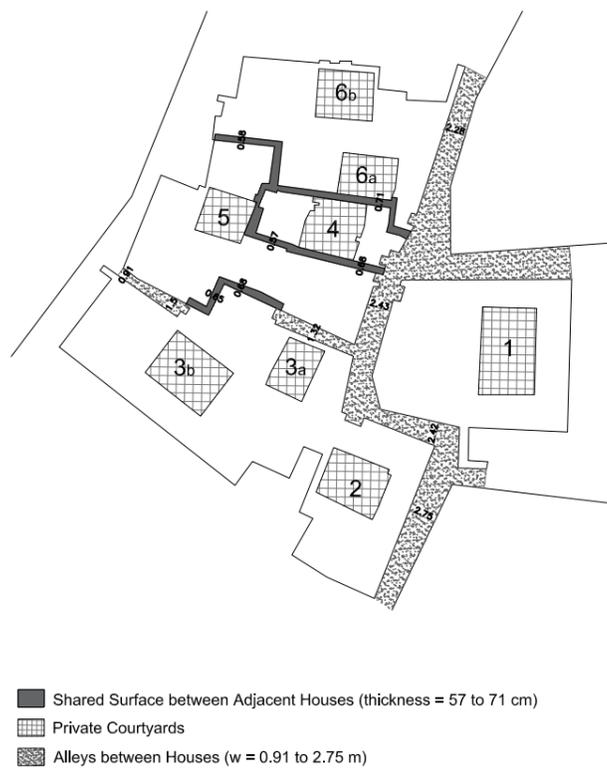
CLUS-1: Egypt



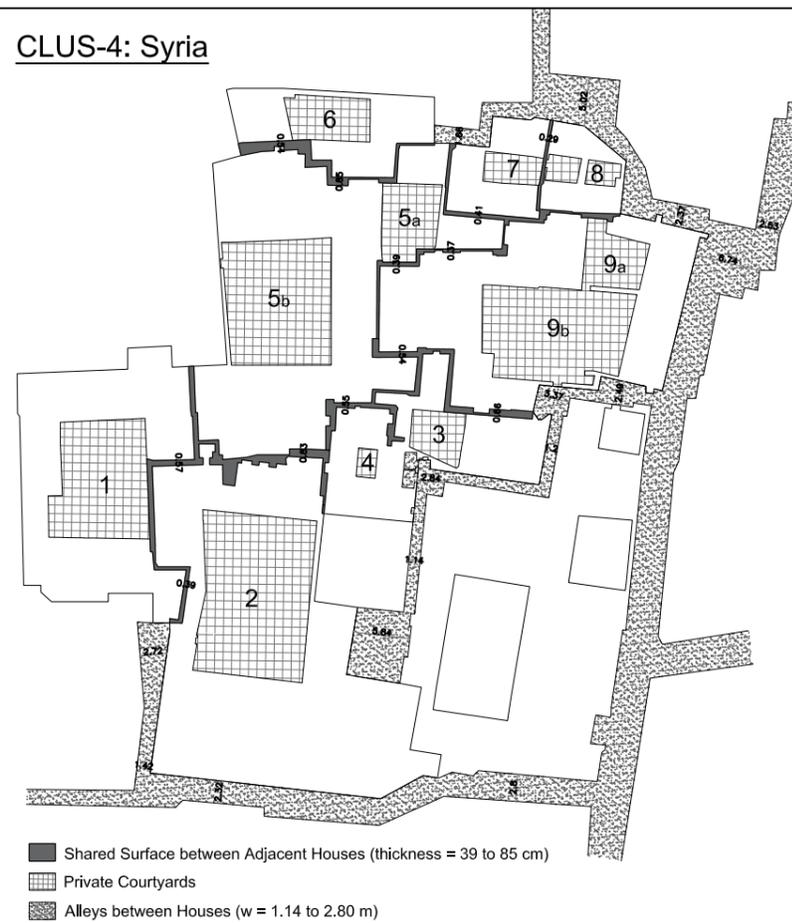
CLUS-2: Iraq



CLUS-3: Iraq



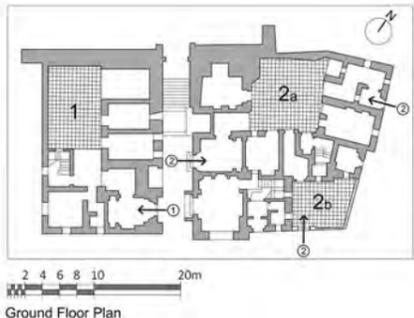
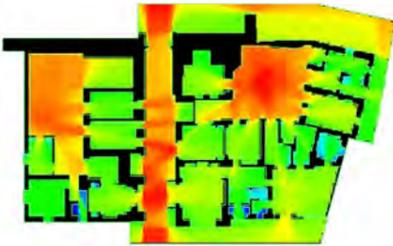
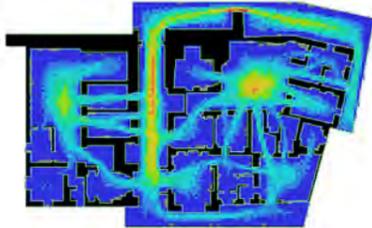
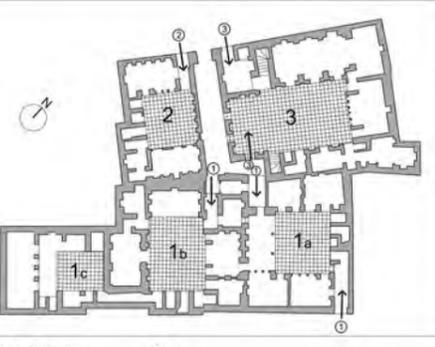
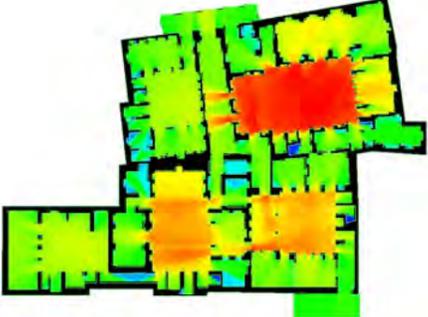
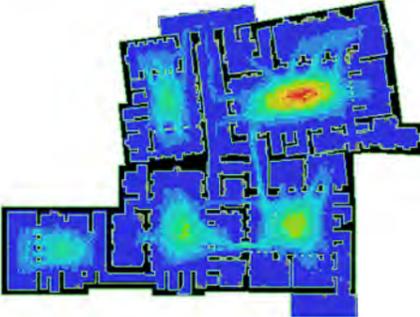
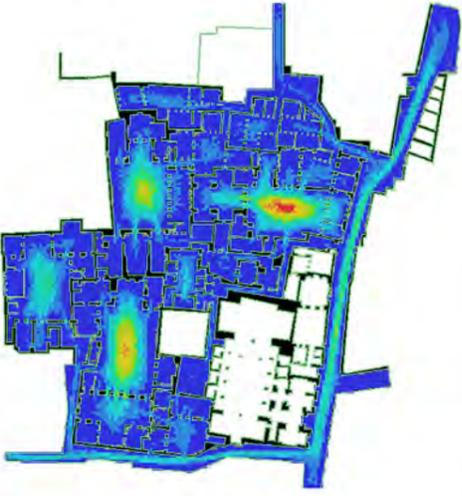
CLUS-4: Syria



Appendix (4-B-11)

**Visibility Graph Analysis (VGA) for the Selected  
Traditional Neighbourhoods**

# Syntactic Analysis (using Visibility Graph Analysis - VGA) for the Spatial Configuration of Traditional Neighborhoods (Clusters of Houses) located in the Middle East and North Africa (Carried out by Author using 'DepthMapX 0.50 Software')

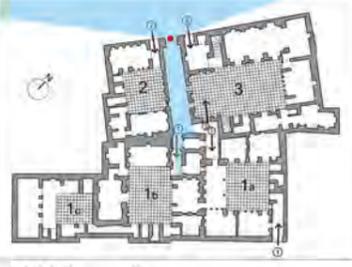
| Case No.          | As-Built Plan  | Connectivity Analysis<br>(Number of points that are directly connected to other spaces) | Agent Analysis<br>(Pattern of movement and frequent use of spaces, released from the public gathering space) |
|-------------------|--|---|--|
| CLUS-1<br>(Egypt) |  <p style="text-align: center;">Ground Floor Plan</p>   |       |                           |
| CLUS-2<br>(Iraq)  |  <p style="text-align: center;">Ground Floor Plan</p>  |     |                          |
| CLUS-3<br>(Iraq)  |  <p style="text-align: center;">Ground Floor Plan</p> |     |                         |
| CLUS-4<br>(Syria) |  <p style="text-align: center;">Ground Floor Plan</p> |     |                         |



Appendix (4-B-12)

**Isovist Analysis for the Selected  
Traditional Neighbourhoods**

**Visibility Study for the Ground Floor of Traditional Neighborhoods (Clusters of Houses)**  
**located in the Middle East and North Africa**  
 (Carried out by Author using 'Syntax2D 1.3.0.7 Software')

| Case No.                  | Visual Fields from the Main Entry Point of the Neighborhood  | Visual Fields from the Entry Point(s) of Each House in the Cluster                                    |  |  |
|---------------------------|--|---|--|--|
| <p>CLUS-1<br/>(Egypt)</p> |  <p>Ground Floor Plan</p>  | <p>House (1)</p>    | <p>House (2)</p>    |  |
| <p>CLUS-2<br/>(Iraq)</p>  |  <p>Ground Floor Plan</p> | <p>House (1)</p>  | <p>House (2)</p>  | <p>House (3)</p>  |
| <p>CLUS-3<br/>(Iraq)</p>  |  <p>Ground Floor Plan</p> | <p>House (1)</p>  | <p>House (2)</p>  | <p>House (3)</p>  |
|                           |  | <p>House (4)</p>  | <p>House (5)</p>  | <p>House (6)</p>  |

Visibility Study for the Ground Floor of Traditional Neighborhoods (Clusters of Houses)  
 located in the Middle East and North Africa  
 (Carried out by Author using 'Syntax2D 1.3.0.7 Software')



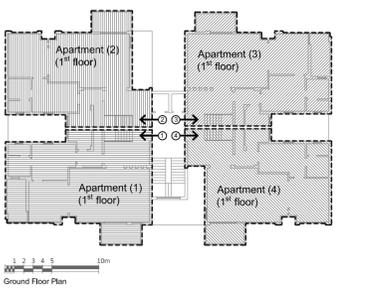
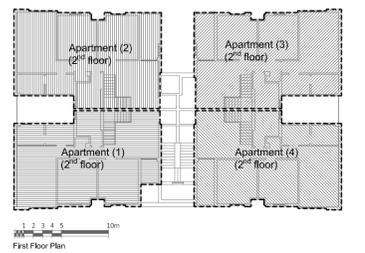
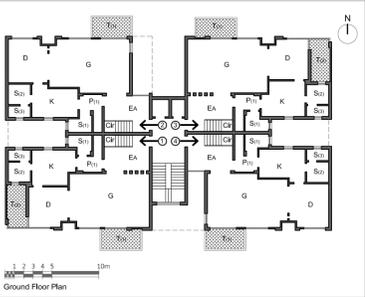
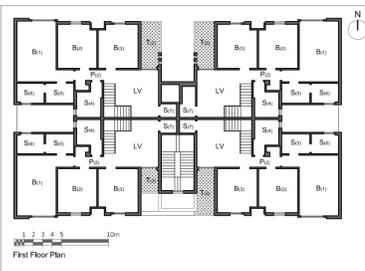
Appendix (4-B-13)

**As-built Plans for the Selected  
Contemporary Apartment Buildings**

# As-Built Plan - Contemporary Apartment Buildings (5 cases)

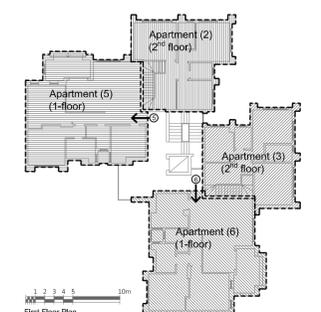
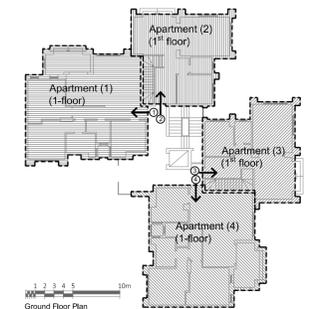
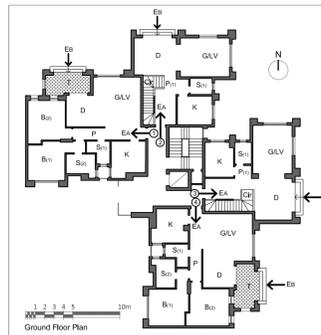
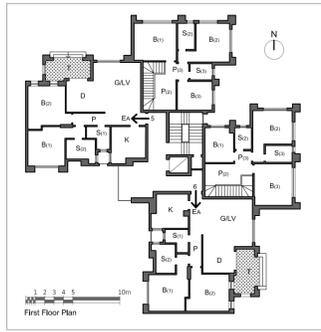
APR-1

West town residences, Cairo, Egypt.  
(redrawn by the author, after <http://www.nileestate.com>)



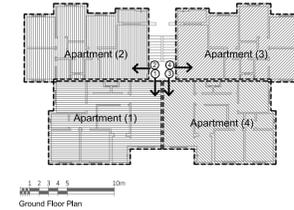
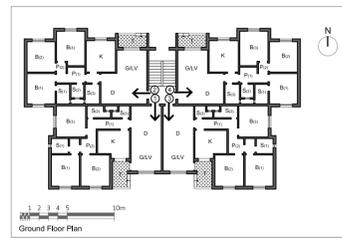
APR-2

The village gate project, Egypt.  
(redrawn by the author, after <http://www.mlseg.info>)



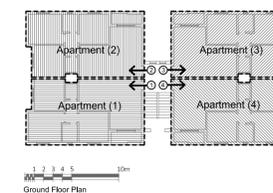
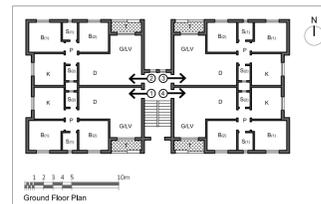
APR-3

An apartment building, Amman, Jordan  
(redrawn by the author, after <http://www.csbe.org>)



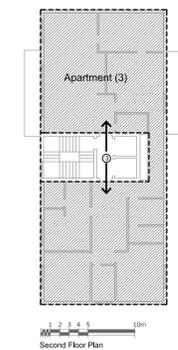
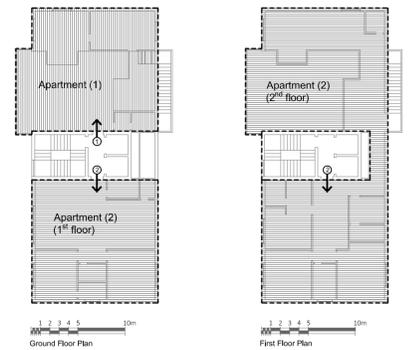
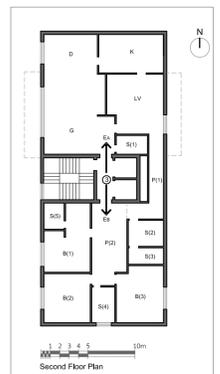
APR-4

An apartment building, Amman, Jordan  
(redrawn by the author, after <http://www.csbe.org>)



APR-5

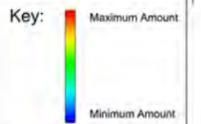
A residential tower in Kuwait.  
Designed by Wael Al-Masri, 2016.  
(redrawn by the author)



Appendix (4-B-14)

**Visibility Graph Analysis (VGA) for the Selected  
Contemporary Apartment Buildings**

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
 for the Spatial Configuration of Contemporary Apartment Buildings in the Middle East, North Africa, and  
 the Gulf Area (Carried out by Author using 'DepthMapX 0.50 Software')



Apartment Buildings (located in Egypt)

| Case No. | As-Built Plan | Connectivity<br>(Number of points that are directly connected to other spaces) | Visual Integration<br>(Representation of potentially core area in the layout) | Through-Vision Analysis | Depth of Spaces from the Main Entrance<br>(Metric Step) | Agent Analysis<br>(Pattern of movement and frequent use of spaces, released from the main entrance) |
|----------|---------------|--|---|-------------------------|---|---|
| APA-1    |               |  |   |                         |   |   |
| APA-2    |               |  |   |                         |   |   |

Apartment Buildings (located in Jordan)

| Case No. | As-Built Plan | Connectivity<br>(Number of points that are directly connected to other spaces) | Visual Integration<br>(Representation of potentially core area in the layout) | Through-Vision Analysis | Depth of Spaces from the Main Entrance<br>(Metric Step) | Agent Analysis<br>(Pattern of movement and frequent use of spaces, released from the main entrance) |
|----------|---------------|--|---|-------------------------|---|---|
| APA-3    |               |  |   |                         |   |   |
| APA-4    |               |  |   |                         |   |   |

Apartment Building (located in Kuwait)

| Case No. | As-Built Plan | Connectivity<br>(Number of points that are directly connected to other spaces) | Visual Integration<br>(Representation of potentially core area in the layout) | Through-Vision Analysis | Depth of Spaces from the Main Entrance<br>(Metric Step) | Agent Analysis<br>(Pattern of movement and frequent use of spaces, released from the main entrance) |
|----------|---------------|--|---|-------------------------|---|---|
| APA-5    |               |  |   |                         |   |   |
|          |               |  |   |                         |   |   |

Appendix (4-B-15)

**Isovist Analysis for the Selected  
Contemporary Apartment Buildings**

**Visibility Study for the Main Floor from Different Points**  
**Inside Contemporary Apartment Buildings in the Middle East, North Africa, and the Gulf Area**  
 (Carried out by Author using 'Syntax2D 1.3.0.7 Software')

**Apartment Buildings (located in Egypt)**

| Case No. | Visual Fields from the Public Space outside Apartments | Visual Fields from the Entry Point of the House | Visual Fields from the Entry Point of the Guest Room | Visual Fields from the Centroid of the Guest Room | Visual Fields along the Movement Path of Guests inside the House |
|----------|--|---|--|---|--|
| APA-1    |  |   |  |   |  |
| APA-2    |  |   |  |   |  |

**Apartment Buildings (located in Jordan)**

| Case No. | Visual Fields from the Public Space outside Apartments | Visual Fields from the Entry Point of the House | Visual Fields from the Entry Point of the Guest Room | Visual Fields from the Centroid of the Guest Room | Visual Fields along the Movement Path of Guests inside the House |
|----------|--|---|--|---|--|
| APA-3    |  |   |  |   |  |
| APA-4    |  |   |  |   |  |

**Apartment Building (located in Kuwait)**

| Case No. | Visual Fields from the Public Space outside Apartments | Visual Fields from the Entry Point of the House | Visual Fields from the Entry Point of the Guest Room | Visual Fields from the Centroid of the Guest Room | Visual Fields along the Movement Path of Guests inside the House |
|----------|--|---|--|---|--|
| APA-5    |  |   |  |   |  |
|          |  |   |  |   |  |

Appendix (4-B-16)

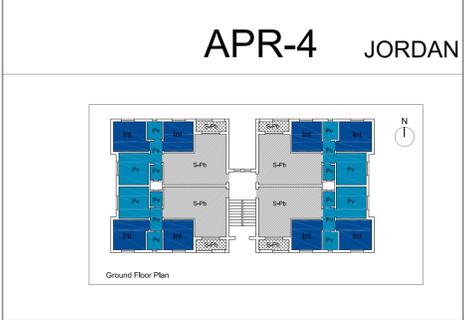
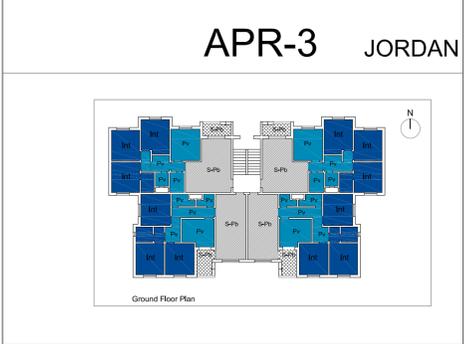
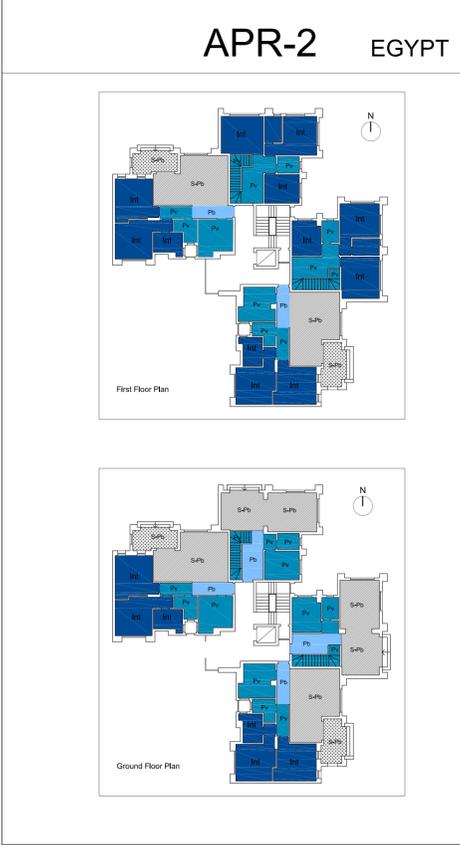
**Hierarchy of Spaces for the Selected  
Contemporary Apartment Buildings**

# Hierarchy of Spaces

## Contemporary Apartment Buildings (5 cases)

Key:

- Public Spaces (Pb)  
(Main Entry Hall)
- Semi-Private Spaces (S-Pv)  
(Courtyard, Gallery, Iwan, Service Entrance)
- Private Spaces (Pv)  
(Living Room, Multi-Purpose Hall, Toilet, Kitchen, Storage Area)
- Intimate Spaces (Int)  
(Bedroom, Bathroom)
- Semi-Public Spaces (S-Pb)  
(Guest Room, Toilet for Guests)



Appendix (4-B-17)

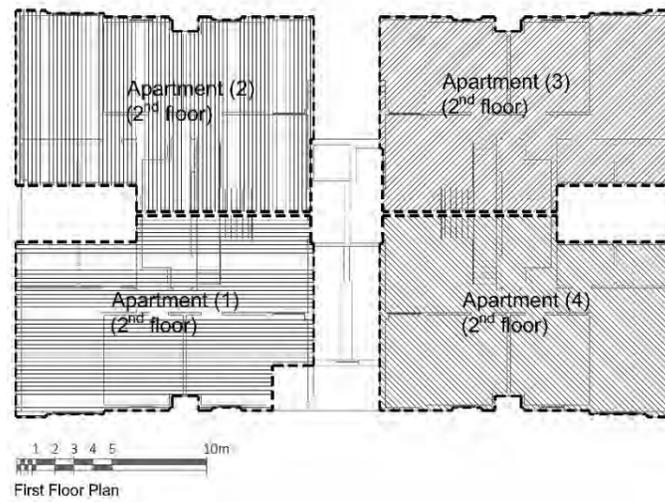
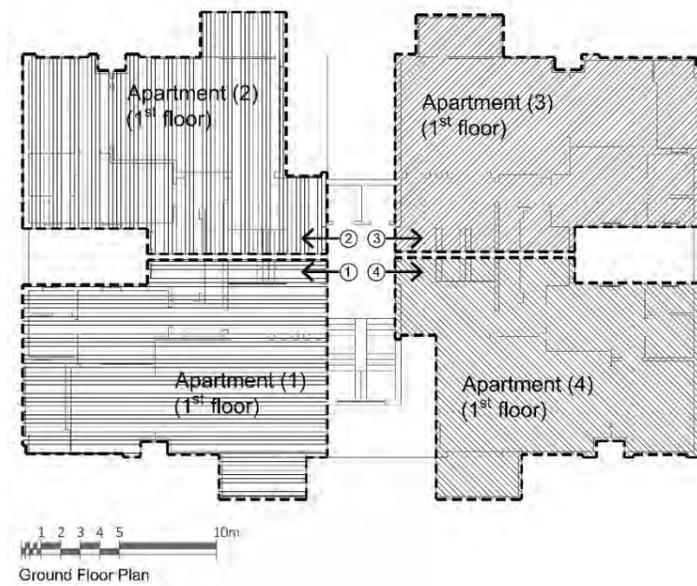
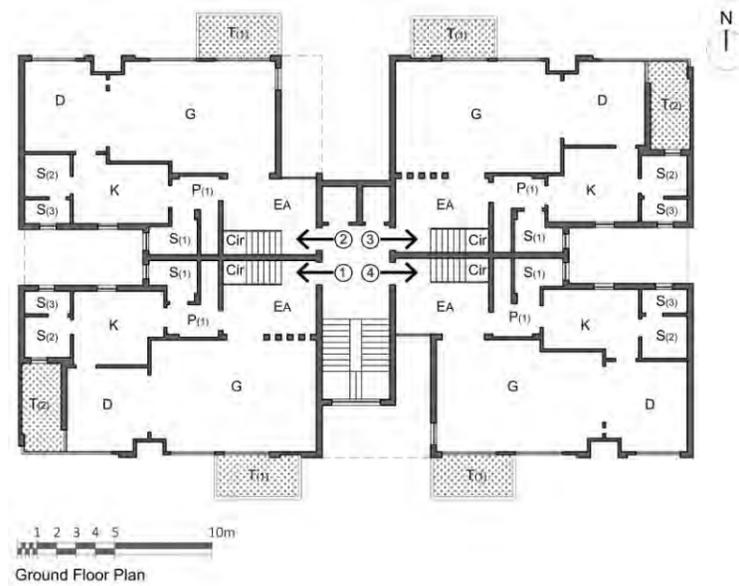
**Syntactic Diagrams for the Selected  
Contemporary Apartment Buildings**

# The Social Logic of the Spatial Arrangement of an Apartment Building in Cairo, Egypt

|        |              |         |       |          |      |
|--------|--------------|---------|-------|----------|------|
| Region | North Africa | Country | Egypt | Case No. | AP-1 |
|--------|--------------|---------|-------|----------|------|

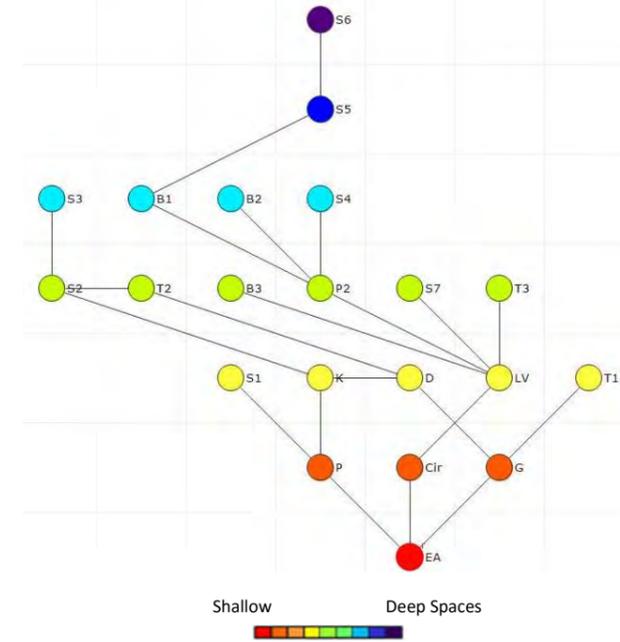
## Architectural Plans for an Apartment Building (West-town Residences Cairo), Cairo, Egypt (Redrawn by Researcher, <http://www.nileestate.com> (accessed 20/10/2016))

**Space Syntax Analysis**  
Diagrams produced by Researcher using AGRAPH Online software  
(<https://www.ntnu.no/ab/spacesyntax>)

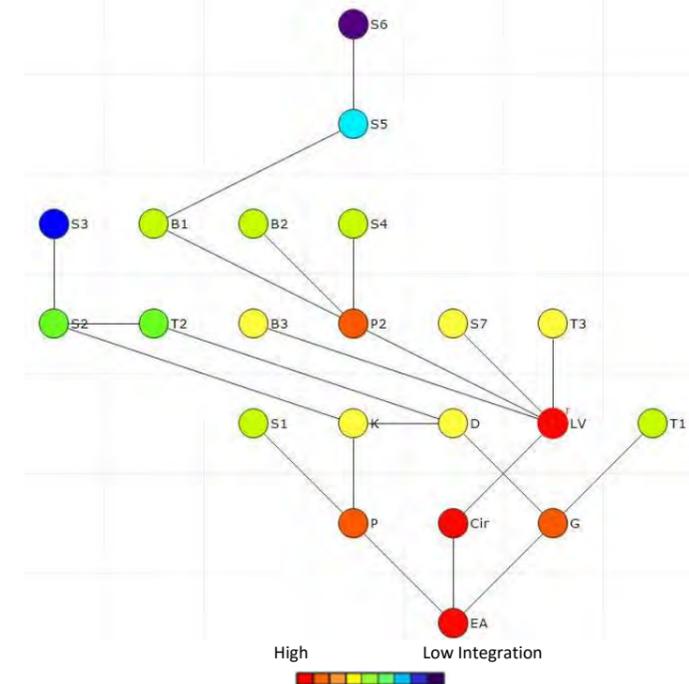


- EA: Main Entrance Hall/Corridor
- EB: Services Entrance
- C : Courtyard
- IW: Iwan
- GL : Gallery
- T : Roof Terrace / Balcony
- G : Guest Room (Reception)
- D : Dining Room
- LV: Family Living Room
- B : Intimate Spaces (Bedrooms)
- K : Kitchen
- S : Services (Toilets, Storage)
- P : Passage / Transitional Space
- DV: Double Volume

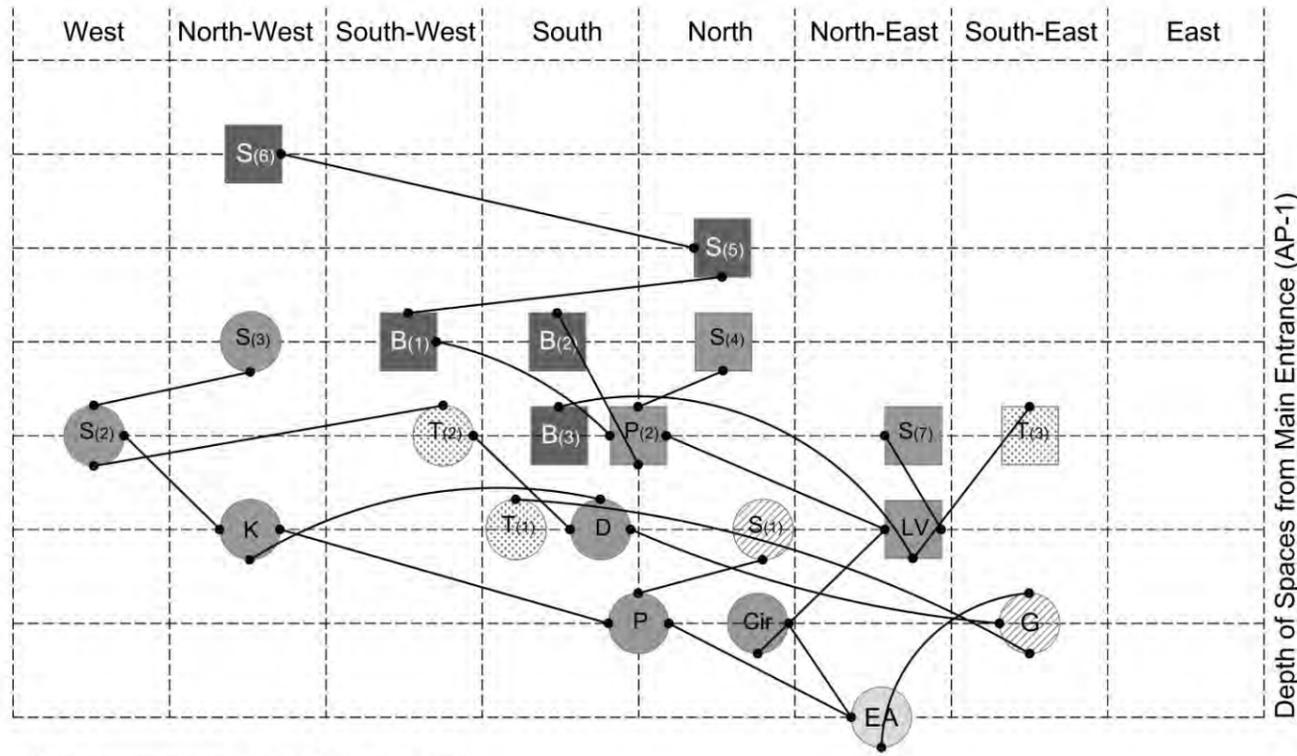
### Depth of Spaces



### Integration of Spaces with the Living Room and the Entrance (the courtyard has the greatest control value)



Hierarchy and Depth of Spaces (according to the orientation, and type of spaces)  
(Researcher)

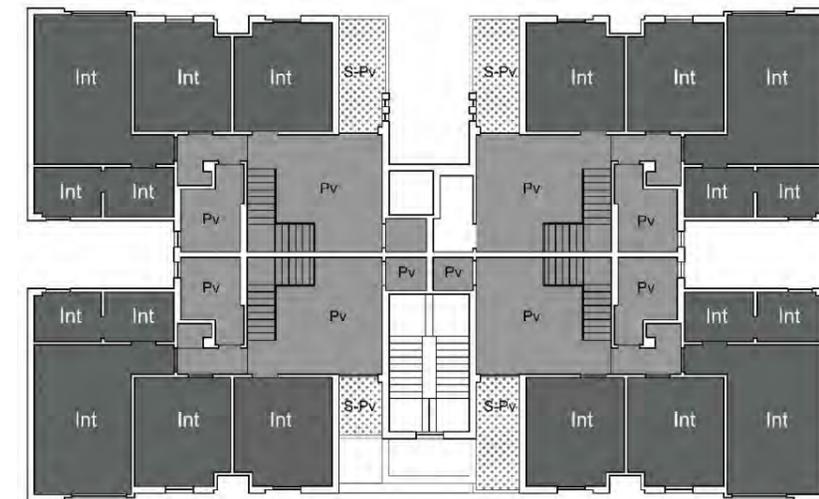


- Spaces located on the Ground Floor
- Spaces located on the First Floor
- Direction of Surface Interaction between Spaces

- Pb** Public Zone (Main Entrance)
- S-Pb** Semi-Public Zone (Reception / Men Guest Room)
- S-Pv** Semi-Private Zone (Courtyard, Iwan)
- Pv** Private Zone (Family Rooms, Services)
- Int** Intimate Zone (Bedrooms)
- Cir** Vertical Circulation (Stairs to roof / upper floors)



1 2 3 4 5 10m  
Ground Floor Plan

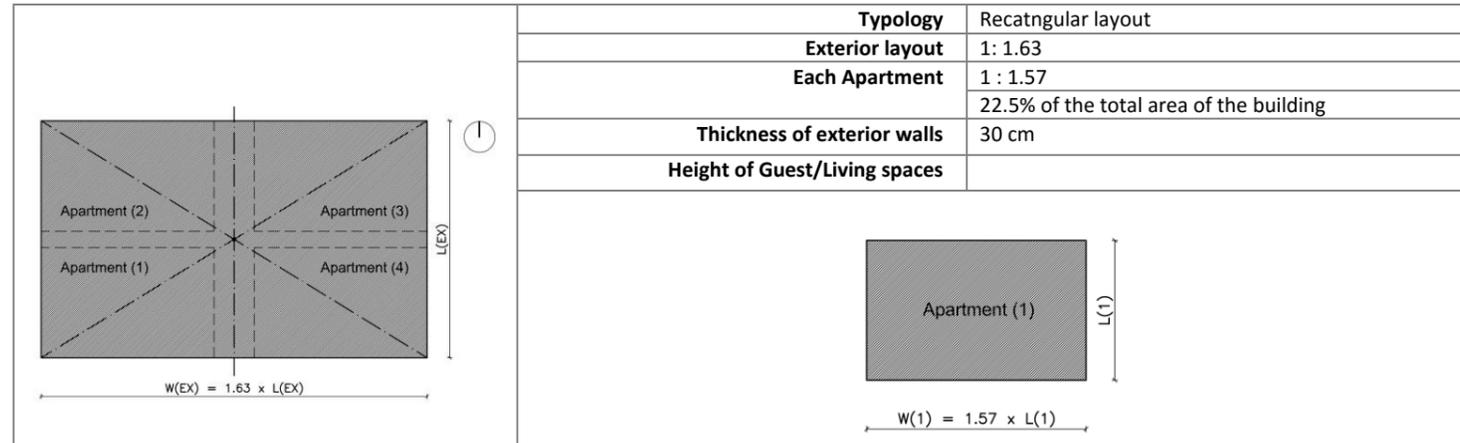


1 2 3 4 5 10m  
First Floor Plan

# The Social Logic of the Spatial Arrangement of an Apartment Building in Cairo, Egypt

|        |              |         |       |          |      |
|--------|--------------|---------|-------|----------|------|
| Region | North Africa | Country | Egypt | Case No. | AP-1 |
|--------|--------------|---------|-------|----------|------|

## Typology and Geometric Properties of the Building and Apartments (Researcher)



| Spaces                      | Dominant Users (Male / Female) | Percentage of area of this space related to the total area of the apartment | Percentage of area of this space related to the floor area where it is located |                       | Proportion of Spaces         |
|-----------------------------|--------------------------------|---|--|-----------------------|------------------------------|
|                             |                                |   | Ground   | 1 <sup>st</sup> Floor |                              |
| Corridor                    | M+F                            | 5.40 %  | 3.00 %   | 7.70 %                | 1 : 1.6 , 1 : 3              |
| Terraces                    | M+F                            | 8.00 %  | 12.80 %  | 3.30 %                | 1 : 2.35 , 1 : 2.1 , 1 : 1.5 |
| Guest Room                  | M+F                            | 16.50 %   | 33.00 %  | -                     | 1 : 1.5                      |
| Living Room                 | M+F                            | 6.00 %  | -  | 11.90 %               | 1 : 1.22                     |
| Dining Room                 | M+F                            | 6.00 %  | 12.10 %  | -                     | 1 : 1.05                     |
| Bedrooms                    | M+F                            | 21.90 %   | -  | 43.80 %               | 1 : 1.12 , 1 : 1.55          |
| Services (storage, toilets) | M+F                            | 13.30 %   | 9.80 %   | 16.80 %               |                              |
| Kitchen                     | M+F                            | 5.50 %  | 11.00 %  | -                     | 1 : 1                        |

## Integration of Spaces using Space Syntax Theory

(Calculations produced by AGRAPH Online software)  
(<https://www.ntnu.no/ab/spacesyntax>)

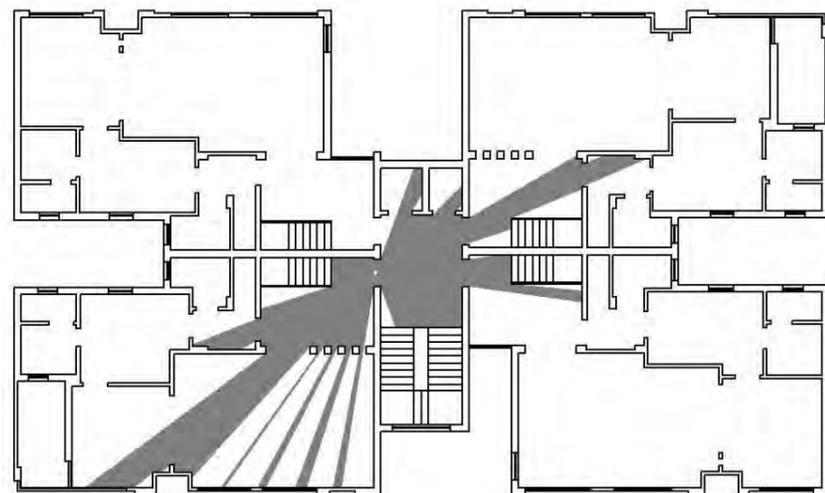
### Control and Integration Values for each space

TDn Total Depth (TD) for actual node  
MDn Mean Depth (MD) for actual node = TD/(K-1)  
K Number of Nodes  
NCn Number of Connections from Node

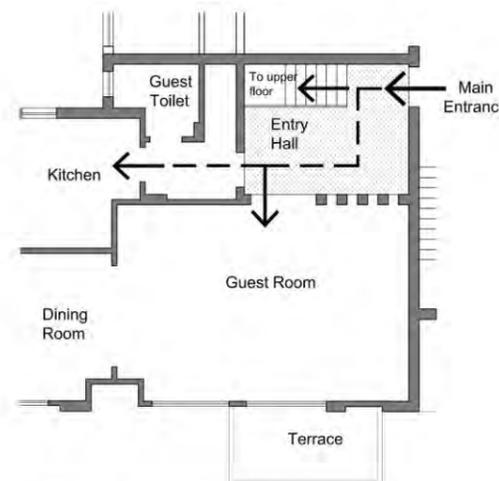
RA Relative Asymmetry = 2\*(MD-1)/(K-2)  
i Integration Value = 1/RA  
CV Control Value

| Spaces | TDn    | MDn  | RA   | i    | CV   | NCn |
|--------|--------|------|------|------|------|-----|
| Cir    | 57     | 2.85 | 0.19 | 5.13 | 0.53 | 2   |
| EA     | 58     | 2.90 | 0.20 | 5.00 | 1.16 | 3   |
| LV     | 58     | 2.90 | 0.20 | 5.00 | 3.75 | 5   |
| P      | 67     | 3.35 | 0.24 | 4.04 | 1.66 | 3   |
| P2     | 67     | 3.35 | 0.24 | 4.04 | 2.70 | 4   |
| G      | 68     | 3.40 | 0.25 | 3.95 | 1.66 | 3   |
| K      | 76     | 3.80 | 0.29 | 3.39 | 1.00 | 3   |
| D      | 77     | 3.85 | 0.30 | 3.33 | 1.16 | 3   |
| B3     | 77     | 3.85 | 0.30 | 3.33 | 0.20 | 1   |
| S7     | 77     | 3.85 | 0.30 | 3.33 | 0.20 | 1   |
| T3     | 77     | 3.85 | 0.30 | 3.33 | 0.20 | 1   |
| B1     | 82     | 4.10 | 0.32 | 3.06 | 0.75 | 2   |
| S1     | 86     | 4.30 | 0.34 | 2.87 | 0.33 | 1   |
| B2     | 86     | 4.30 | 0.34 | 2.87 | 0.25 | 1   |
| S4     | 86     | 4.30 | 0.34 | 2.87 | 0.25 | 1   |
| T1     | 87     | 4.35 | 0.35 | 2.83 | 0.33 | 1   |
| S2     | 91     | 4.55 | 0.37 | 2.67 | 1.83 | 3   |
| T2     | 92     | 4.60 | 0.37 | 2.63 | 0.66 | 2   |
| S5     | 99     | 4.95 | 0.41 | 2.40 | 1.50 | 2   |
| S3     | 110    | 5.50 | 0.47 | 2.11 | 0.33 | 1   |
| S6     | 118    | 5.90 | 0.51 | 1.93 | 0.50 | 1   |
| Min    | 57.00  | 2.85 | 0.19 | 1.93 |      |     |
| Mean   | 80.76  | 4.03 | 0.31 | 3.34 |      |     |
| Max    | 118.00 | 5.90 | 0.51 | 5.13 |      |     |

### Visual analysis from the main entrance towards guest rooms and private/intimate spaces (Produced by Syntax2D) ([https://sourceforge.net/projects/syntax2d/?source=typ\\_redirect](https://sourceforge.net/projects/syntax2d/?source=typ_redirect))



### Pattern of movement from the entrance to other spaces (Researcher)



The main entrance is the only entry point to the house. The entry hall is connected directly with the guest room, the kitchen, and the stair that leads to the upper living space and bedrooms

### Integration Values:

Vertical Circulation > Entrance, Living Area > Corridors > Guest Room > Kitchen > Dining Room > Bedrooms > Terraces > Services (Toilets)

### Lowest Integration Values:

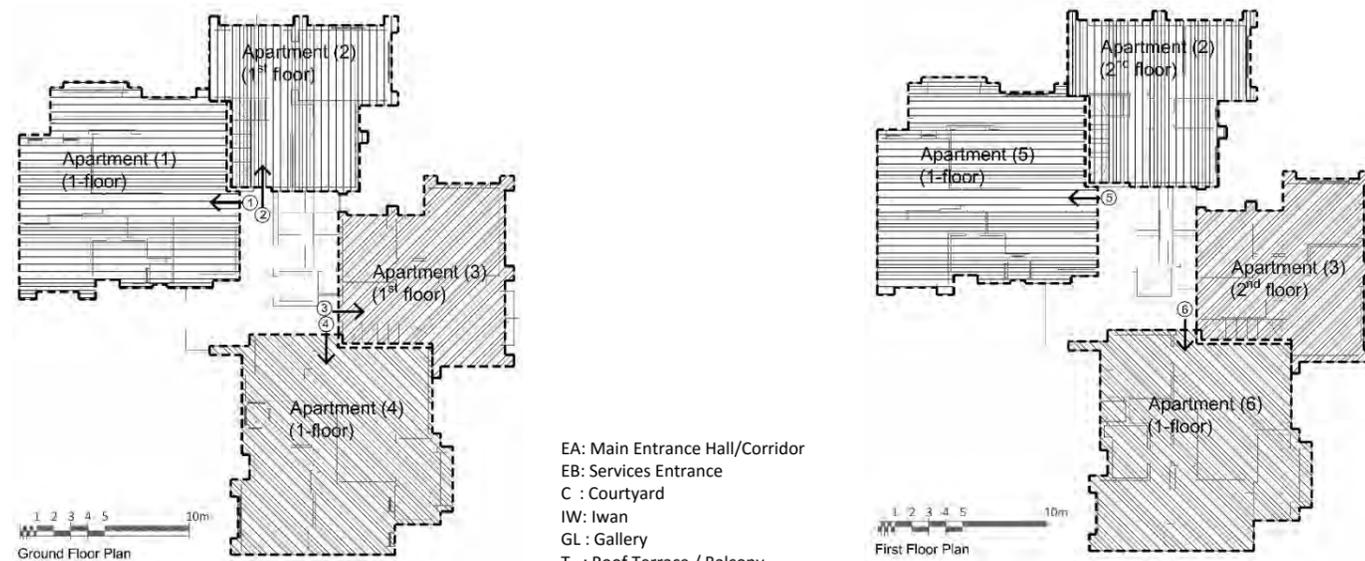
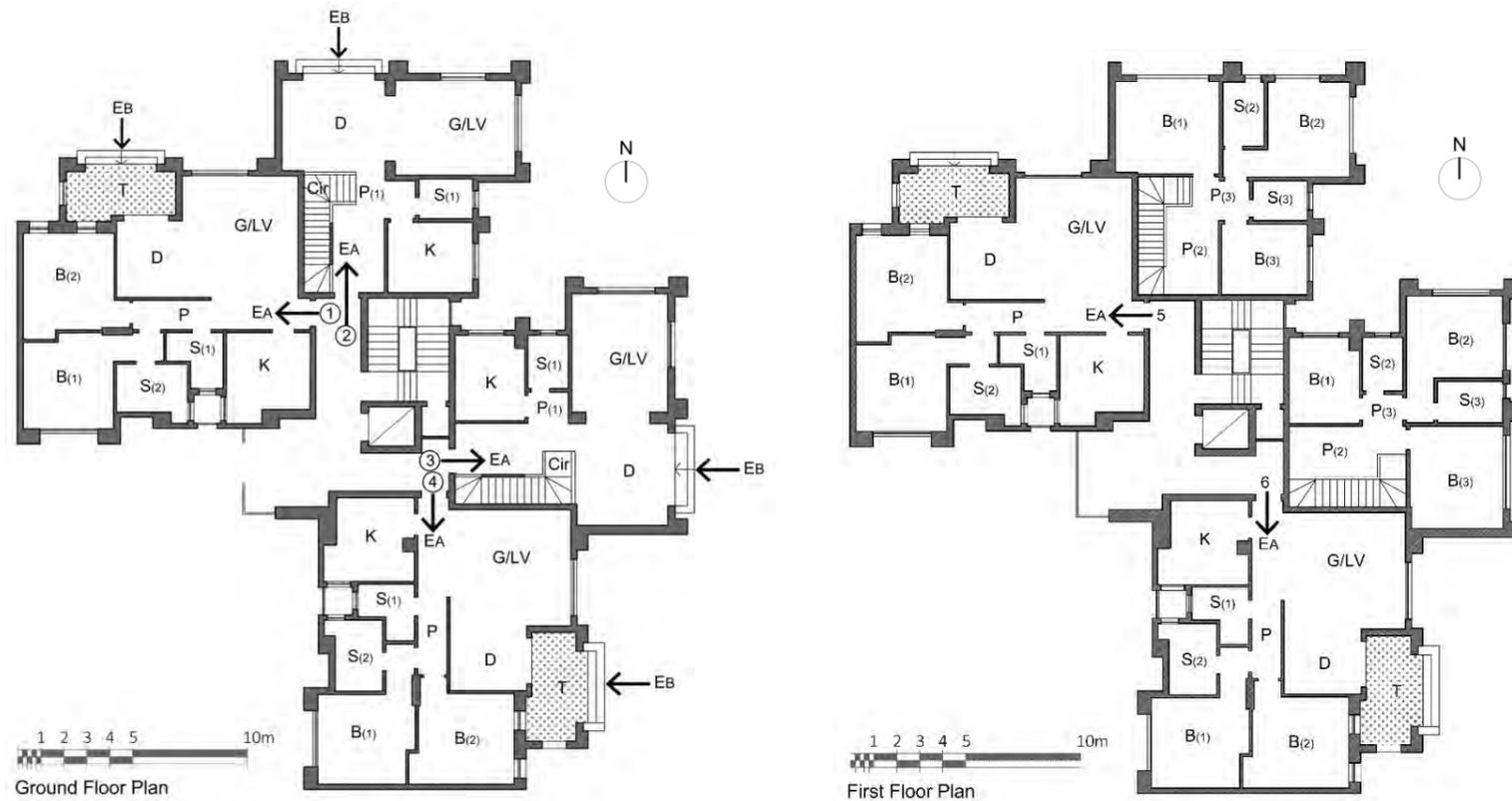
- Services (Toilets)
- Terraces

### Highest Integration and Control Values:

- Vertical circulation (stairs)
- Entrance
- Corridors

# The Social Logic of the Spatial Arrangement of an Apartment Building in Cairo, Egypt

**Architectural Plans for an Apartment Building, Cairo, Egypt**  
 (Redrawn by Researcher, <http://www.nileestate.com> (accessed 20/10/2016))

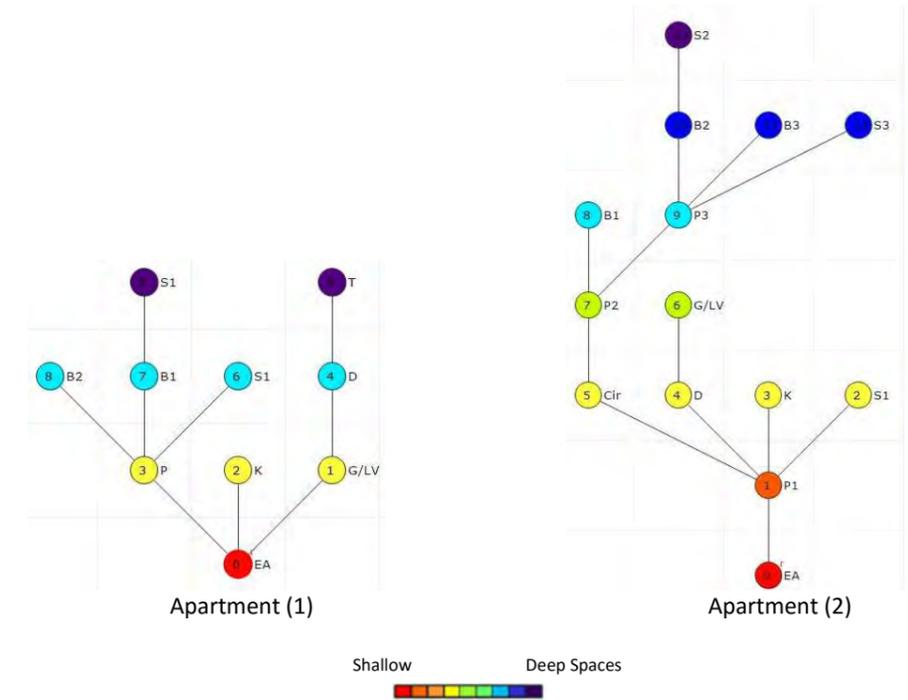


- EA: Main Entrance Hall/Corridor
- EB: Services Entrance
- C : Courtyard
- IW: Iwan
- GL : Gallery
- T : Roof Terrace / Balcony
- G : Guest Room (Reception)
- D : Dining Room
- LV: Family Living Room
- B : Intimate Spaces (Bedrooms)
- K : Kitchen
- S : Services (Toilets, Storage)
- P : Passage / Transitional Space
- DV: Double Volume

| Region | North Africa | Country | Egypt | Case No. | AP-2 |
|--------|--------------|---------|-------|----------|------|
|--------|--------------|---------|-------|----------|------|

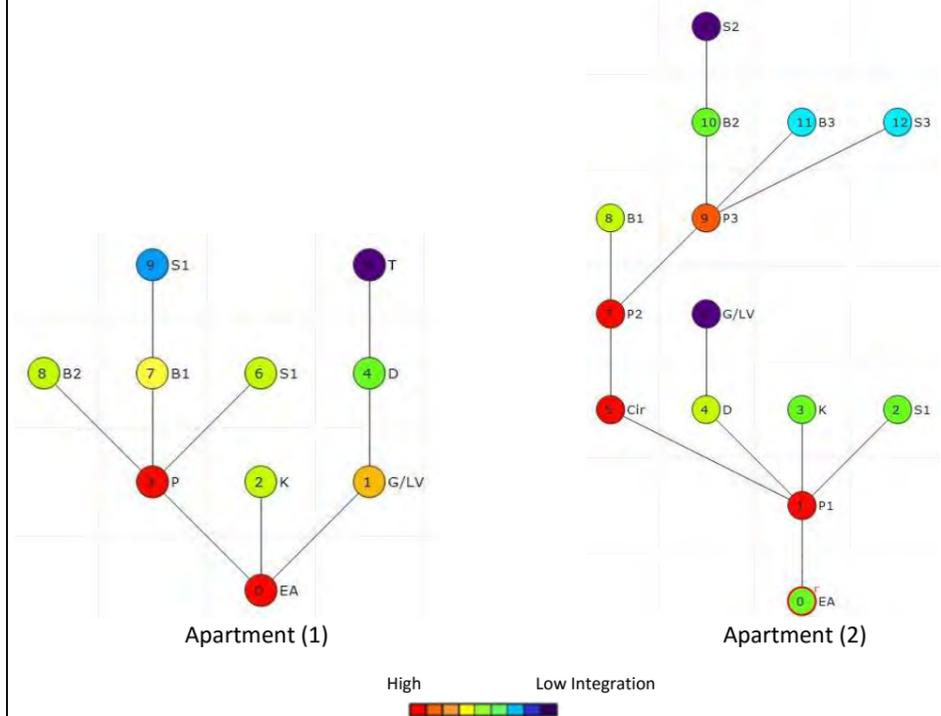
**Space Syntax Analysis**  
 Diagrams produced by Researcher using AGRAPH Online software  
 (<https://www.ntnu.no/ab/spacesyntax>)

## Depth of Spaces



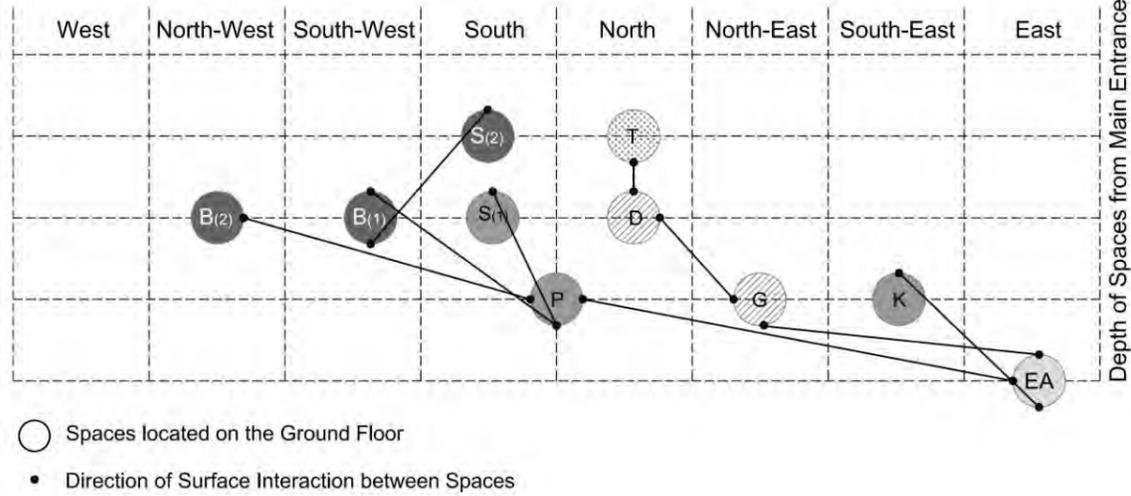
## Integration of Spaces with the Living Room and the Entrance

(the courtyard has the greatest control value)

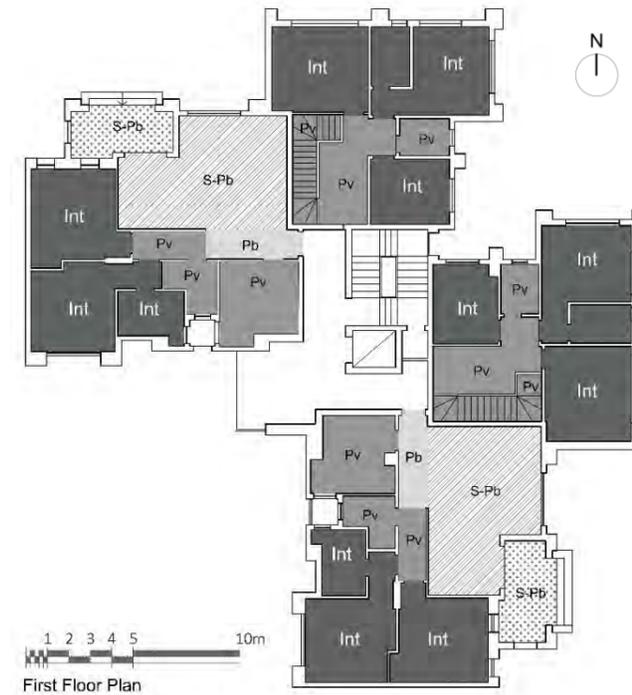
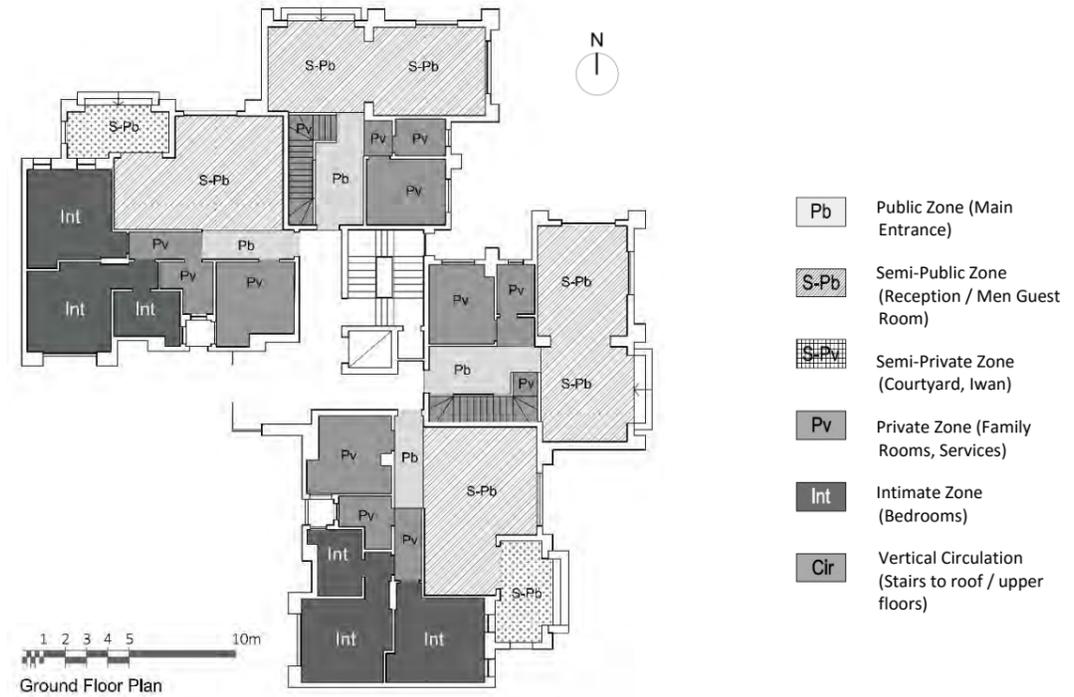
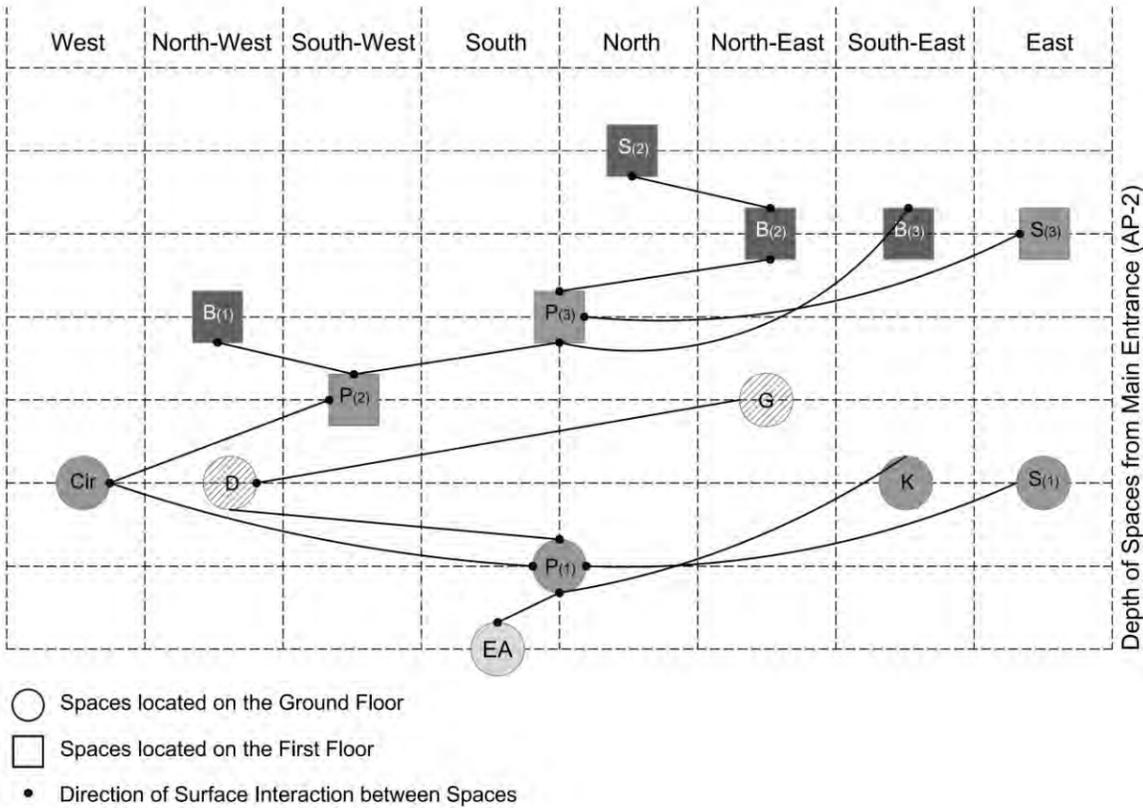


Hierarchy and Depth of Spaces (according to the orientation, and type of spaces)  
(Researcher)

Hierarchy and Depth of Spaces for Apartment (1)



Hierarchy and Depth of Spaces for Apartment (2)



The Social Logic of the Spatial Arrangement of an Apartment Building in Cairo, Egypt

|        |              |         |       |          |      |
|--------|--------------|---------|-------|----------|------|
| Region | North Africa | Country | Egypt | Case No. | AP-2 |
|--------|--------------|---------|-------|----------|------|

Typology and Geometric Properties of the Building and Apartments  
(Researcher)

Integration of Spaces FOR Apartments (1, 4) using Space Syntax Theory  
(Calculations produced by AGRAPH Online software)  
(<https://www.ntnu.no/ab/spacesyntax>)

|  |  |
|--|--|
| <b>Typology</b>  | Each apartment is a square   |
| <b>Apartment 1 (one-floor apartment)</b>   | 1 : 1.05<br>27 % of the total area of the floor                              |
| <b>Apartment 2 (two-floors apartment)</b>  | 1 : 1.10<br>Each level = 17 % of the total area of the floor in the building |
| <b>Thickness of exterior walls</b>   | 30 cm  |
| <b>Height of Guest/Living spaces</b>   |  |
| <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>Geometric Pattern for Apartments 1 and 4<br/>(1-floor apartments)</p> <p><math>W(1) = 1.05 \times L(1)</math></p> </div> <div style="text-align: center;"> <p>Geometric Pattern for Apartments 2 and 3<br/>(2-floors apartments)</p> <p><math>W(2) = 1.1.1 \times L(2)</math></p> </div> </div> |  |

Control and Integration Values for each space (Apartments 1 and 4)

TDn Total Depth (TD) for actual node RA Relative Asymmetry =  $2 * (MD-1) / (K-2)$   
 MDn Mean Depth (MD) for actual node =  $TD / (K-1)$  i Integration Value =  $1 / RA$   
 K Number of Nodes CV Control Value  
 NCn Number of Connections from Node

| Spaces | TDn   | MDn  | RA   | i    | CV   | NCn |
|--------|-------|------|------|------|------|-----|
| EA     | 17    | 1.88 | 0.22 | 4.50 | 1.75 | 3   |
| P      | 17    | 1.88 | 0.22 | 4.50 | 2.83 | 4   |
| G/LV   | 21    | 2.33 | 0.33 | 3.00 | 0.83 | 2   |
| B1     | 23    | 2.55 | 0.38 | 2.57 | 1.25 | 2   |
| K      | 25    | 2.77 | 0.44 | 2.25 | 0.33 | 1   |
| S1     | 25    | 2.77 | 0.44 | 2.25 | 0.25 | 1   |
| B2     | 25    | 2.77 | 0.44 | 2.25 | 0.25 | 1   |
| D      | 27    | 3.00 | 0.50 | 2.00 | 1.50 | 2   |
| S1     | 31    | 3.44 | 0.61 | 1.63 | 0.50 | 1   |
| T      | 35    | 3.88 | 0.72 | 1.38 | 0.50 | 1   |
| Min    | 17.00 | 1.88 | 0.22 | 1.38 |      |     |
| Mean   | 24.60 | 2.73 | 0.43 | 2.63 |      |     |
| Max    | 35.00 | 3.88 | 0.72 | 4.50 |      |     |

Integration Values:

Entrance, Corridors > Guest Room > Kitchen > Bedrooms > Dining Room > Services (Toilets) > Terrace

Lowest Integration Values:

- Services (Toilets)
- Terrace

Highest Integration and Control Values:

- Entrance
- Corridors

| Type (1): one-floor apartment | Dominant Users (Male / Female) | Percentage of area of this space related to the total area of the apartment | Percentage of area of this space related to the floor area where it is located | Proportion of Spaces |
|-------------------------------|--------------------------------|---|--|----------------------|
| Corridor                      | M+F                            | 5.6 %   | 5.6 %  | 1 : 4.8              |
| Terraces                      | M+F                            | 7.0 %   | 7.0 %  | 1 : 2.1              |
| Guest/Living Room             | M+F                            | 20.7 %  | 20.7 %   | 1 : 1.05             |
| Dining Room                   | M+F                            | 7.7 %   | 7.7 %  | 1 : 1.16             |
| Bedrooms                      | M+F                            | 28.5 %  | 28.5 %   | 1 : 1 , 1 : 1.15     |
| Services (storage, toilets)   | M+F                            | 8.5 %   | 8.5 %  |                      |
| Kitchen                       | M+F                            | 10.8 %  | 10.8 %   | 1 : 1.1              |
| Entry Hall                    | M+F                            | 1.7 %   | 1.7 %  | 1 : 1.05             |

| Type (2): two-floors apartment | Dominant Users (Male / Female) | Percentage of area of this space related to the total area of the apartment | Percentage of area of this space related to the floor area where it is located |                       | Proportion of Spaces           |
|--------------------------------|--------------------------------|---|--|-----------------------|--------------------------------|
|                                |                                |   | Ground   | 1 <sup>st</sup> Floor |                                |
| Corridor                       | M+F                            | 11 %  | 5.25 %   | 16.5 %                | 1 : 1.65 , 1 : 1.47            |
| Terraces                       | M+F                            | -   | -  | -                     | -                              |
| Guest/Living Room              | M+F                            | 13.5 %  | 27.0 %   | -                     | 1 : 1.25                       |
| Dining Room                    | M+F                            | 11.1 %  | 22.0 %   | -                     | 1 : 1.05                       |
| Bedrooms                       | M+F                            | 28.9 %  | -  | 57.8 %                | 1 : 1.125 , 1 : 1.1 , 1 : 1.25 |
| Services (storage, toilets)    | M+F                            | 8.3 %   | 5.3 %  | 11.3 %                |                                |
| Kitchen                        | M+F                            | 7.0 %   | 14.3 %   | -                     | 1 : 1.25                       |
| Entry Hall                     | M+F                            | 5.5 %   | 10.9 %   | -                     | 1 : 1.66                       |

# The Social Logic of the Spatial Arrangement of an Apartment Building in Cairo, Egypt

|        |              |         |       |          |      |
|--------|--------------|---------|-------|----------|------|
| Region | North Africa | Country | Egypt | Case No. | AP-2 |
|--------|--------------|---------|-------|----------|------|

## Typology and Geometric Properties of the Building and Apartments (Researcher)

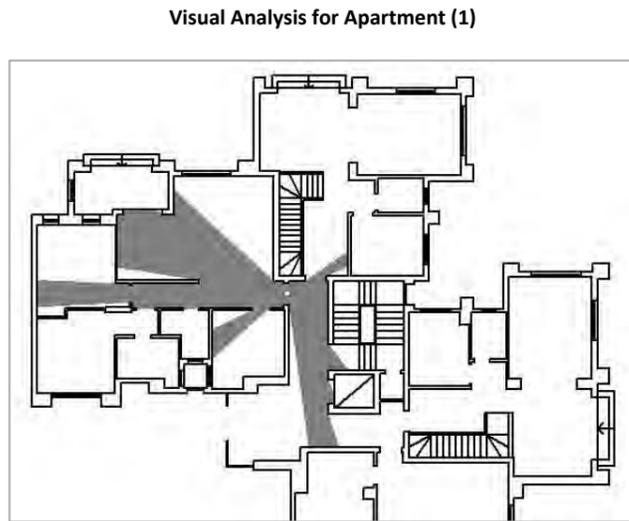
**Integration of Spaces (for Apartments 2, 3) using Space Syntax Theory**  
 (Calculations produced by AGRAPH Online software)  
<https://www.ntnu.no/ab/spacesyntax>

**Visual analysis from the main entrance towards guest rooms and private/intimate spaces** (Produced by Syntax2D)  
[https://sourceforge.net/projects/syntax2d/?source=typ\\_redirect](https://sourceforge.net/projects/syntax2d/?source=typ_redirect)

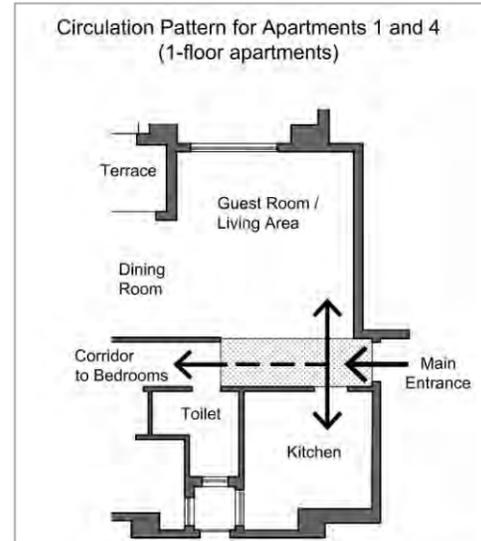
**Pattern of movement from the entrance to other spaces** (Researcher)

### Control and Integration Values for each space (Apartments 2 and 3)

TDn Total Depth (TD) for actual node  
 MDn Mean Depth (MD) for actual node = TD/(K-1)  
 K Number of Nodes  
 NCn Number of Connections from Node  
 RA Relative Asymmetry = 2\*(MD-1)/(K-2)  
 i Integration Value = 1/RA  
 CV Control Value



Generally, there is no direct visual connection between the entrance/guest room, and bedrooms



The entry hall is connected directly with the reception area that is used by both guests and family members. It is also connected with the kitchen, and a corridor leads to bedrooms. However, there is no visual barriers between the entrance and the living area or the corridor.

| Spaces | TDn    | MDn  | RA   | i    | CV   | NCn |
|--------|--------|------|------|------|------|-----|
| Cir    | 30     | 2.30 | 0.21 | 4.58 | 0.53 | 2   |
| P2     | 30     | 2.30 | 0.21 | 4.58 | 1.75 | 3   |
| P1     | 32     | 2.46 | 0.24 | 4.10 | 4.00 | 5   |
| P3     | 34     | 2.61 | 0.26 | 3.71 | 2.83 | 4   |
| D      | 42     | 3.23 | 0.37 | 2.68 | 1.20 | 2   |
| B1     | 42     | 3.23 | 0.37 | 2.68 | 0.33 | 1   |
| EA     | 44     | 3.38 | 0.39 | 2.51 | 0.20 | 1   |
| S1     | 44     | 3.38 | 0.39 | 2.51 | 0.20 | 1   |
| K      | 44     | 3.38 | 0.39 | 2.51 | 0.20 | 1   |
| B2     | 44     | 3.38 | 0.39 | 2.51 | 1.25 | 2   |
| B3     | 46     | 3.53 | 0.42 | 2.36 | 0.25 | 1   |
| S3     | 46     | 3.53 | 0.42 | 2.36 | 0.25 | 1   |
| G/LV   | 54     | 4.15 | 0.52 | 1.90 | 0.50 | 1   |
| S2     | 56     | 4.30 | 0.55 | 1.81 | 0.50 | 1   |
| Min    | 57.00  | 2.85 | 0.19 | 1.93 |      |     |
| Mean   | 80.76  | 4.03 | 0.31 | 3.34 |      |     |
| Max    | 118.00 | 5.90 | 0.51 | 5.13 |      |     |

### Integration Values:

Vertical Circulation > Corridors > Dining Room > Bedroom (1) > Entrance > Kitchen > Bedrooms (2, 3) > Guest Room > Services (Toilets)

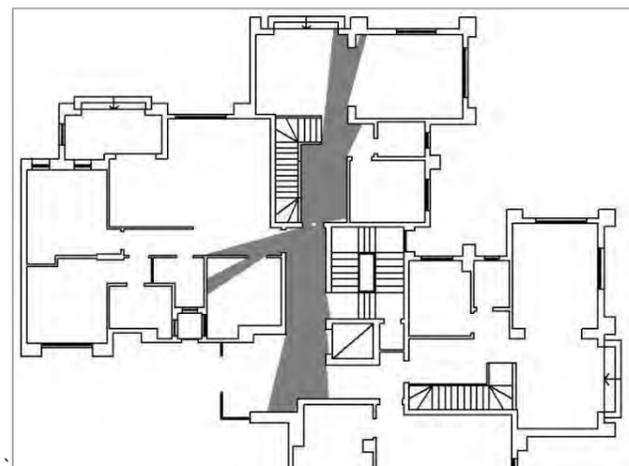
### Lowest Integration Values:

- Services (Toilets)
- Guest Room

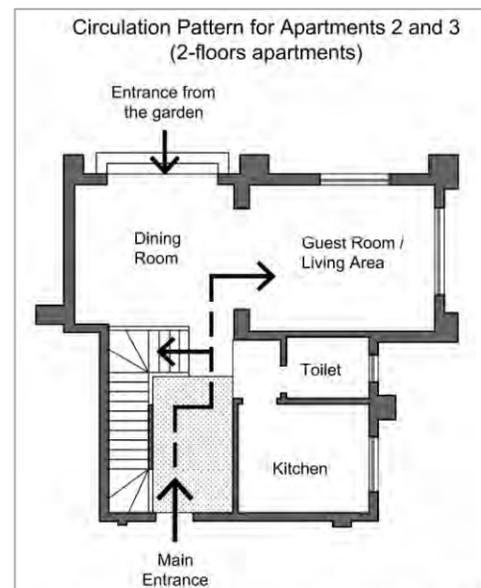
### Highest Integration and Control Values:

- Vertical circulation (stairs)
- Corridors

### Visual Analysis for Apartment (2)



Generally, there is no direct visual connection between the entrance and bedrooms, as all private spaces (living room and bedrooms) are located on the first floor



There is no direct connection between the entry hall and the guest room, as visitors need to pass through the dining area, and beside the stair that leads to upper floor. However, the guest room is used by both visitors, and family members.

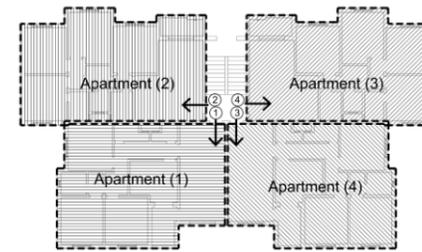
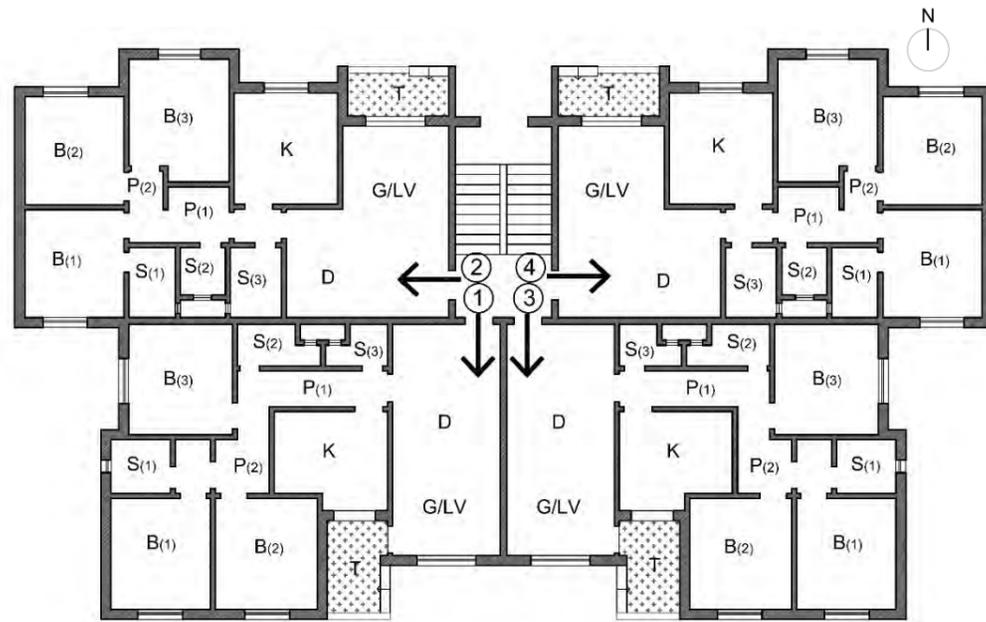
# The Social Logic of the Spatial Arrangement of an Apartment Building in Amman, Jordan

|        |             |         |        |          |      |
|--------|-------------|---------|--------|----------|------|
| Region | Middle East | Country | Jordan | Case No. | AP-3 |
|--------|-------------|---------|--------|----------|------|

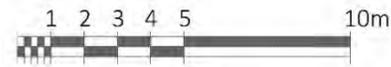
## Architectural Plans for an Apartment Building, Amman, Jordan (Redrawn by Researcher, <http://www.csbe.org> (accessed 20/10/2016))

## Space Syntax Analysis

Diagrams produced by Researcher using AGRAPH Online software  
(<https://www.ntnu.no/ab/spacesyntax>)

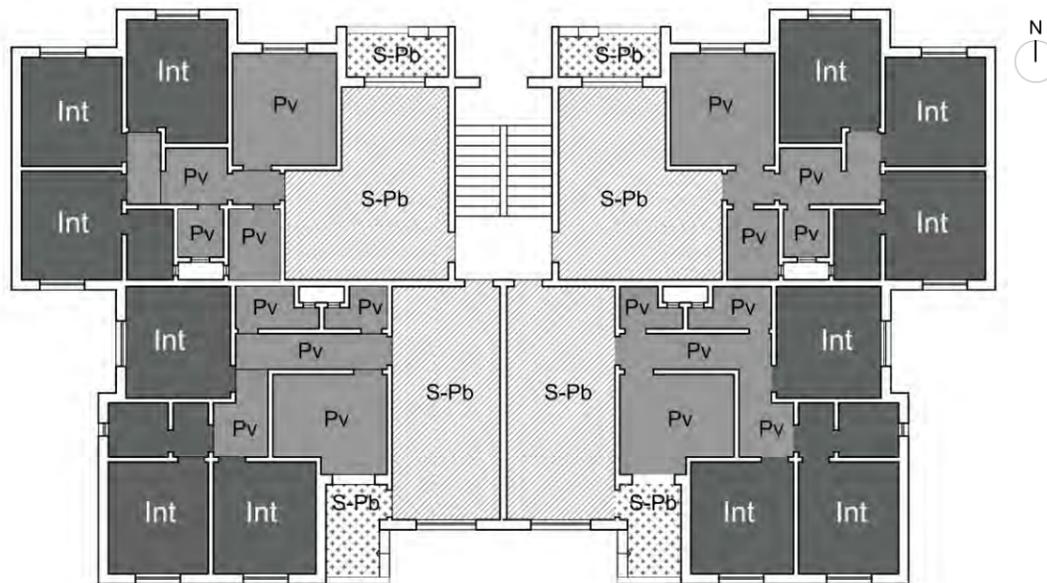


- EA: Main Entrance Hall/Corridor
- EB: Services Entrance
- C : Courtyard
- IW: Iwan
- GL: Gallery
- T : Roof Terrace / Balcony
- G : Guest Room (Reception)
- D : Dining Room
- LV: Family Living Room
- B : Intimate Spaces (Bedrooms)
- K : Kitchen
- S : Services (Toilets, Storage)
- P : Passage / Transitional Space
- DV: Double Volume

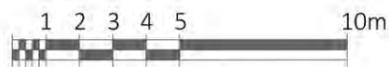


Ground Floor Plan

## Hierarchy of Spaces (Researcher)

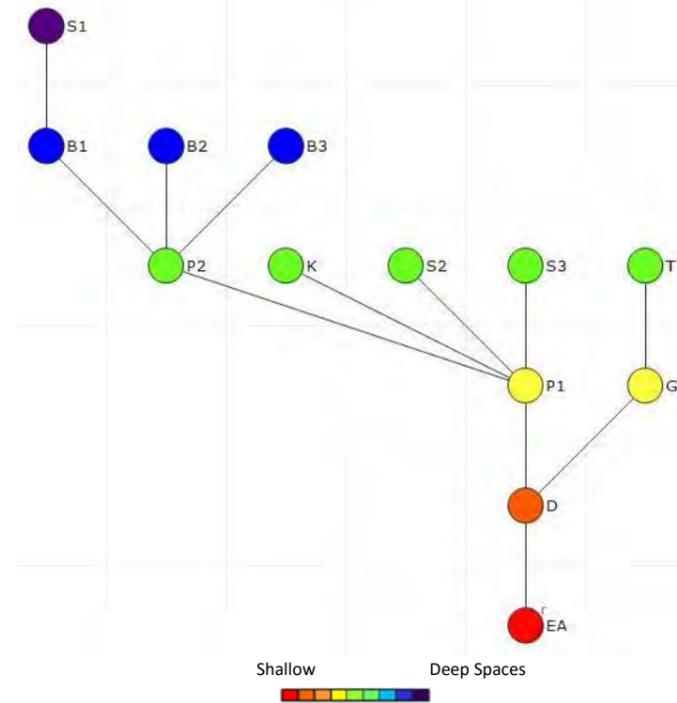


- Pb** Public Zone (Main Entrance)
- S-Pb** Semi-Public Zone (Reception / Men Guest Room)
- S-Pv** Semi-Private Zone (Courtyard, Iwan)
- Pv** Private Zone (Family Rooms, Services)
- Int** Intimate Zone (Bedrooms)
- Cir** Vertical Circulation (Stairs to roof / upper floors)

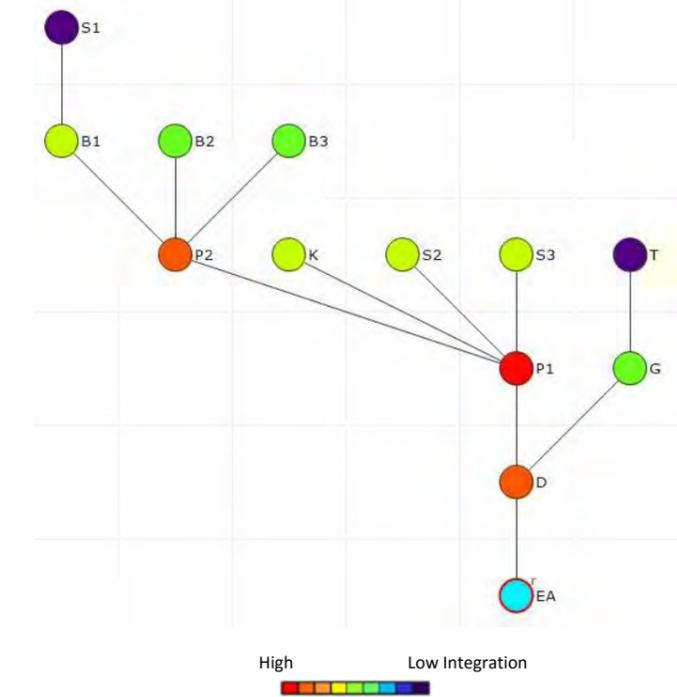


Ground Floor Plan

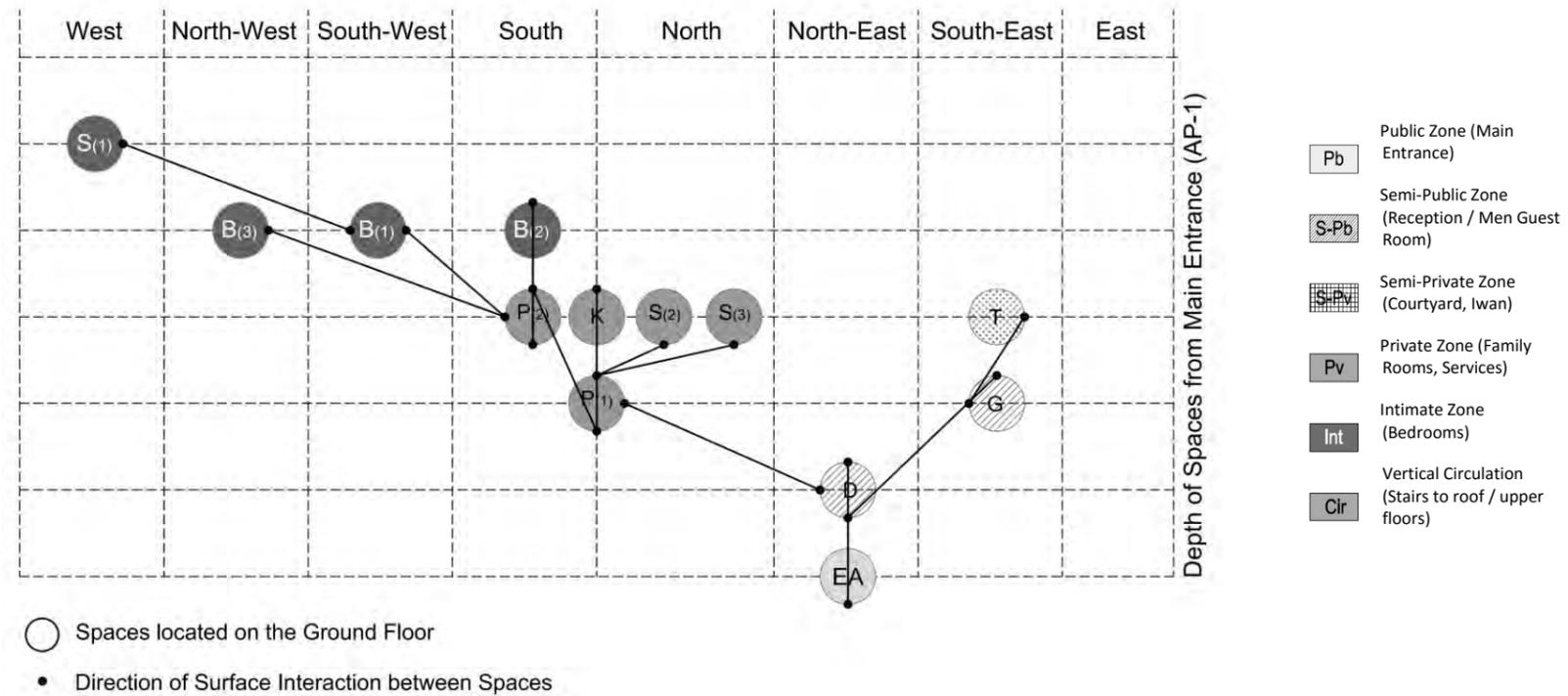
## Depth of Spaces



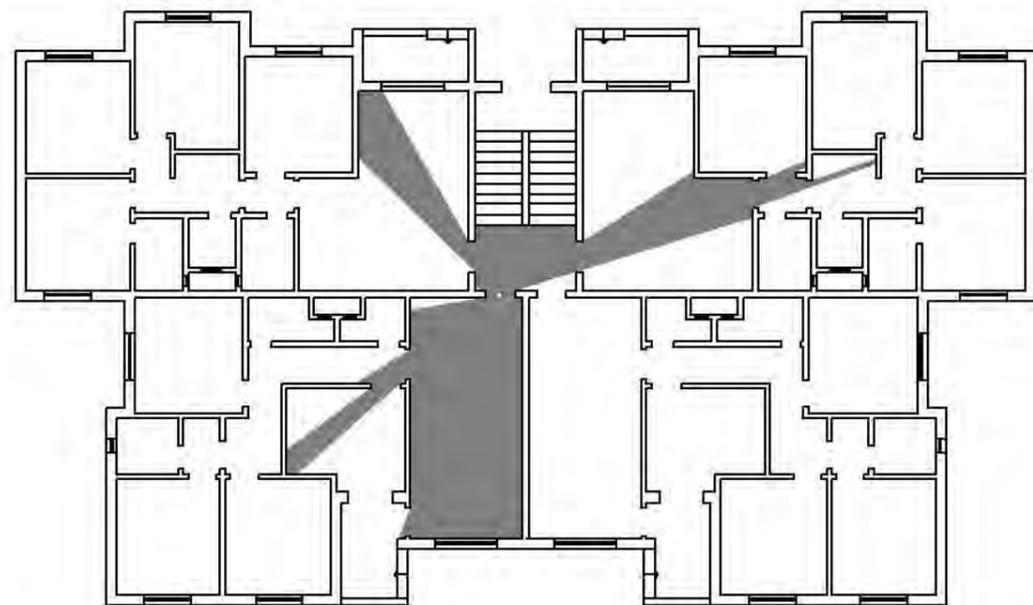
## Integration of Spaces with the Living Room and the Entrance (the courtyard has the greatest control value)



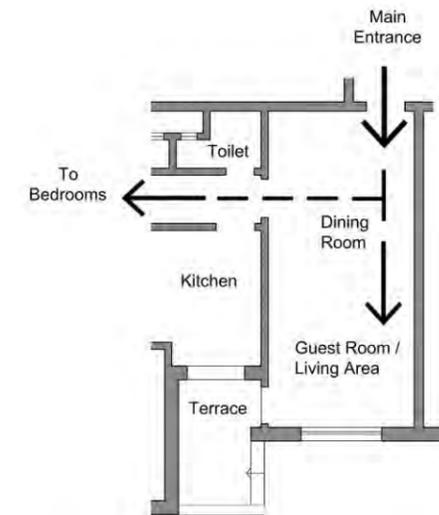
Hierarchy and Depth of Spaces (according to the orientation, and type of spaces)  
(Researcher)



Visual analysis from the main entrance towards guest rooms and private/intimate spaces (Produced by Syntax2D) ([https://sourceforge.net/projects/syntax2d/?source=typ\\_redirect](https://sourceforge.net/projects/syntax2d/?source=typ_redirect))



Pattern of movement from the entrance to other spaces (Researcher)

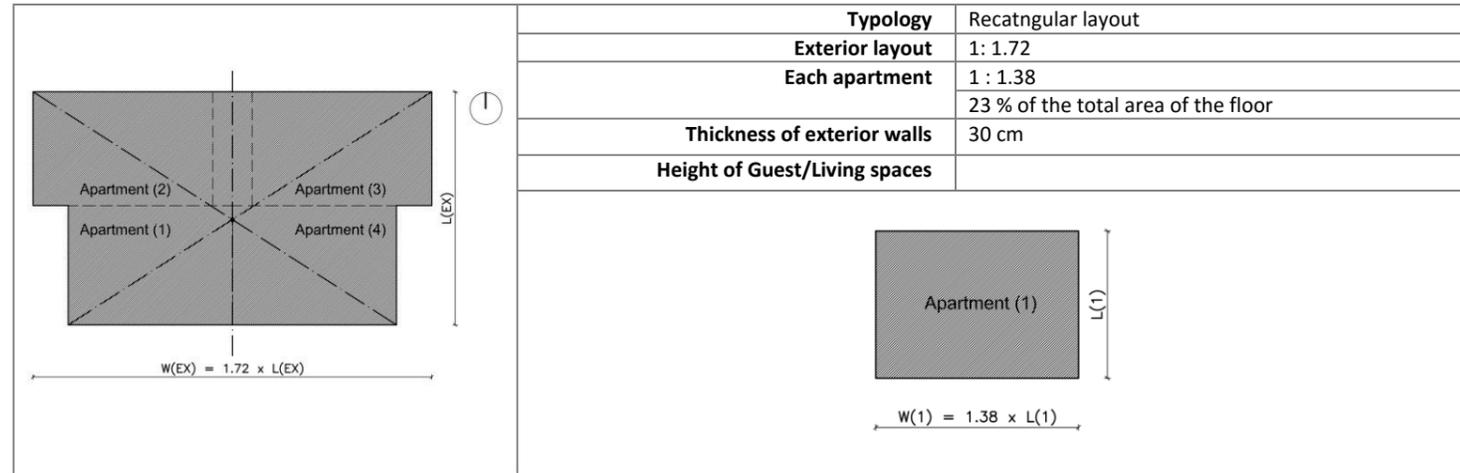


There is no entry hall. The entrance door is connected directly with the reception area that is used as dining room, guest/family space. A corridor that leads to other spaces (toilets, kitchen, and bedrooms) is also connected directly with the dining room.

# The Social Logic of the Spatial Arrangement of an Apartment Building in Amman, Jordan

|        |             |         |        |          |      |
|--------|-------------|---------|--------|----------|------|
| Region | Middle East | Country | Jordan | Case No. | AP-3 |
|--------|-------------|---------|--------|----------|------|

## Typology and Geometric Properties of the Building and Apartments (Researcher)



|                               |                                     |
|-------------------------------|-------------------------------------|
| Typology                      | Recatngular layout                  |
| Exterior layout               | 1: 1.72                             |
| Each apartment                | 1 : 1.38                            |
| Thickness of exterior walls   | 23 % of the total area of the floor |
| Height of Guest/Living spaces | 30 cm                               |

| Spaces                      | Dominant Users (Male / Female) | Percentage of area of this space related to the total area of the apartment | Percentage of area of this space related to the floor area where it is located | Proportion of Spaces |
|-----------------------------|--------------------------------|---|--|----------------------|
| Corridor                    | M+F                            | 8.80 %  | 8.80 %   | 1 : 1 , 1 : 4.25     |
| Terraces                    | M+F                            | 5.70 %  | 5.70 %   | 1 : 1.53             |
| Guest/Living Room           | M+F                            | 12.10 %   | 12.10 %  | 1 : 1.08             |
| Dining Room                 | M+F                            | 12.10 %   | 12.10 %  | 1 : 1.08             |
| Bedrooms                    | M+F                            | 34.70 %   | 34.70 %  | 1 : 1.07 , 1: 1.1    |
| Services (storage, toilets) | M+F                            | 9.10 %  | 9.10 %   |                      |
| Kitchen                     | M+F                            | 10.20 %   | 10.20 %  | 1 : 1.33             |

## Integration of Spaces using Space Syntax Theory

(Calculations produced by AGRAPH Online software)  
(<https://www.ntnu.no/ab/spacesyntax>)

### Control and Integration Values for each space

TDn Total Depth (TD) for actual node  
 MDn Mean Depth (MD) for actual node =  $TD/(K-1)$   
 K Number of Nodes  
 NCn Number of Connections from Node  
 RA Relative Asymmetry =  $2*(MD-1)/(K-2)$   
 i Integration Value =  $1/RA$   
 CV Control Value

| Spaces | TDn   | MDn  | RA   | i    | CV   | NCn |
|--------|-------|------|------|------|------|-----|
| P1     | 21    | 1.75 | 0.13 | 7.33 | 3.58 | 5   |
| P2     | 24    | 2.00 | 0.18 | 5.50 | 2.70 | 4   |
| D      | 26    | 2.16 | 0.21 | 4.71 | 1.70 | 3   |
| S3     | 32    | 2.66 | 0.30 | 3.30 | 0.20 | 1   |
| S2     | 32    | 2.66 | 0.30 | 3.30 | 0.20 | 1   |
| K      | 32    | 2.66 | 0.30 | 3.30 | 0.20 | 1   |
| B1     | 33    | 2.75 | 0.31 | 3.14 | 1.25 | 2   |
| G      | 35    | 2.91 | 0.34 | 2.86 | 1.33 | 2   |
| B2     | 35    | 2.91 | 0.34 | 2.86 | 0.25 | 1   |
| B3     | 35    | 2.91 | 0.34 | 2.86 | 0.25 | 1   |
| EA     | 37    | 3.08 | 0.37 | 2.64 | 0.33 | 1   |
| S1     | 44    | 3.66 | 0.48 | 2.06 | 0.50 | 1   |
| T      | 46    | 3.83 | 0.51 | 1.94 | 0.50 | 1   |
| Min    | 21.00 | 1.75 | 0.13 | 7.33 |      |     |
| Mean   | 33.23 | 2.76 | 0.32 | 3.52 |      |     |
| Max    | 46.00 | 3.83 | 0.51 | 1.94 |      |     |

### Integration Values:

Corridors > Dining Room > Services, Kitchen > Bedroom (1) > Guest Room, Bedrooms (2, 3) > Entrance > Services (Toilets) > Terrace

### Lowest Integration Values:

- Terraces
- Services (Toilets)
- Entrance

### Highest Integration and Control Values:

- Corridors

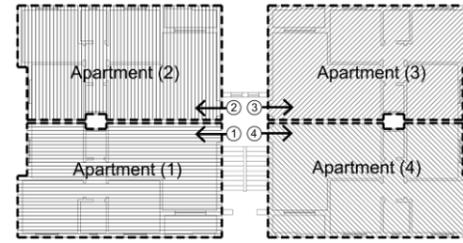
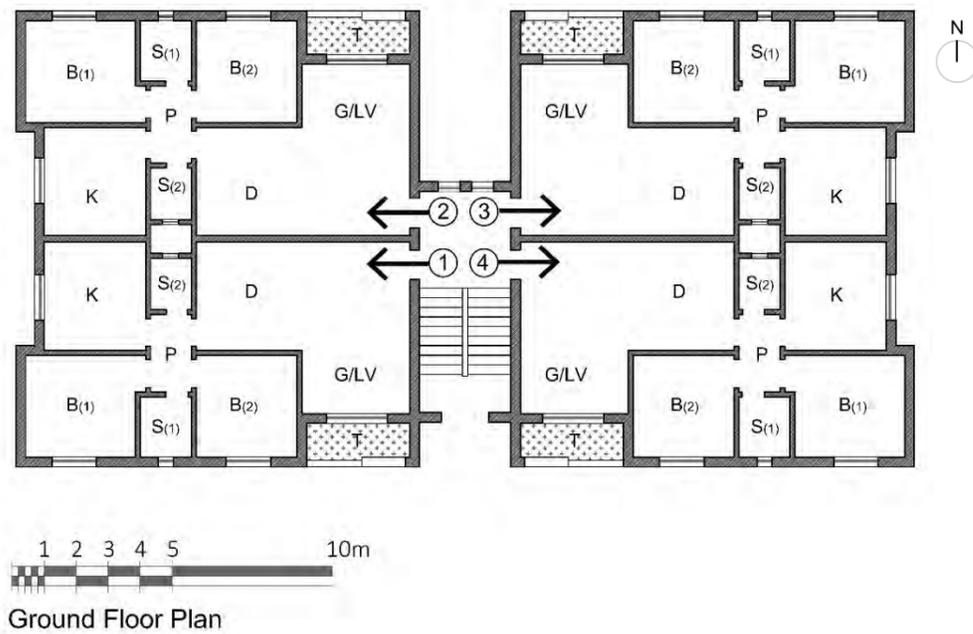
# The Social Logic of the Spatial Arrangement of an Apartment Building in Amman, Jordan

|        |             |         |        |          |      |
|--------|-------------|---------|--------|----------|------|
| Region | Middle East | Country | Jordan | Case No. | AP-4 |
|--------|-------------|---------|--------|----------|------|

## Architectural Plans for an Apartment Building, Amman, Jordan (Redrawn by Researcher, <http://www.csbe.org> (accessed 20/10/2016))

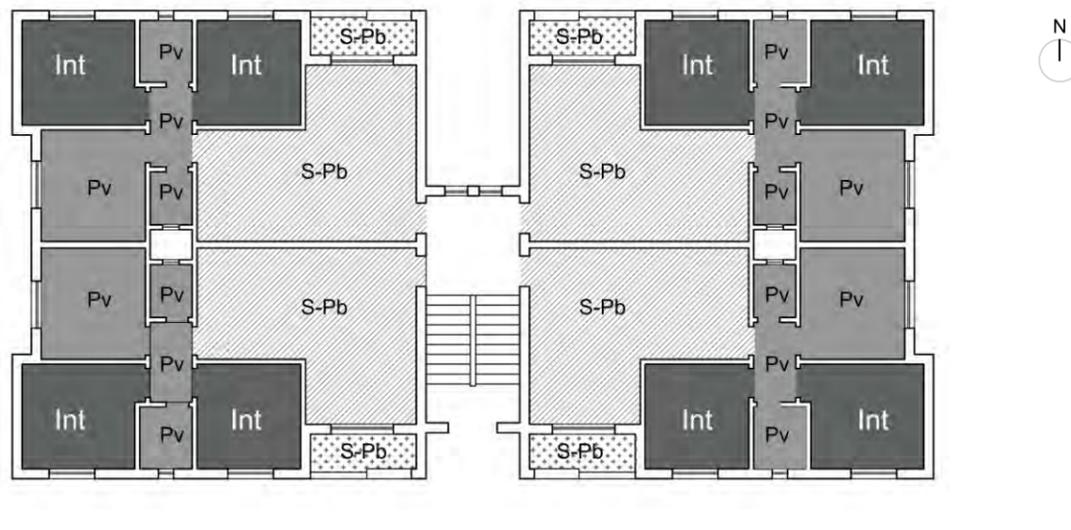
## Space Syntax Analysis

Diagrams produced by Researcher using AGRAPH Online software  
(<https://www.ntnu.no/ab/spacesyntax>)



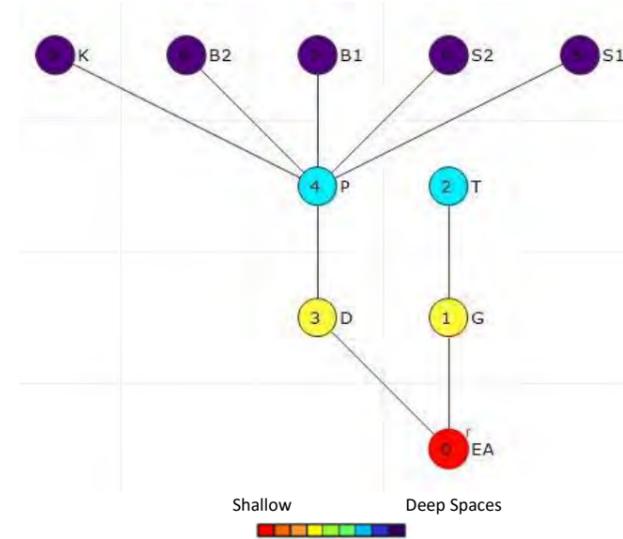
- EA: Main Entrance Hall/Corridor
- EB: Services Entrance
- C : Courtyard
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- GL : Gallery
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- B : Intimate Spaces (Bedrooms)
- K : Kitchen
- S : Services (Toilets, Storage)
- P : Passage / Transitional Space
- DV: Double Volume

## Hierarchy of Spaces (Researcher)

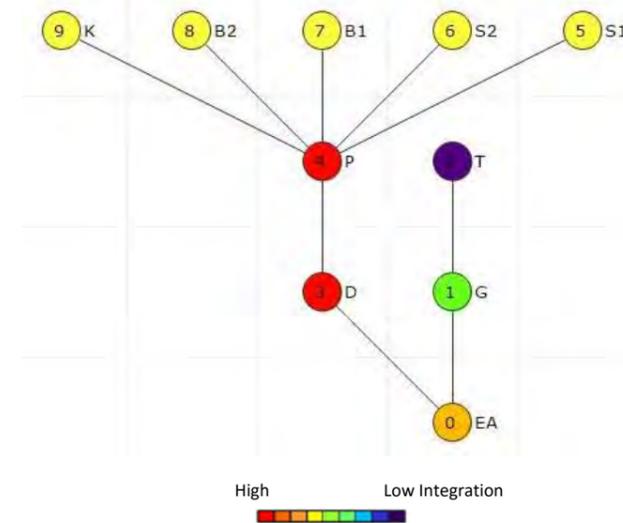


- Pb Public Zone (Main Entrance)
- S-Pb Semi-Public Zone (Reception / Men Guest Room)
- S-Pv Semi-Private Zone (Courtyard, Iwan)
- Pv Private Zone (Family Rooms, Services)
- Int Intimate Zone (Bedrooms)
- Cir Vertical Circulation (Stairs to roof / upper floors)

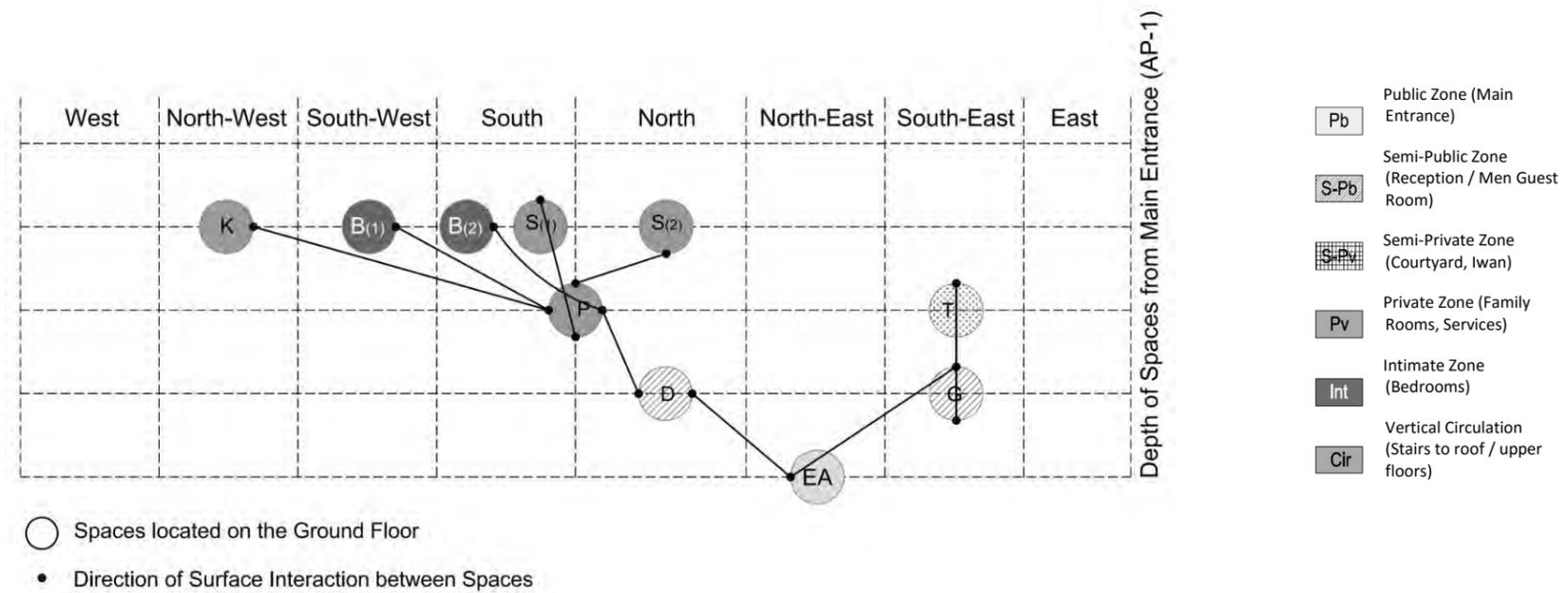
## Depth of Spaces



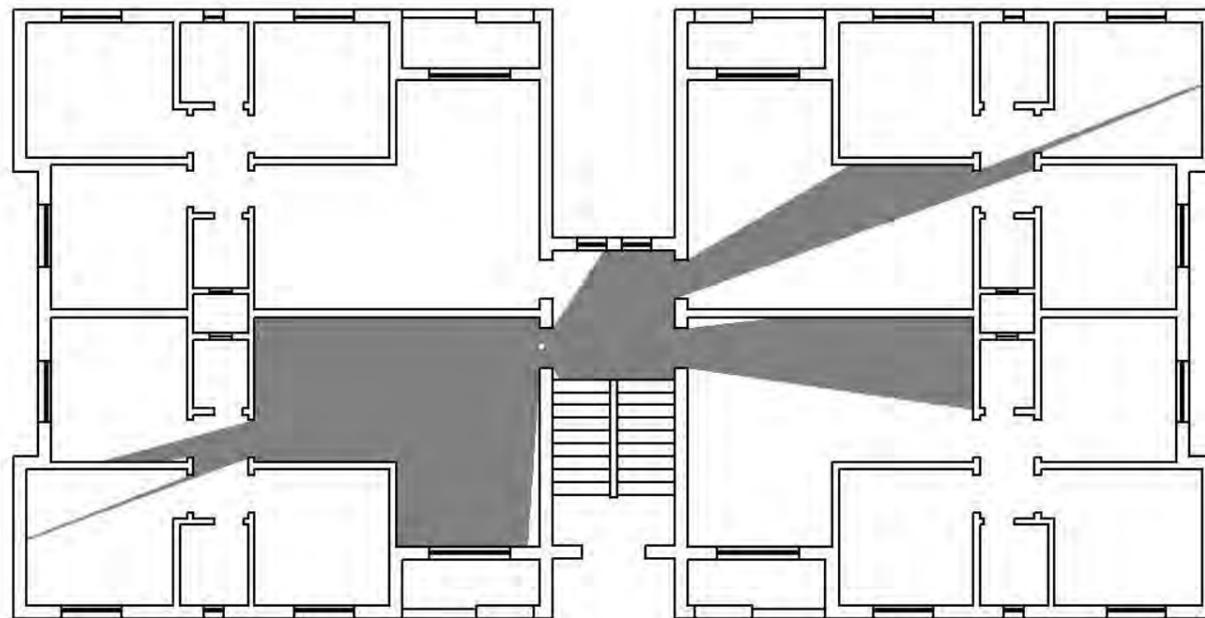
## Integration of Spaces with the Living Room and the Entrance (the courtyard has the greatest control value)



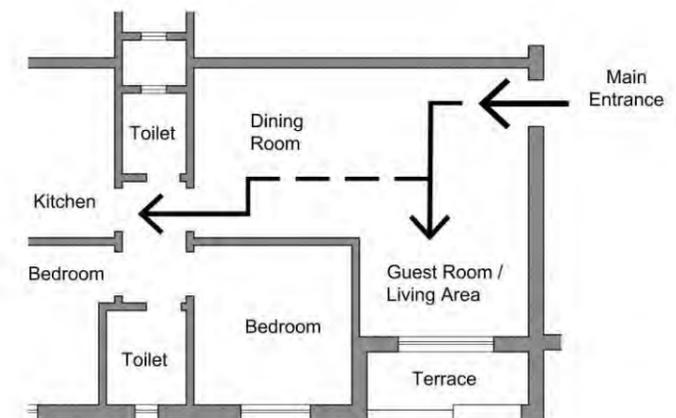
Hierarchy and Depth of Spaces (according to the orientation, and type of spaces)  
(Researcher)



Visual analysis (for Apartment (1)) from the main entrance towards guest rooms and private/intimate spaces  
(Produced by Syntax2D, [https://sourceforge.net/projects/syntax2d/?source=typ\\_redirect](https://sourceforge.net/projects/syntax2d/?source=typ_redirect))



Pattern of movement from the entrance to other spaces  
(Researcher)



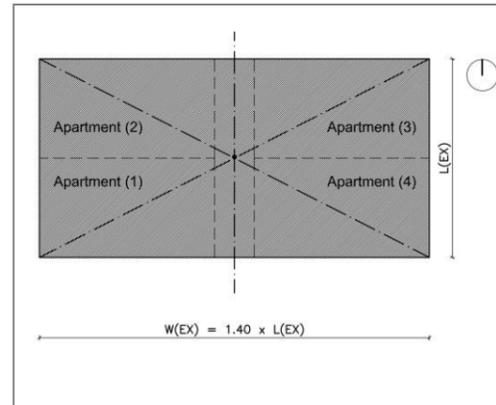
There is no entry hall. The entrance door is connected directly with the reception area that is used as dining room, guest/family space. A corridor that leads to other spaces (toilets, kitchen, and bedrooms) is also connected directly with the dining room.

The Social Logic of the Spatial Arrangement of an Apartment Building in Amman, Jordan

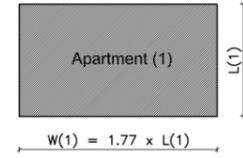
|        |             |         |        |          |      |
|--------|-------------|---------|--------|----------|------|
| Region | Middle East | Country | Jordan | Case No. | AP-4 |
|--------|-------------|---------|--------|----------|------|

Typology and Geometric Properties of the Building and Apartments  
(Researcher)

Integration of Spaces using Space Syntax Theory  
(Calculations produced by AGRAPH Online software)  
<https://www.ntnu.no/ab/spacesyntax>



|                               |                                       |
|-------------------------------|---------------------------------------|
| Typology                      | Rectangular layout                    |
| Exterior layout               | 1: 1.40                               |
| Each Apartment                | 1: 1.77                               |
|                               | 22.5 % of the total area of the floor |
| Thickness of exterior walls   | 30 cm                                 |
| Height of Guest/Living spaces |                                       |



|                             | Dominant Users (Male / Female) | Percentage of area of this space related to the total area of the Apartment | Percentage of area of this space related to the floor area where it is located | Proportion of Spaces |
|-----------------------------|--------------------------------|---|--|----------------------|
| Corridor                    | M+F                            | 3.75 %  | 3.75 %   | 1 : 1.9              |
| Terraces                    | M+F                            | 4.70 %  | 4.70 %   | 1 : 3.1              |
| Guest/Living Room           | M+F                            | 22.50 %   | 22.50 %  | 1 : 1.6              |
| Dining Room                 | M+F                            | 13.75 %   | 13.75 %  | 1 : 1                |
| Bedrooms                    | M+F                            | 27.50 %   | 27.50 %  | 1 : 1.08 , 1: 1.03   |
| Services (storage, toilets) | M+F                            | 6.25 %  | 6.25 %   |                      |
| Kitchen                     | M+F                            | 13.75 %   | 13.75 %  | 1 : 1.07             |

Control and Integration Values for each space

TDn Total Depth (TD) for actual node  
 MDn Mean Depth (MD) for actual node = TD/(K-1)  
 K Number of Nodes  
 NCn Number of Connections from Node  
 RA Relative Asymmetry = 2\*(MD-1)/(K-2)  
 i Integration Value = 1/RA  
 CV Control Value

| Spaces | TDn | MDn  | RA   | i    | CV   | NCn |
|--------|-----|------|------|------|------|-----|
| P      | 15  | 1.66 | 0.16 | 6.00 | 5.50 | 6   |
| D      | 17  | 1.88 | 0.22 | 4.50 | 0.66 | 2   |
| EA     | 21  | 2.33 | 0.33 | 3.00 | 1.00 | 2   |
| S1     | 23  | 2.55 | 0.38 | 2.57 | 0.16 | 1   |
| S2     | 23  | 2.55 | 0.38 | 2.57 | 0.16 | 1   |
| B1     | 23  | 2.55 | 0.38 | 2.57 | 0.16 | 1   |
| B2     | 23  | 2.55 | 0.38 | 2.57 | 0.16 | 1   |
| K      | 23  | 2.55 | 0.38 | 2.57 | 0.16 | 1   |
| G      | 27  | 3.00 | 0.50 | 2.00 | 1.50 | 2   |
| T      | 35  | 3.88 | 0.72 | 1.38 | 0.50 | 1   |
| Min    | 15  | 1.66 | 0.16 | 1.38 |      |     |
| Mean   | 23  | 2.55 | 0.38 | 2.97 |      |     |
| Max    | 35  | 3.88 | 0.72 | 6.00 |      |     |

Integration Values:

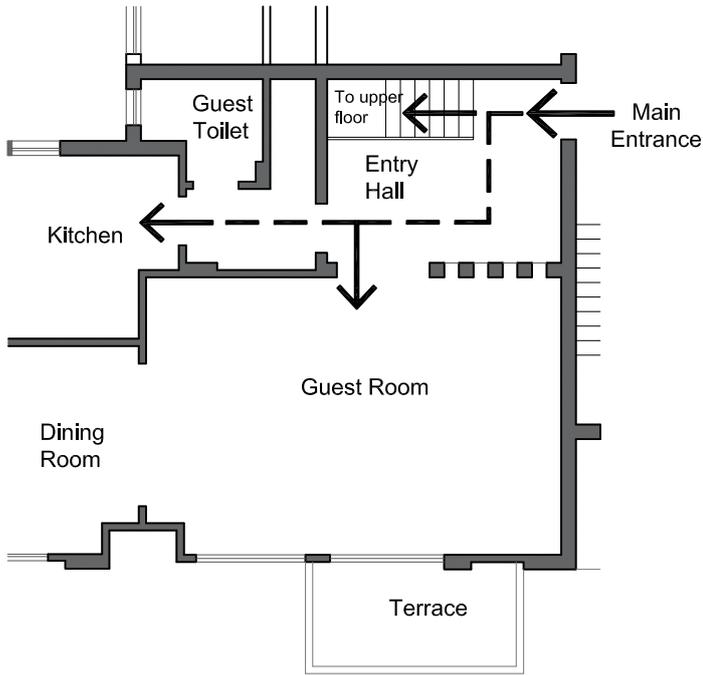
Corridors > Dining Room > Services, Kitchen > Bedroom (1) > Guest Room, Bedrooms (2, 3) > Entrance > Services (Toilets) > Terrace

Lowest Integration Values:

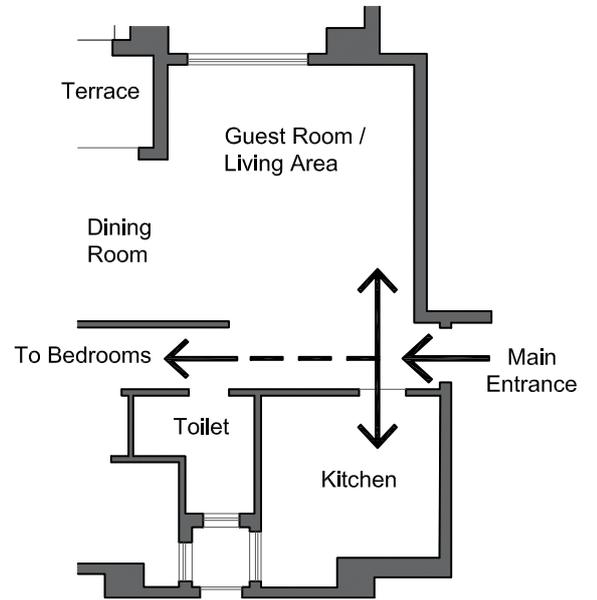
- Terraces
- Guest Room

Highest Integration and Control Values:

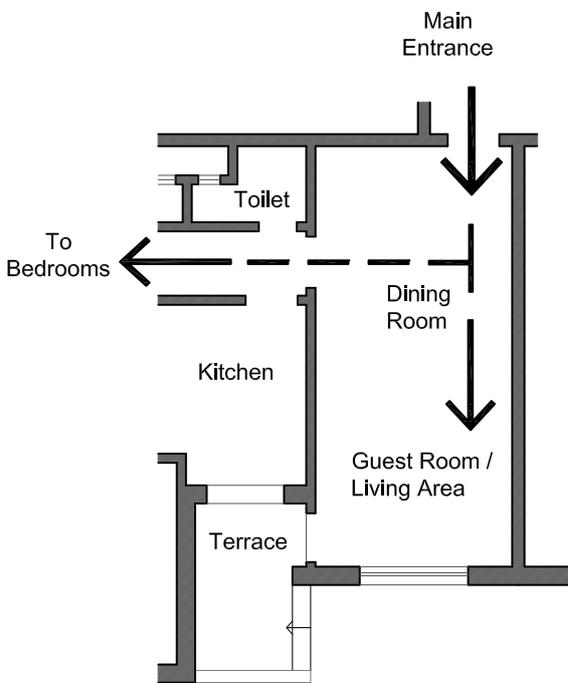
- Corridors
- Dining Room
- Entrance



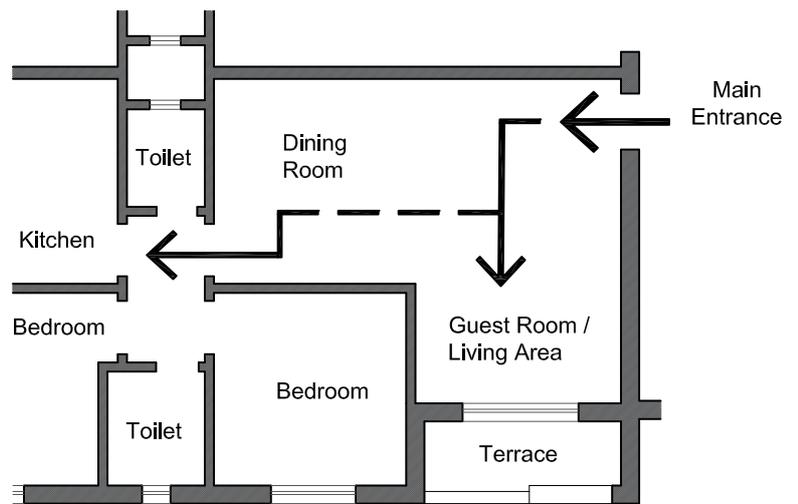
AP-1



AP-2



AP-3



AP-4

Appendix (4-B-18)

**Spatial and Geometric Calculations for the Selected  
Contemporary Apartment Buildings**

### Spatail Data extracted from Contemporary Apartment Buildings

| Case   | Area (G) | Area (1st) | Total excluding terraces | Total with terraces | Covered |      | Open |    | Total (covered+open) | EXCLUDING TERRACES |             |             |           |            |    |     |     | Sum of Hierarchy |     |     |
|--------|----------|------------|--------------------------|---------------------|---------|------|------|----|----------------------|--------------------|-------------|-------------|-----------|------------|----|-----|-----|------------------|-----|-----|
|        |          |            |                          |                     |         |      |      |    |                      | Area (Pb)          | Area (S-Pb) | Area (S-Pv) | Area (Pv) | Area (Int) |    |     |     |                  |     |     |
| APA-1  | 138      | 148        | 286                      | 307                 | 286     | 100% | 0    | 0% | 286                  | 16                 | 6%          | 66          | 27%       |            | 0% | 85  | 34% | 81               | 33% | 248 |
| APA-2A | 132      |            | 132                      | 145                 | 132     | 100% | 0    | 0% | 132                  | 6                  | 5%          | 37          | 34%       |            | 0% | 23  | 21% | 44               | 40% | 110 |
| APA-2B | 89       | 89         | 178                      | 178                 | 178     | 100% | 0    | 0% | 178                  | 11                 | 7%          | 42          | 27%       |            | 0% | 49  | 32% | 52               | 34% | 154 |
| APA-3A | 130      |            | 130                      | 136                 | 130     | 100% | 0    | 0% | 130                  | 1                  | 1%          | 22          | 27%       |            | 0% | 23  | 28% | 35               | 43% | 81  |
| APA-3B | 97       |            | 97                       | 102                 | 97      | 100% | 0    | 0% | 97                   | 2                  | 3%          | 22          | 28%       |            | 0% | 23  | 29% | 33               | 41% | 80  |
| APA-4  | 84       |            | 84                       | 88                  | 84      | 100% | 0    | 0% | 84                   | 4                  | 6%          | 26          | 37%       |            | 0% | 19  | 27% | 22               | 31% | 71  |
| APA-5A | 211      | 305        | 516                      | 516                 | 516     | 100% | 0    | 0% | 516                  | 6                  | 1%          | 119         | 26%       |            | 0% | 240 | 53% | 92               | 20% | 457 |
| APA-5B | 181      |            | 181                      | 181                 | 181     | 100% | 0    | 0% | 181                  | 4                  | 3%          |             | 0%        |            | 0% | 99  | 62% | 56               | 35% | 159 |
| APA-5C | 370      |            | 370                      | 370                 | 370     | 100% | 0    | 0% | 370                  | 8                  | 2%          | 81          | 25%       |            | 0% | 148 | 45% | 92               | 28% | 329 |
|        | 159      | 181        | 219                      | 229                 | 219     | 100% | 0%   | 0% | 219                  | 6                  | 4%          | 52          | 25%       |            | 0% | 79  | 37% | 56               | 34% | 188 |

| Case   | Guest |     | Dining |     | Living covered |     | Main Court 1 |    | Main Court 2 |    | Serv. Court | Gallery |    | Terraces |    | Iwan |    | Bedrooms |     |
|--------|-------|-----|--------|-----|----------------|-----|--------------|----|--------------|----|-------------|---------|----|----------|----|------|----|----------|-----|
| APA-1  | 47    | 18% | 19     | 7%  | 24             | 9%  |              | 0% |              | 0% |             | 0%      | 0% | 21       | 8% |      | 0% | 69       | 26% |
| APA-2A | 27    | 22% | 10     | 8%  |                | 0%  |              | 0% |              | 0% |             | 0%      | 13 | 11%      |    | 0%   | 37 | 30%      |     |
| APA-2B | 22    | 14% | 20     | 13% |                | 0%  |              | 0% |              | 0% |             | 0%      |    | 0%       |    | 0%   | 47 | 30%      |     |
| APA-3A | 12    | 14% | 10     | 12% |                | 0%  |              | 0% |              | 0% |             | 0%      | 6  | 7%       |    | 0%   | 32 | 37%      |     |
| APA-3B | 11    | 13% | 7      | 8%  |                | 0%  |              | 0% |              | 0% |             | 0%      | 5  | 6%       |    | 0%   | 30 | 36%      |     |
| APA-4  | 20    | 25% | 10     | 13% |                | 0%  |              | 0% |              | 0% |             | 0%      | 4  | 5%       |    | 0%   | 22 | 28%      |     |
| APA-5A | 86    | 19% | 24     | 5%  | 68             | 15% |              | 0% |              | 0% |             | 0%      |    | 0%       |    | 0%   | 85 | 19%      |     |
| APA-5B |       |     |        |     | 52             | 33% |              | 0% |              | 0% |             | 0%      |    | 0%       |    | 0%   | 50 | 32%      |     |
| APA-5C | 52    | 18% | 24     | 8%  | 37             | 13% |              | 0% |              | 0% |             | 0%      |    | 0%       |    | 0%   | 85 | 29%      |     |
|        | 35    | 18% | 16     | 9%  | 45             | 8%  |              | 0% |              | 0% |             | 0%      | 10 | 4%       |    | 0%   | 51 | 30%      |     |

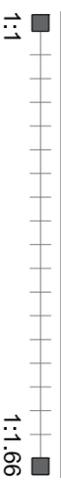
| Case   | Services with Kitch |     | Kitchen | Main EN |    | Service EN |    | Corridor & Stairs |     | Total | Main Liv |           |      |    | Guest |           |         |    | No. of Guest Rooms | WALLS |    |
|--------|---------------------|-----|---------|---------|----|------------|----|-------------------|-----|-------|----------|-----------|------|----|-------|-----------|---------|----|--------------------|-------|----|
|        |                     |     |         |         |    |            |    | x                 | y   |       | prop.    | direction | x    | y  | prop. | direction | M/F/M+F |    |                    |       |    |
| APA-1  | 54                  | 20% | 16      | 16      | 6% |            | 0% | 18                | 7%  | 268   | 4.6      | 5         | 0.92 | SE | 8.55  | 5.75      | 1.49    | NW | M+F                | 1     | 35 |
| APA-2A | 25                  | 20% | 14      | 6       | 5% |            | 0% | 5                 | 4%  | 123   |          |           |      |    | 5.3   | 5.05      | 1.05    | NE | M+F                | 1     | 30 |
| APA-2B | 25                  | 16% | 12      | 11      | 7% |            | 0% | 30                | 19% | 155   |          |           |      |    | 5.25  | 4.15      | 1.27    | NE | M+F                | 1     | 30 |
| APA-3A | 17                  | 20% | 10      |         | 0% |            | 0% | 9                 | 10% | 86    |          |           |      |    | 3.5   | 3.25      | 1.08    | SE | M+F                | 1     | 25 |
| APA-3B | 19                  | 23% | 11      | 2       | 2% |            | 0% | 9                 | 11% | 83    |          |           |      |    | 3.75  | 3.2       | 1.17    | NE | M+F                | 1     | 25 |
| APA-4  | 16                  | 20% | 11      |         | 0% |            | 0% | 7                 | 9%  | 79    |          |           |      |    | 3.35  | 3.25      | 1.03    | NE | M+F                | 1     | 30 |
| APA-5A | 75                  | 16% | 29      | 6       | 1% |            | 0% | 113               | 25% | 457   | 10.1     | 4         | 2.53 | NE | 10.25 | 8.5       | 1.21    | E  | M+F                | 1     | 35 |
| APA-5B | 48                  | 30% | 27      | 4       | 3% |            | 0% | 4                 | 3%  | 158   | 7.55     | 7.4       | 1.02 | E  |       |           |         |    |                    |       | 35 |
| APA-5C | 40                  | 14% | 29      | 8       | 3% |            | 0% | 49                | 17% | 295   | 6.35     | 6         | 1.06 | E  | 8.5   | 6.5       | 1.31    | W  | M+F                | 1     | 35 |
|        | 35                  | 20% | 18      | 8       | 3% |            | 0% | 27                | 12% | 189   | 7.15     | 5.60      | 1.38 |    | 6.06  | 4.96      | 1.20    |    |                    |       | 31 |

Appendix (5-A-1)

**Parametric Relationships between Social Sustainability  
and Elements of Design at the Scale of Residential Units**

### 1. Main Courtyard (MC)

1.1. Proportion (W:L)



Human Comfort ——— +

1.2. Percentage of Area  
(relative to the Total Area of the House)



Density and Crowding ——— -

Social Interaction ——— +

Acoustical Privacy ——— +

Spirituality ——— +

1.3. Location / Orientation

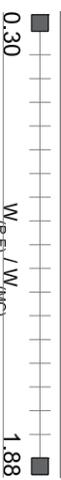


Human Comfort ——— +

Olfactory Privacy ——— +

Viewing the Outside ——— -

1.4. Width of Adjacent Rooms ( $W_{(rooms)} / W_{(MC)}$ )



MC: Center  $W_{(REJ)} / W_{(MC)}$  1.88

$W_{(RS)} / W_{(MC)}$  1.87

$W_{(RN)} / W_{(MC)}$  2.07

$W_{(RW)} / W_{(MC)}$  2.22

MC: South  $W_{(REJ)} / W_{(MC)}$  0.92

$W_{(RW)} / W_{(MC)}$  1.17

$W_{(RN)} / W_{(MC)}$  1.71

MC: East  $W_{(RW)} / W_{(MC)}$  1.52

$W_{(RN)} / W_{(MC)}$  0.85

$W_{(RS)} / W_{(MC)}$  1.02

MC: West  $W_{(REJ)} / W_{(MC)}$  1.67

$W_{(RN)} / W_{(MC)}$  1.12

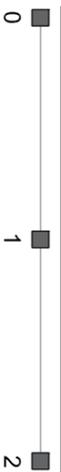
$W_{(RS)} / W_{(MC)}$  1.26

Safety and Security ——— +

Acoustical Privacy ——— -

### 2. Iwan (IW)

2.1. Number of Iwans



Social Interaction ——— +

Hierarchy of Spaces ——— -

2.2. Location / Orientation



Human Comfort ——— +

2.3. Proportion (W:L)



IW: North 1:1.51

IW: East 1:1.6

IW: West 1:1.8

Human Comfort ——— +

2.4. Width ( $W_{(IW)} / W_{(MC)}$ )



IW: North 0.80

IW: South 0.65

IW: East 0.66

IW: West 0.48

Viewing the Outside ——— -

### 3. Gallery (GL)

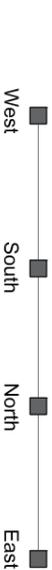
3.1. Number of Galleries



Accessibility ——— +

Hierarchy of Spaces ——— -

3.2. Location / Orientation



Human Comfort ——— +

3.3. Width (W) in meters



GL: North 3.60

GL: East 3.10

GL: West 4.80

Accessibility ——— +

Visual Privacy ——— -

Viewing the Outside ——— +

3.4. No. of Openings



Viewing the Outside ——— -

3.5. Width ( $W_{(GL)} / W_{(MC)}$ )



GL: North 0.53

GL: South 0.47

GL: East 0.47

GL: West 0.43

Viewing the Outside ——— -

### 4. Main Entrance (EA)

4.1. Relationship with Adjacent Spaces



Hierarchy of Spaces ——— +

Visual Privacy ——— -

Safety and Security ——— +

4.2. Geometric Properties



Accessibility ——— +

Visual Privacy ——— -

Visual Privacy ——— +

4.3. Patterns of Openings



Visual Privacy ——— -

Visual Privacy ——— +

4.4. Percentage of Area  
(relative to the Total Area of the House)



EA: Room 5.3%

EA: Corridor 3.8%

EA: L-shape 3.5%

EA: Z-shape 5.3%

Accessibility ——— -

Accessibility ——— +

4.5. Width of Space (in meters)



EA: Room 3.60

EA: Corridor 1.90

EA: L-shape 1.90

EA: Z-shape 1.90

Accessibility ——— -

Accessibility ——— +

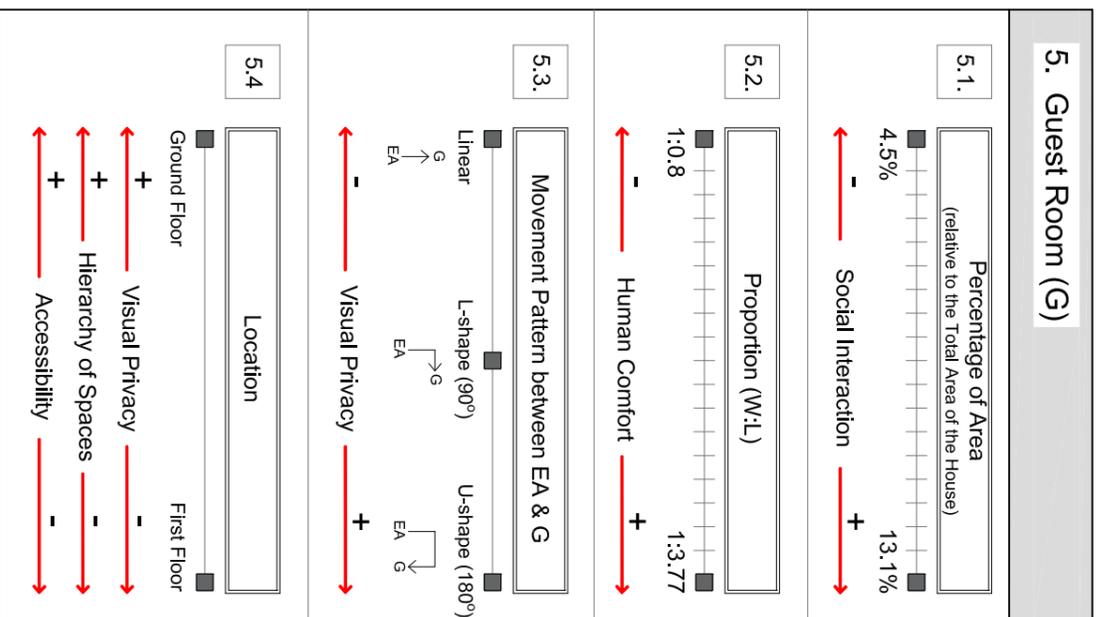
4.5. Width of Doors (in meters)



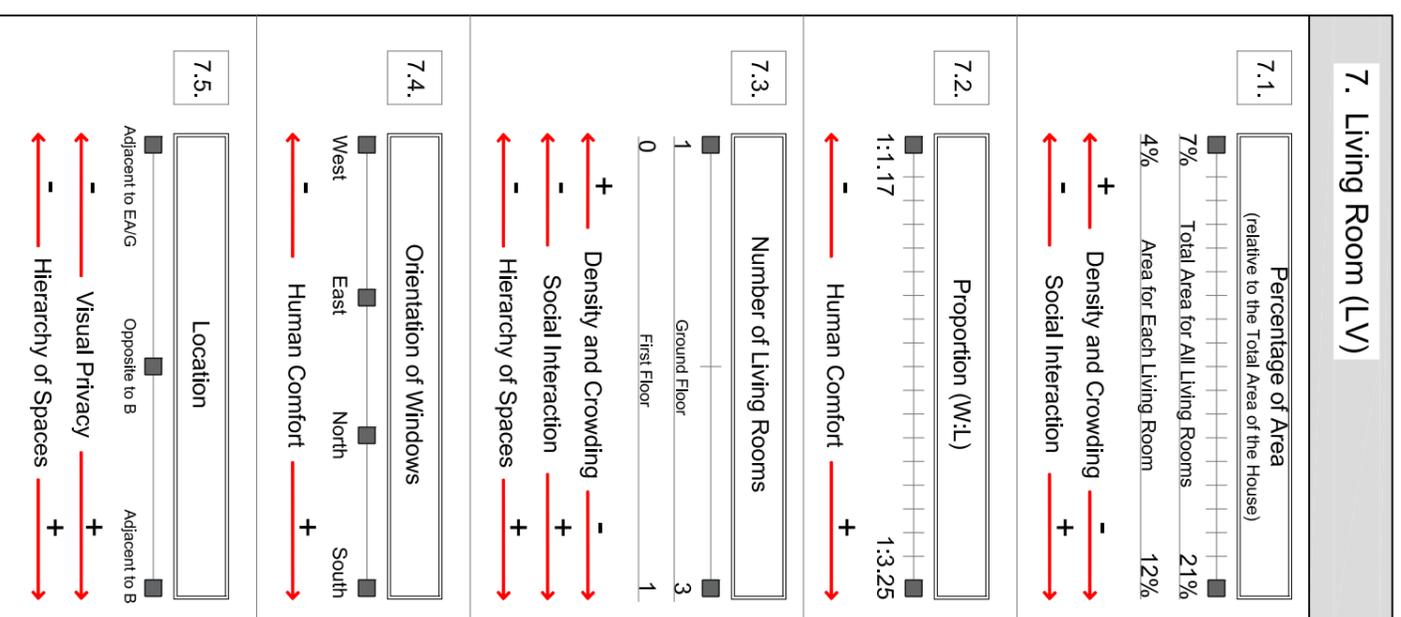
Accessibility ——— -

Accessibility ——— +

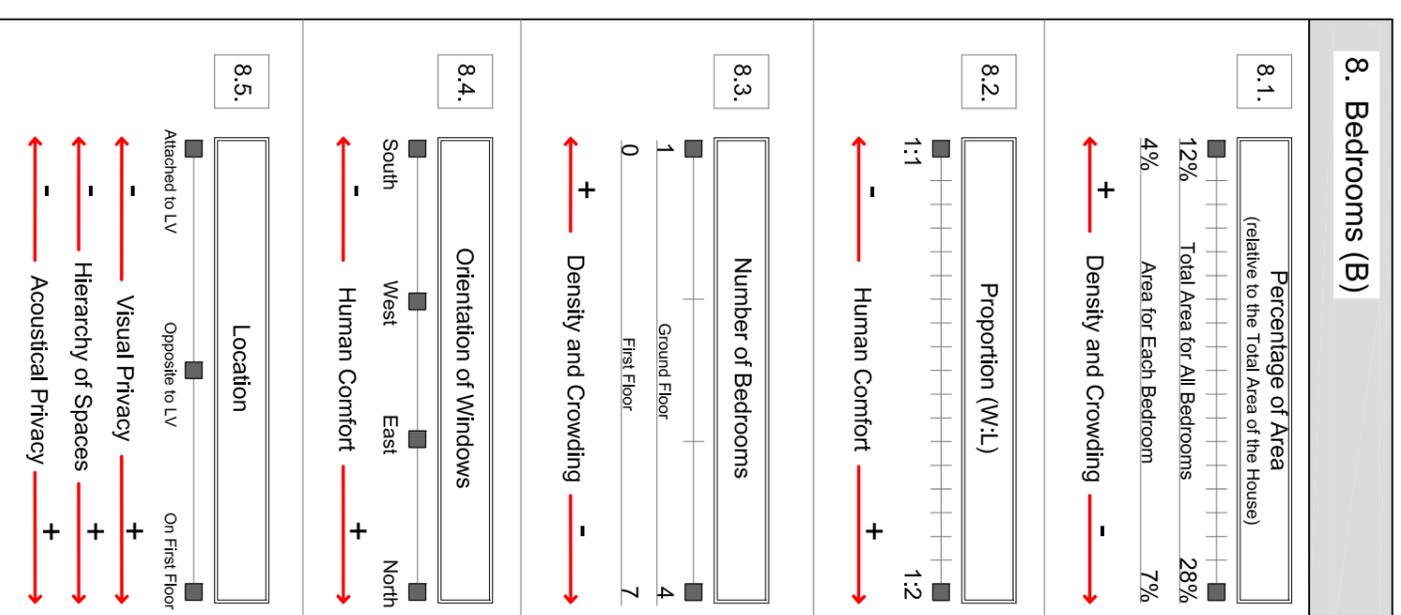
### 5. Guest Room (G)



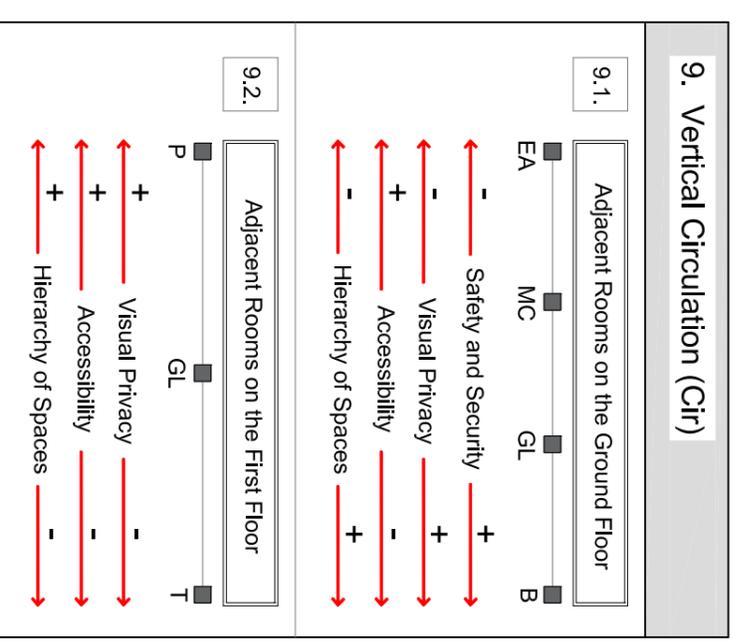
### 7. Living Room (LV)



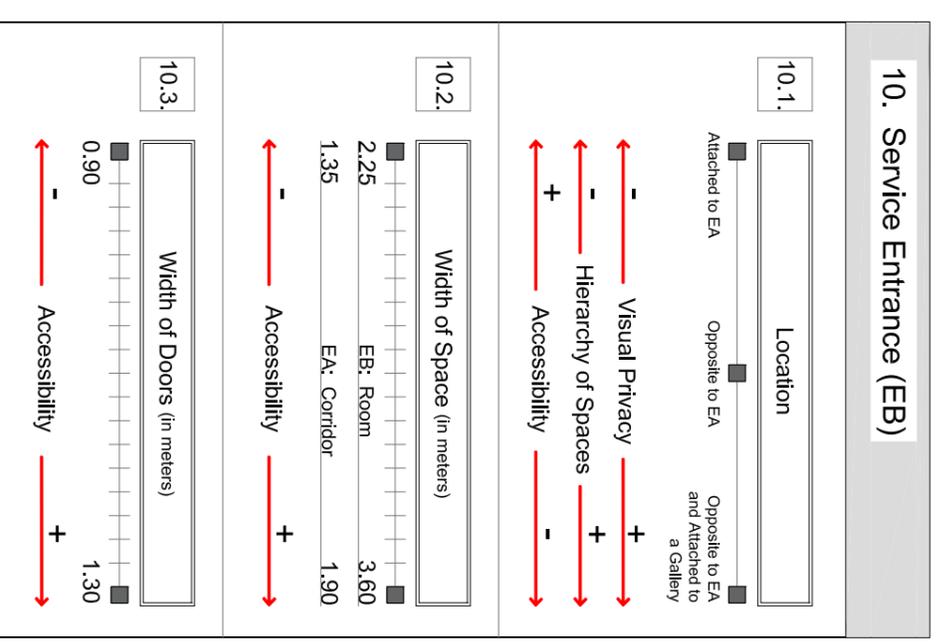
### 8. Bedrooms (B)



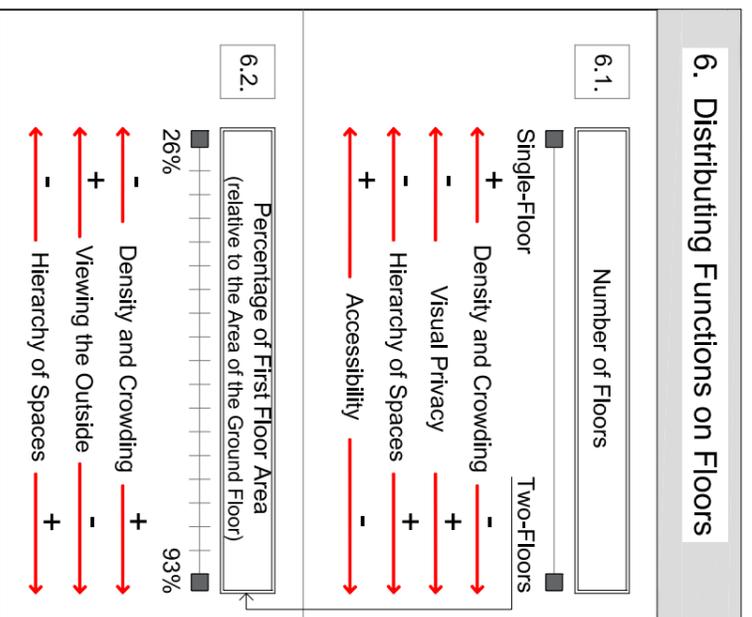
### 9. Vertical Circulation (Cir)



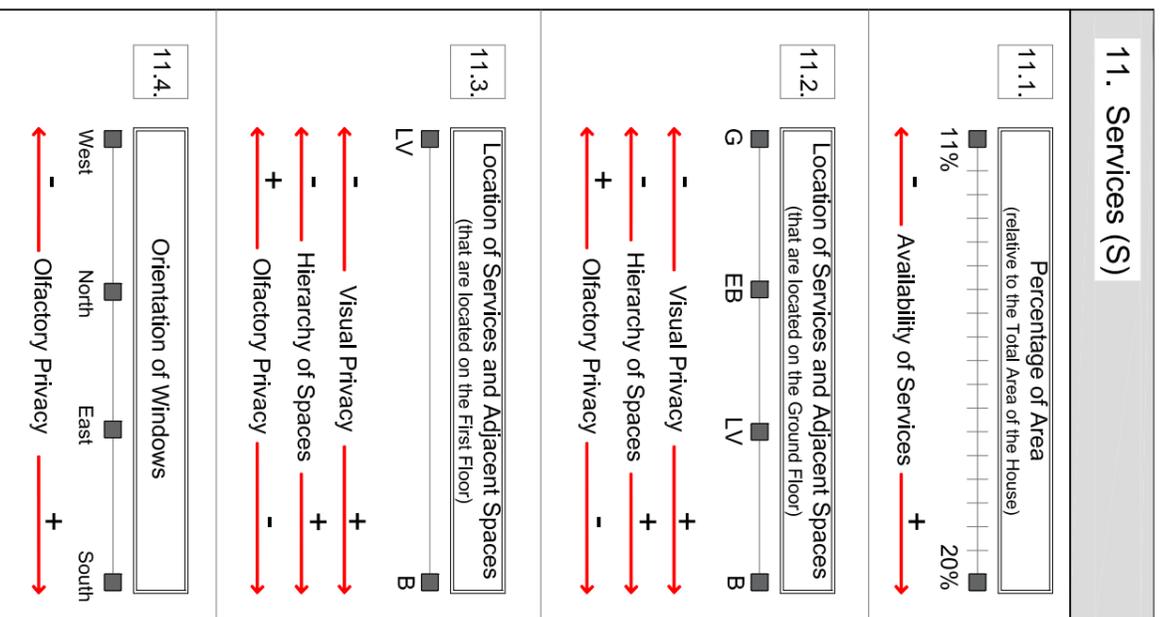
### 10. Service Entrance (EB)



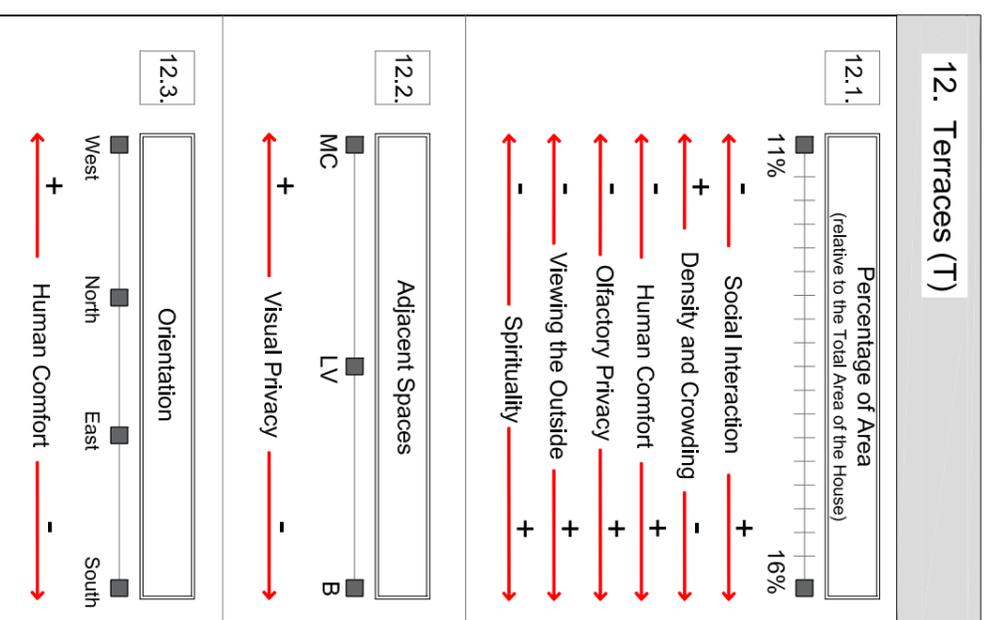
### 6. Distributing Functions on Floors



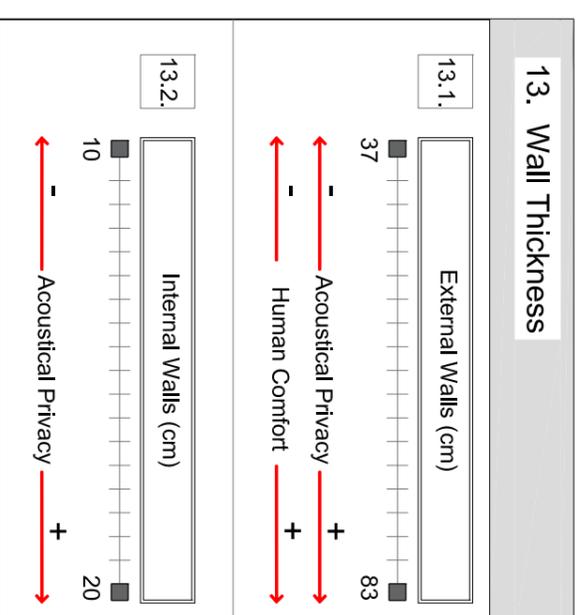
### 11. Services (S)



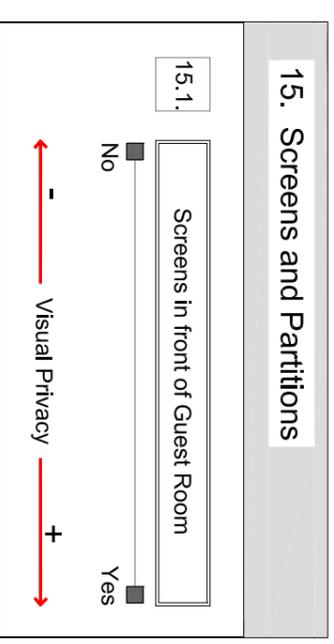
### 12. Terraces (T)



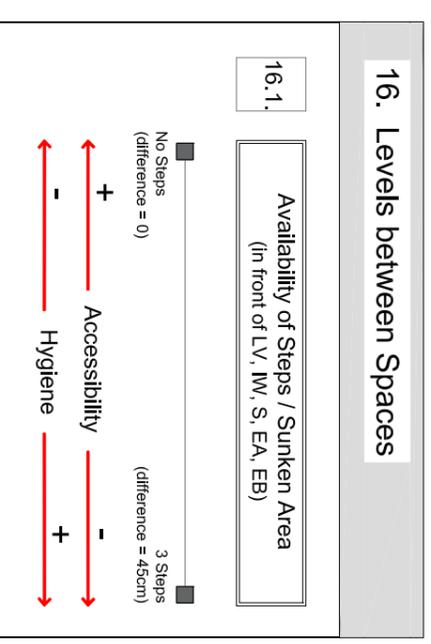
### 13. Wall Thickness



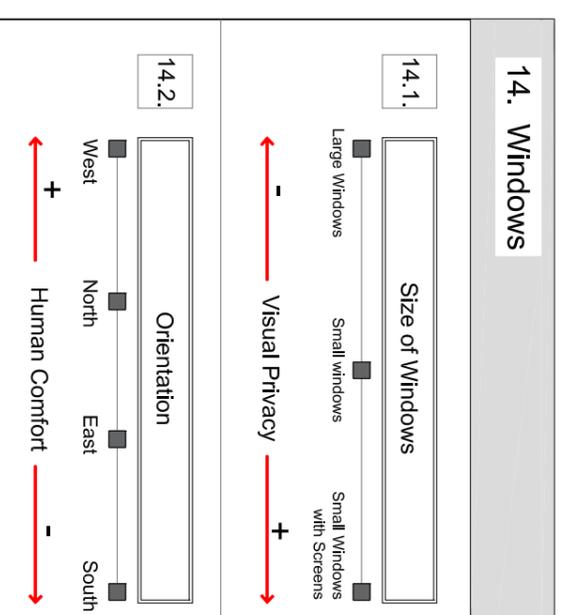
### 15. Screens and Partitions



### 16. Levels between Spaces



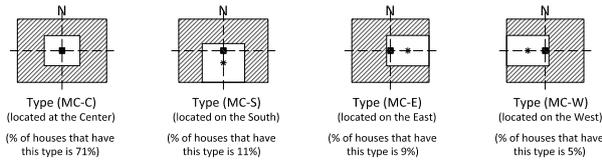
### 14. Windows



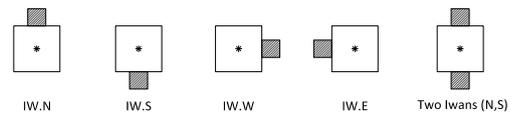
Appendix (5-A-2)

**Parametric Rules for the Configuration of Vernacular  
Houses in MENA Region**

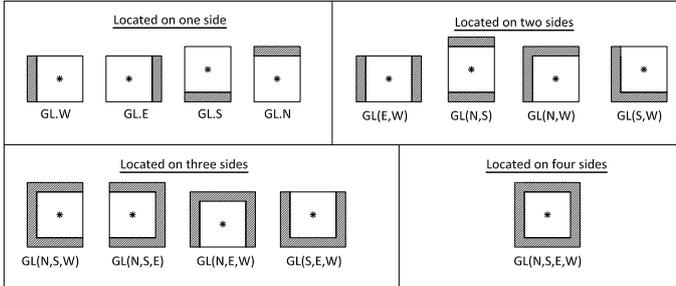
### Prototypes for the location of the Main Courtyard (MC)



### Prototypes for Iwans (IW)

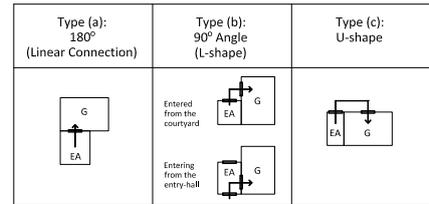


### Prototypes for Galleries (GL)



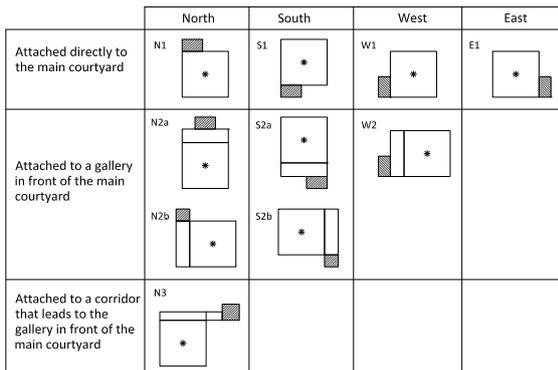
### Prototypes for the Guest Room (G)

Prototypes of Movement Patterns from the Main Entry Hall (EA) to the Entrance of the Guest Room

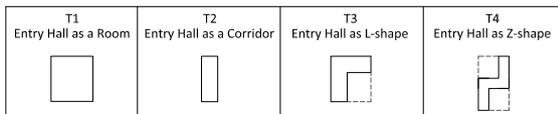


### Prototypes for the Main Entrance Hall (EA)

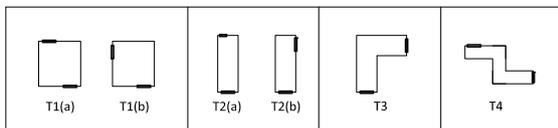
Prototypes for Main Entrances according to their Location



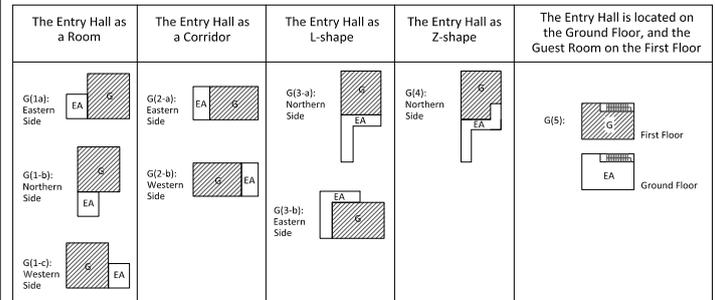
Prototypes for Main Entrances according to their Shape



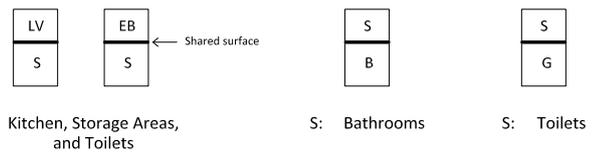
Prototypes for Main Entrances according to the Location of Openings



Prototypes of Guest Rooms according to their Location in relation to the Main Entry Hall



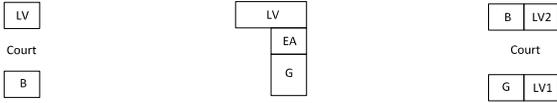
### Prototypes for the Services (S)



### Prototypes for the Vertical Circulation (Cir)



### Prototypes for Living Rooms (LV) and Bedrooms (B) that are located on the Ground Floor

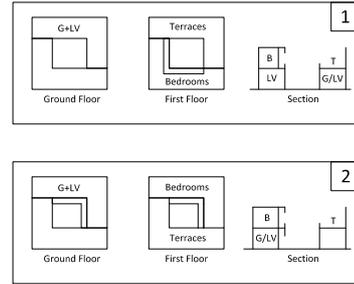


### Prototypes for the Service Entrance (EB)

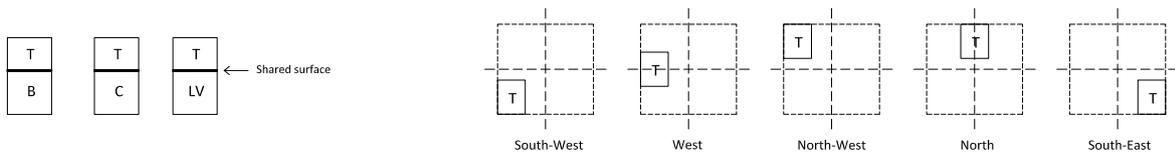


### Prototypes for Living Rooms (LV) and Bedrooms (B) that are located on the Upper Floors

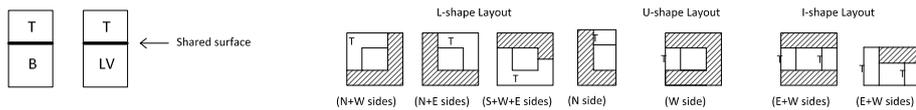
| The Layout of the Ground Floor                            | For MC-S                            |                                | For MC-C                          |                                   |                                   |                                     |                                   |                                   | For MC-E                         |
|---|-------------------------------------|--------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-------------------------------------|-----------------------------------|-----------------------------------|----------------------------------|
|   | Type S1<br>U-shape<br>(N+E+W sides) | Type S2<br>I-shape<br>(N side) | Type C1<br>O-shape<br>(All sides) | Type C2<br>L-shape<br>(S+E sides) | Type C3<br>L-shape<br>(S+W sides) | Type C4<br>U-shape<br>(N+E+S sides) | Type C5<br>I-shape<br>(N+S sides) | Type C6<br>L-shape<br>(N+E sides) | Type E<br>L-shape<br>(S+W sides) |
| The Layout of the First Floor                             |                                     |                                |                                   |                                   |                                   |                                     |                                   |                                   |                                  |
| % of the 1 <sup>st</sup> Floor Area from the Ground Floor | 87%                                 | 36%                            | 73% ↔ 93%<br>(AVG = 83%)          | 34% ↔ 65%<br>(AVG = 47%)          | 26% ↔ 46%<br>(AVG = 36%)          | 47%                                 | 70%                               | 40%                               | 73%                              |
| No. of Bedrooms   | 4                                   | 3                              | 4, 5, 6, 7                        | 1, 3, 4                           | 2, 3                              | 3                                   | 2                                 | 3                                 | 3, 4                             |

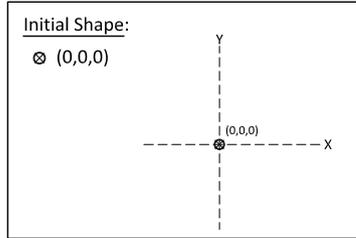


### Prototypes for Terraces (T) that are located on the Ground Floor



### Prototypes for Terraces (T) that are located on Upper Floors





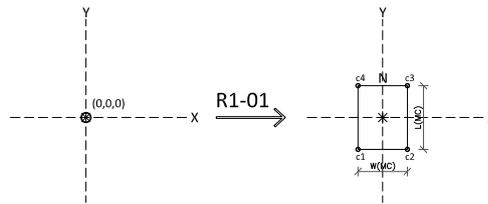
## Stage (1): Rules for Generating a Main Courtyard (MC)

### Descriptions:

MC: open space

MC: semi-private space (S-Pv)

### Rule (1-1): Geometric Properties for the Main Courtyard (MC)



### Design Parameters:

$$1.0 \leq W_{(MC)} / L_{(MC)} \leq 1.66$$

$$(6.4\% * Area_{(AP)}) \leq Area_{(MC)} \leq (29.8\% * Area_{(AP)})$$

### where:

$W_{(MC)}$  : width of the main courtyard

$L_{(MC)}$  : length of the main courtyard

$Area_{(MC)}$  : area of the main courtyard

$Area_{(AP)}$  : allowable built-up area for the apartment

Type (AP-1) : 1-floor Apartment (100-110 m<sup>2</sup>)

Type (AP-2a) : 1-floor Apartment (110-140 m<sup>2</sup>)

Type (AP-2b) : 2-floor Apartment (140-180 m<sup>2</sup>)

Type (AP-3a) : 1-floor Apartment (180-220 m<sup>2</sup>)

Type (AP-3) : 2-floor Apartment (220-250 m<sup>2</sup>)

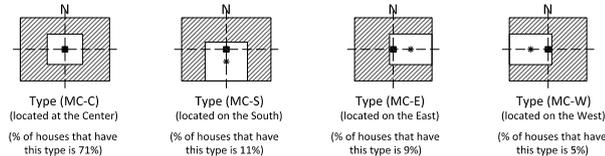
N : North direction

○ : corners of main courtyard

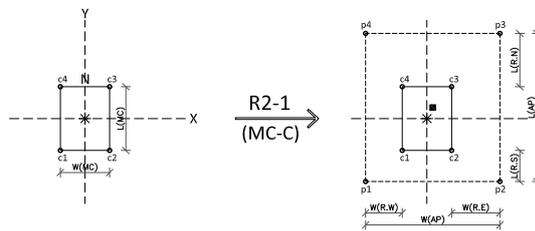
\* : the centroid of the main courtyard = (x,y,z)<sub>MC</sub>

## Stage (2): Rules for Generating Schematic Layout for the Ground Floor (based on the location of the main courtyard)

### Typologies for the Location of the Main Courtyard



### Rule (2-01): Generating Schematic Layout for the Ground Floor that has a Main Courtyard located at the Center (Type MC-C)



### Design Parameters:

$$0.34 \leq W_{(MC)} / W_{(AP)} \leq 0.53$$

$$-2.33 \leq X_{(MC)} - X_{(AP)} \leq 4.11 \text{ m (AVG} = 0.07 \text{ m)}$$

$$-4.25 \leq Y_{(MC)} - Y_{(AP)} \leq 1.95 \text{ m (AVG} = -0.25 \text{ m)}$$

$$L_{(AP)} = L_{(MC)} + L_{(R,N)} + L_{(R,S)}$$

$$W_{(AP)} = W_{(MC)} + W_{(R,E)} + W_{(R,W)}$$

### For Apartments located in the Middle-East:

$$0.31 \leq W_{(R,E)} / W_{(MC)} \leq 1.17 \text{ (AVG} = 0.68)$$

$$0.26 \leq W_{(R,W)} / W_{(MC)} \leq 1.13 \text{ (AVG} = 0.64)$$

$$0.16 \leq L_{(R,N)} / L_{(MC)} \leq 1.51 \text{ (AVG} = 0.55)$$

$$0.16 \leq L_{(R,S)} / L_{(MC)} \leq 1.02 \text{ (AVG} = 0.53)$$

### For Apartments located in North-Africa:

$$0.30 \leq W_{(R,E)} / W_{(MC)} \leq 1.38 \text{ (AVG} = 0.60)$$

$$0.27 \leq W_{(R,W)} / W_{(MC)} \leq 1.04 \text{ (AVG} = 0.53)$$

$$0.36 \leq L_{(R,N)} / L_{(MC)} \leq 1.49 \text{ (AVG} = 0.74)$$

$$0.35 \leq L_{(R,S)} / L_{(MC)} \leq 0.96 \text{ (AVG} = 0.66)$$

### For Apartments located in the Gulf Area:

$$0.34 \leq W_{(R,E)} / W_{(MC)} \leq 1.88 \text{ (AVG} = 0.94)$$

$$0.32 \leq W_{(R,W)} / W_{(MC)} \leq 2.22 \text{ (AVG} = 1.01)$$

$$0.35 \leq L_{(R,N)} / L_{(MC)} \leq 2.07 \text{ (AVG} = 1.00)$$

$$0.28 \leq L_{(R,S)} / L_{(MC)} \leq 1.87 \text{ (AVG} = 1.06)$$

■ : the centroid of the initial layout of the apartment (x,y,z)<sub>AP</sub>

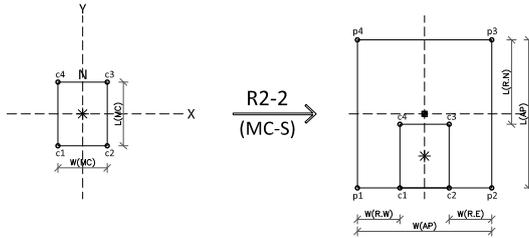
$W_{(R,W)}$  : width of rooms that are located on the Western side of the courtyard

$W_{(R,E)}$  : width of rooms that are located on the Eastern side of the courtyard

$L_{(R,S)}$  : length of rooms that are located on the Southern side of the courtyard

$L_{(R,N)}$  : length of rooms that are located on the Northern side of the courtyard

**Rule (2-02): Generating Schematic Layout for the Ground Floor that has a Main Courtyard located on the Southern Side of the Layout (Type MC-S)**



**Design Parameters:**

$$0.34 \leq W_{(MC)} / W_{(AP)} \leq 0.53$$

$$L_{(AP)} = L_{(MC)} + L_{(R.N)}$$

$$W_{(AP)} = W_{(MC)} + W_{(R.E)} + W_{(R.W)}$$

$$(x)_{(MC)} = (x)_{(AP)}$$

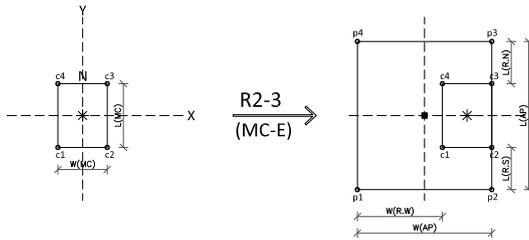
$$0.41 \leq W_{(R.E)} / W_{(MC)} \leq 0.92 \quad (\text{AVG}=0.62)$$

$$0.67 \leq W_{(R.W)} / W_{(MC)} \leq 1.17 \quad (\text{AVG}=0.78)$$

$$0.45 \leq L_{(R.N)} / L_{(MC)} \leq 1.71 \quad (\text{AVG}=1.14)$$

$$L_{(R.S)} = 0.00$$

**Rule (2-04): Generating Schematic Layout for the Ground Floor that has a Main Courtyard located on the Eastern Side of the Layout (Type MC-E)**



**Design Parameters:**

$$0.34 \leq W_{(MC)} / W_{(AP)} \leq 0.53$$

$$L_{(AP)} = L_{(MC)} + L_{(R.N)} + L_{(R.S)}$$

$$W_{(AP)} = W_{(MC)} + W_{(R.W)}$$

$$(y)_{(MC)} = (y)_{(AP)}$$

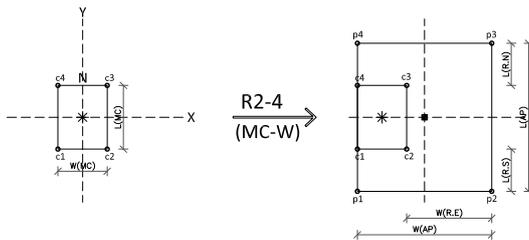
$$W_{(R.E)} = 0.00$$

$$0.82 \leq W_{(R.W)} / W_{(MC)} \leq 1.52 \quad (\text{AVG}=1.07)$$

$$0.66 \leq L_{(R.N)} / L_{(MC)} \leq 0.85 \quad (\text{AVG}=0.73)$$

$$0.46 \leq L_{(R.S)} / L_{(MC)} \leq 1.02 \quad (\text{AVG}=0.80)$$

**Rule (2-06): Generating Schematic Layout for the Ground Floor that has a Main Courtyard located on the Western Side of the Layout (Type MC-W)**



**Design Parameters:**

$$0.34 \leq W_{(MC)} / W_{(AP)} \leq 0.53$$

$$L_{(AP)} = L_{(MC)} + L_{(R.S)} + L_{(R.N)}$$

$$W_{(AP)} = W_{(MC)} + W_{(R.E)}$$

$$(y)_{(MC)} = (y)_{(AP)}$$

$$0.75 \leq W_{(R.E)} / W_{(MC)} \leq 1.67 \quad (\text{AVG}=1.21)$$

$$W_{(R.W)} = 0.00$$

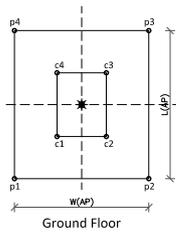
$$0.67 \leq L_{(R.N)} / L_{(MC)} \leq 1.12 \quad (\text{AVG}=0.90)$$

$$0.78 \leq L_{(R.S)} / L_{(MC)} \leq 1.26 \quad (\text{AVG}=1.02)$$

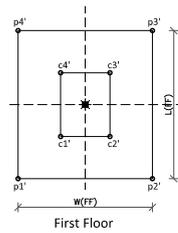
# Stage (3): Rules for Generating Schematic Layout for the 1st Floor in 2-Floor Houses

Typologies for the Layout of the First Floor

| The Layout of the Ground Floor                            | For MC-S              |                  | For MC-C              |                       |                       |                       |                     |                     | For MC-E            |
|---|-----------------------|------------------|-----------------------|-----------------------|-----------------------|-----------------------|---------------------|---------------------|---------------------|
|   | Type S1               | Type S2          | Type C1               | Type C2               | Type C3               | Type C4               | Type C5             | Type C6             | Type E              |
| The Layout of the First Floor                             | U-shape (N+E+W sides) | I-shape (N side) | O-shape (All sides)   | L-shape (S+E sides)   | L-shape (S+W sides)   | U-shape (N+E+5 sides) | I-shape (N+S sides) | L-shape (N+E sides) | L-shape (S+W sides) |
| % of the 1 <sup>st</sup> Floor Area from the Ground Floor | 87%                   | 36%              | 73% ↔ 93% (AVG = 83%) | 34% ↔ 65% (AVG = 47%) | 26% ↔ 46% (AVG = 36%) | 47%                   | 70%                 | 40%                 | 73%                 |



R3-1a  
Type C1



$$73\% * Area_{(GF)} \leq Area_{(FF)} \leq 93\% * Area_{(GF)} \quad (AVG = 83\%)$$

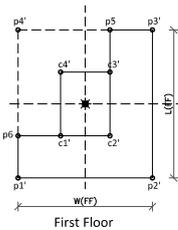
$$W_{(FF)} \leq W_{(AP)}$$

$$L_{(FF)} \leq L_{(AP)}$$

$$(x_c, y_c) = (x_{c'}, y_{c'}, h)$$

where:  
h = height of ground floor + thickness of slab between ground floor and first floor

R3-1b  
Type C2



$$34\% * Area_{(GF)} \leq Area_{(FF)} \leq 65\% * Area_{(GF)} \quad (AVG = 47\%)$$

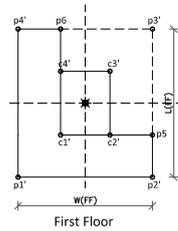
$$W_{(FF)} \leq W_{(AP)}$$

$$L_{(FF)} \leq L_{(AP)}$$

$$(x_c, y_c) = (x_{c'}, y_{c'}, h)$$

where:  
h = height of ground floor + thickness of slab between ground floor and first floor

R3-1c  
Type C3



$$26\% * Area_{(GF)} \leq Area_{(FF)} \leq 46\% * Area_{(GF)} \quad (AVG = 36\%)$$

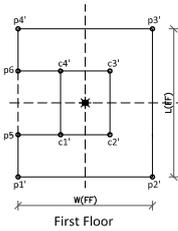
$$W_{(FF)} \leq W_{(AP)}$$

$$L_{(FF)} \leq L_{(AP)}$$

$$(x_c, y_c) = (x_{c'}, y_{c'}, h)$$

where:  
h = height of ground floor + thickness of slab between ground floor and first floor

R3-1d  
Type C4



$$Area_{(FF)} \leq 47\% * Area_{(GF)}$$

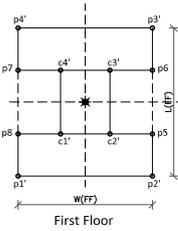
$$W_{(FF)} \leq W_{(AP)}$$

$$L_{(FF)} \leq L_{(AP)}$$

$$(x_c, y_c) = (x_{c'}, y_{c'}, h)$$

where:  
h = height of ground floor + thickness of slab between ground floor and first floor

R3-1e  
Type C5



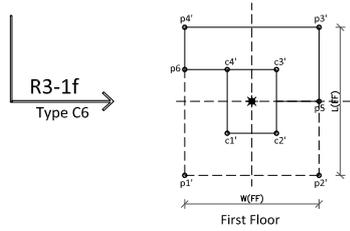
$$Area_{(FF)} \leq 70\% * Area_{(GF)}$$

$$W_{(FF)} \leq W_{(AP)}$$

$$L_{(FF)} \leq L_{(AP)}$$

$$(x_c, y_c) = (x_{c'}, y_{c'}, h)$$

where:  
h = height of ground floor + thickness of slab between ground floor and first floor



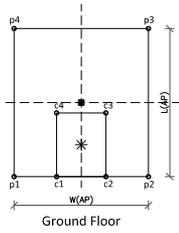
$$\text{Area}_{(FF)} \leq 40\% * \text{Area}_{(GF)}$$

$$W_{(FF)} \leq W_{(AP)}$$

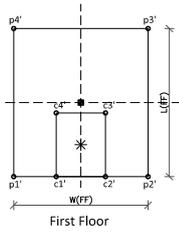
$$L_{(FF)} \leq L_{(AP)}$$

$$(x_c, y_c) = (x_c', y_c', h)$$

where:  
h = height of ground floor + thickness of slab  
between ground floor and first floor



R3-2a  
U-shape  
(N+E+W sides)



$$\text{Area}_{(FF)} \leq 87\% * \text{Area}_{(GF)}$$

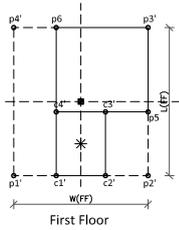
$$W_{(FF)} \leq W_{(AP)}$$

$$L_{(FF)} \leq L_{(AP)}$$

$$(x_c, y_c) = (x_c', y_c', h)$$

where:  
h = height of ground floor + thickness of slab  
between ground floor and first floor

R3-2b  
I-shape  
(N side)



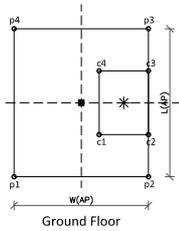
$$\text{Area}_{(FF)} \leq 36\% * \text{Area}_{(GF)}$$

$$W_{(FF)} \leq W_{(AP)}$$

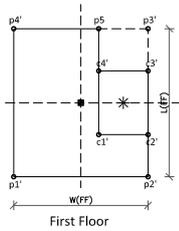
$$L_{(FF)} \leq L_{(AP)}$$

$$(x_c, y_c) = (x_c', y_c', h)$$

where:  
h = height of ground floor + thickness of slab  
between ground floor and first floor



R3-3a  
L-shape  
(S+W sides)



$$\text{Area}_{(FF)} \leq 73\% * \text{Area}_{(GF)}$$

$$W_{(FF)} \leq W_{(AP)}$$

$$L_{(FF)} \leq L_{(AP)}$$

$$(x_c, y_c) = (x_c', y_c', h)$$

where:  
h = height of ground floor + thickness of slab  
between ground floor and first floor

## Stage (4): Rules for the Configuration of Semi-Open Spaces (*Iwans* (IW))

### Descriptions:

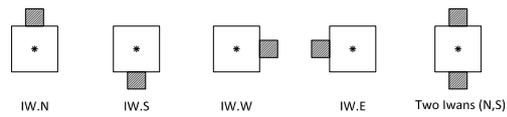
IW: it is a semi-open space (shared surface with courtyard is an opening)

IW: it is a semi-private space (S-Pv)

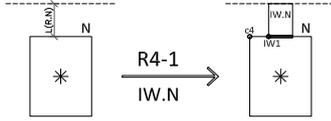
IW: it is located only in the Middle East and North Africa, and it does not exist in the Gulf Area



### Typologies for *Iwans* according to their Location:



### Rule (4-01): Generating ONE *Iwan* (IW-N) on the Northern side of the courtyard



#### Design Parameters:

$$1.18 \leq W_{(IW,N)} / L_{(IW,N)} \leq 1.97$$

$$0.44 \leq W_{(IW,N)} / W_{(MC)} \leq 0.80$$

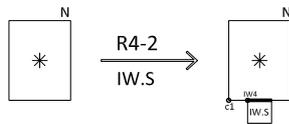
$$L_{(IW,N)} = L_{(R,N)}$$

#### Options for the Location of IW-N :

$$1) (x,y)_{IW,N} = (x,y)_{MC} + (L_{(MC)}/2) + (L_{(IW,N)}/2)$$

$$2) (x,y)_{IW1} = (x,y)_{c4}$$

### Rule (4-02): Generating ONE *Iwan* (IW-S) on the Southern side of the courtyard



#### Design Parameters:

$$1.00 \leq W_{(IW,S)} / L_{(IW,S)} \leq 1.51$$

$$0.21 \leq W_{(IW,S)} / W_{(MC)} \leq 0.65$$

#### Options for the Location of IW-S :

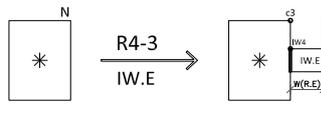
$$1) (x,y)_{IW,S} = (x,y)_{MC} - ((L_{(MC)}/2) + (L_{(IW,S)}/2))$$

$$2) (x,y)_{IW4} = (x,y)_{c1}$$

$$3) (x,y)_{IW,S} = (x,y)_{MC} + ((W_{(MC)}/2) + (W_{(IW,S)}/2) + d)$$

$$0 \leq d \leq (L_{(MC)}/2) - (L_{(IW,S)}/2)$$

### Rule (4-03): Generating ONE *Iwan* (IW-E) on the Eastern side of the courtyard



#### Design Parameters:

$$1.18 \leq W_{(IW,E)} / L_{(IW,E)} \leq 1.60$$

$$0.42 \leq L_{(IW,E)} / L_{(MC)} \leq 0.66$$

$$L_{(IW,E)} = W_{(R,E)}$$

#### Options for the Location of IW-E :

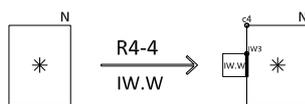
$$1) (x,y)_{IW,E} = (x,y)_{MC} + ((W_{(MC)}/2) + (W_{(IW,E)}/2))$$

$$2) (x,y)_{IW4} = (x,y)_{c3}$$

$$3) (x,y)_{IW,E} = (x,y)_{MC} + ((W_{(MC)}/2) + (W_{(IW,E)}/2) + d)$$

$$0 \leq d \leq (L_{(MC)}/2) - (L_{(IW,E)}/2)$$

### Rule (4-04): Generating ONE *Iwan* (IW-W) on the Western side of the courtyard



#### Design Parameters:

$$1.33 \leq W_{(IW,W)} / L_{(IW,W)} \leq 1.80$$

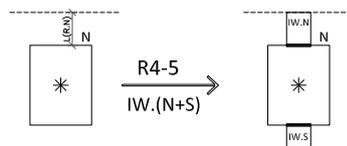
$$0.44 \leq L_{(IW,W)} / L_{(MC)} \leq 0.48$$

#### Options for the Location of IW-W :

$$1) (x,y)_{IW,W} = (x,y)_{MC} - ((W_{(MC)}/2) + (W_{(IW,W)}/2))$$

$$2) (x,y)_{IW3} = (x,y)_{c4}$$

### Rule (4-05): Generating TWO *Iwans* (IW.N, IW.S) on the Northern & Southern sides of the courtyard



#### Design Parameters:

$$1.52 \leq W_{(IW,N)} / L_{(IW,N)} \leq 2.14$$

$$1.04 \leq W_{(IW,S)} / L_{(IW,S)} \leq 1.42$$

$$0.18 \leq W_{(IW,N)} / W_{(MC)} \leq 0.63$$

$$0.30 \leq W_{(IW,S)} / W_{(MC)} \leq 0.65$$

$$L_{(IW,N)} = L_{(R,N)}$$

#### Options for the Location of IW-N :

$$1) (x,y)_{IW,N} = (x,y)_{MC} - ((W_{(MC)}/2) + (W_{(IW,N)}/2))$$

$$2) (x,y)_{IW,S} = (x,y)_{MC} - ((L_{(MC)}/2) + (L_{(IW,S)}/2))$$

$$3) (x,y)_{IW,N} = (x,y)_{MC} + ((W_{(MC)}/2) + (W_{(IW,N)}/2) + d)$$

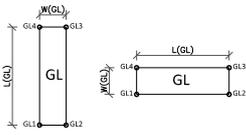
$$0 \leq d \leq (L_{(MC)}/2) - (L_{(IW,N)}/2)$$

## Stage (5): Rules for the Configuration of Semi-Open Spaces (Galleries (GL))

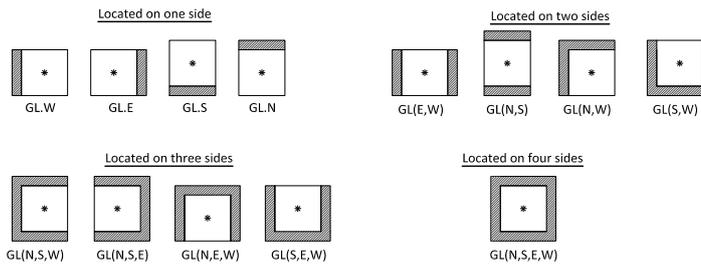
### Descriptions:

GL: it is a semi-open space (3 to 4 openings are located on the shared surface with the courtyard)

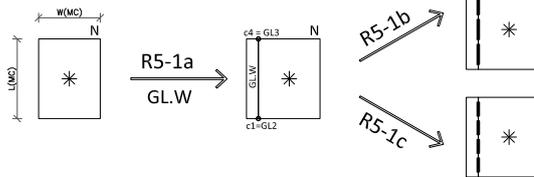
GL: it is a semi-private space (S-Pv)



### Typologies for Galleries according to their relation with Courtyards



### Rule (5-01): Generating Gallery (GL.W) on the Western side of the courtyard



#### Design Parameters:

$$L_{(GL.W)} = L_{(MC)}$$

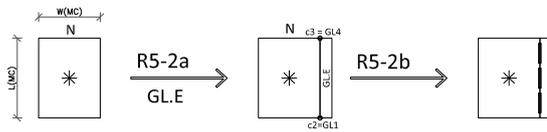
$$1.10 \leq W_{(GL.W)} \leq 4.80 \text{ m}$$

$$(0.15 * W_{(MC)}) \leq W_{(GL.W)} \leq (0.43 * W_{(MC)})$$

$$(x,y)_{(GL3)} = (x,y)_{(c4)}$$

$$(x,y)_{(GL2)} = (x,y)_{(c1)}$$

### Rule (5-02): Generating Gallery (GL.E) on the Eastern side of the courtyard



#### Design Parameters:

$$L_{(GL.E)} = L_{(MC)}$$

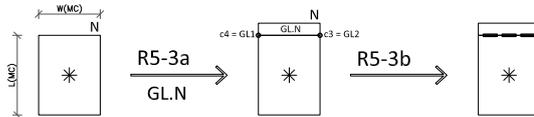
$$1.40 \leq W_{(GL.E)} \leq 3.10 \text{ m}$$

$$(0.10 * W_{(MC)}) \leq W_{(GL.E)} \leq (0.47 * W_{(MC)})$$

$$(x,y)_{(GL1)} = (x,y)_{(c2)}$$

$$(x,y)_{(GL4)} = (x,y)_{(c3)}$$

### Rule (5-03): Generating Gallery (GL.N) on the Northern side of the courtyard



#### Design Parameters:

$$L_{(GL.N)} = W_{(MC)}$$

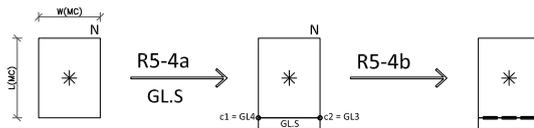
$$1.15 \leq W_{(GL.N)} \leq 3.65 \text{ m}$$

$$(0.13 * L_{(MC)}) \leq W_{(GL.N)} \leq (0.53 * L_{(MC)})$$

$$(x,y)_{(GL1)} = (x,y)_{(c4)}$$

$$(x,y)_{(GL2)} = (x,y)_{(c3)}$$

### Rule (5-04): Generating Gallery (GL.S) on the Southern side of the courtyard



#### Design Parameters:

$$L_{(GL.S)} = W_{(MC)}$$

$$1.50 \leq W_{(GL.S)} \leq 3.60 \text{ m}$$

$$(0.17 * L_{(MC)}) \leq W_{(GL.S)} \leq (0.47 * L_{(MC)})$$

$$(x,y)_{(GL4)} = (x,y)_{(c1)}$$

$$(x,y)_{(GL3)} = (x,y)_{(c2)}$$

## Stage (6): Rules for the Spatial Configuration of the Main Entry Hall (EA)

### Descriptions:

EA: the main entrance of the house, which is used by guests and/or family members  
 EA: it is a public space (Pb)  
 EA: it has to open to the outside context

### Typologies for Main Entrances according to their Location

|   | North      | South      | West | East |
|---|------------|------------|------|------|
| Attached directly to the main courtyard   | N1         | S1         | W1   | E1   |
| Attached to a gallery in front of the main courtyard                            | N2a<br>N2b | S2a<br>S2b | W2   |      |
| Attached to a corridor that leads to the gallery in front of the main courtyard | N3         |            |      |      |

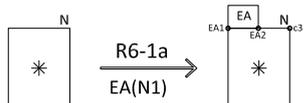
### Typologies for Main Entrances according to their Shape

| T1                   | T2                       | T3                    | T4                    |
|----------------------|--------------------------|-----------------------|-----------------------|
| Entry Hall as a Room | Entry Hall as a Corridor | Entry Hall as L-shape | Entry Hall as Z-shape |

### Typologies for Main Entrances according to the Location of Openings

|       |       |       |       |    |    |
|-------|-------|-------|-------|----|----|
| T1(a) | T1(b) | T2(a) | T2(b) | T3 | T4 |
|-------|-------|-------|-------|----|----|

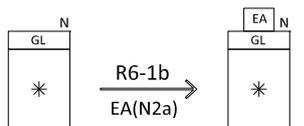
## Rules for Generating Main Entry Hall (EA.N) on the Northern side of the Courtyard



R6-1a  
EA(N1)

### Options for the location of EA:

- $(x, y)_{EA1} = (x, y)_{c4}$
- $(x, y)_{EA2} = (x, y)_{c3}$

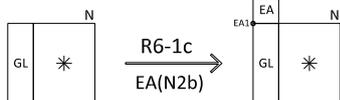


R6-1b  
EA(N2a)

### Design Parameters:

$$(x, y)_{EA} = (x, y)_{MC} + W_{GL} + (L_{EA}/2)$$

where:  
 $(x, y)_{EA}$ : center of the Entry Hall  
 $(x, y)_{MC}$ : center of the Courtyard

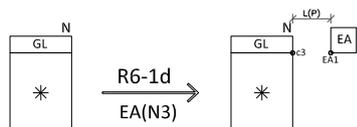


R6-1c  
EA(N2b)

### Design Parameters:

$$(x, y)_{EA1} = (x, y)_{GL4}$$

$$W_{EA} = W_{GL}$$



R6-1d  
EA(N3)



L(P): length of corridor between the gallery and the entry hall

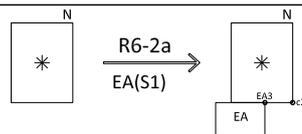
W(P): width of corridor between the gallery and the entry hall

### Design Parameters:

$$(x, y)_{EA1} = ((x_{c3} + L_{P}), (y_{c3}))$$

$$W_{P} = W_{GL}$$

## Rules for Generating Main Entry Hall (EA.S) on the Southern side of the Courtyard

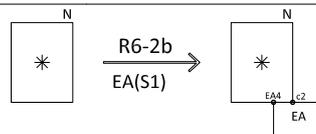


R6-2a  
EA(S1)

### Design Parameters:

$$(x)_{c1} \leq (x)_{EA3} \leq (x)_{c2}$$

$$(y)_{EA3} = (y)_{c2} = (y)_{c1}$$

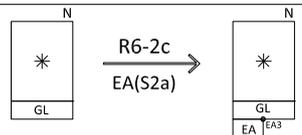


R6-2b  
EA(S1)

### Design Parameters:

$$(x)_{c1} \leq (x)_{EA4} \leq (x)_{c2}$$

$$(y)_{EA4} = (y)_{c2} = (y)_{c1}$$

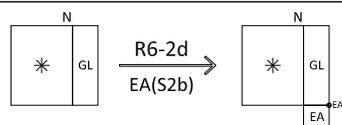


R6-2c  
EA(S2a)

### Design Parameters:

$$(x)_{GL1} \leq (x)_{EA3} \leq (x)_{GL2}$$

$$(y)_{EA3} = (y)_{GL2} = (y)_{GL1}$$



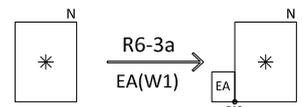
R6-2d  
EA(S2b)

### Design Parameters:

$$(x, y)_{EA3} = (x, y)_{GL2}$$

$$W_{EA} = W_{GL}$$

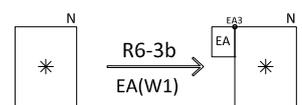
## Rules for Generating Main Entry Hall (EA.W) on the Western side of the Courtyard



R6-3a  
EA(W1)

### Design Parameters:

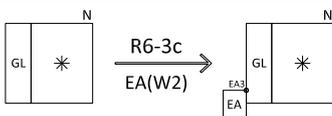
$$(x, y)_{EA2} = (x, y)_{c1}$$



R6-3b  
EA(W1)

### Design Parameters:

$$(x, y)_{EA3} = (x, y)_{c4}$$



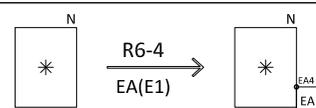
R6-3c  
EA(W2)

### Design Parameters:

$$(x)_{EA3} = (x)_{GL1}$$

$$(y)_{GL1} \leq (y)_{EA3} \leq ((y)_{GL4}/2)$$

## Rules for Generating Main Entry Hall (EA.E) on the Eastern side of the Courtyard



R6-4  
EA(E1)

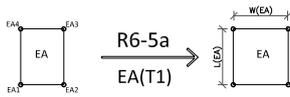
### Design Parameters:

$$(x)_{EA4} = (x)_{MC2} = (x)_{MC3}$$

$$(y)_{MC2} \leq (y)_{EA4} \leq (y)_{MC3}$$

### Rules for Determining the Shape of the Main Entry Hall

#### EA(T1): Entry Hall as a Room



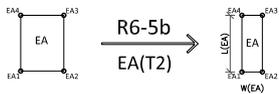
#### Design Parameters:

$$(2.2\% * \text{Area}_{(L)}) \leq (W_{(EA)} * L_{(EA)}) \leq (5.3\% * \text{Area}_{(L)})$$

$$2.25 \leq W_{(EA)} \leq 3.60 \text{ m}$$

$$L_{(EA)} = \text{length of adjacent room}$$

#### EA(T2): Entry Hall as a Corridor



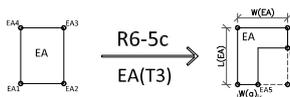
#### Design Parameters:

$$(1.4\% * \text{Area}_{(L)}) \leq (W_{(EA)} * L_{(EA)}) \leq (3.8\% * \text{Area}_{(L)})$$

$$1.35 \leq W \leq 1.90 \text{ m}$$

$$L_{(EA)} = \text{length of adjacent room}$$

#### EA(T3): Entry Hall as L-shape



#### Design Parameters:

$$(W_{(EA)} * L_{(EA)}) \leq (3.5\% * \text{Area}_{(L)})$$

$$1.35 \leq W_{(a)} \leq 1.90 \text{ m}$$

$$L_{(EA)}, W_{(EA)} = \text{width \& length of adjacent rooms}$$

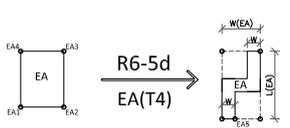
$$(x)_{EA5} = (x)_{EA1} + W_{(a)}$$

$$(y)_{EA5} = (y)_{EA1}$$

$$(y)_{EA6} = (y)_{EA3} - L_{(a)}$$

$$(x)_{EA6} = (x)_{EA3}$$

#### EA(T4): Entry Hall as Z-shape



#### Design Parameters:

$$(W_{(EA)} * L_{(EA)}) \leq (5.3\% * \text{Area}_{(L)})$$

$$1.35 \leq W \leq 1.90 \text{ m}$$

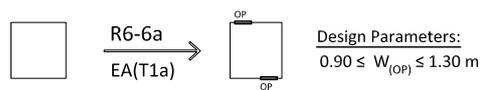
$$L_{(EA)}, W_{(EA)} = \text{width and length of adjacent rooms}$$

$$(x)_{EA5} = (x)_{EA1} + W$$

$$(y)_{EA5} = (y)_{EA1}$$

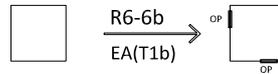
### Rules for Determining Openings for the Main Entry Hall

#### Openings for EA(T1): Entry Hall as a Room

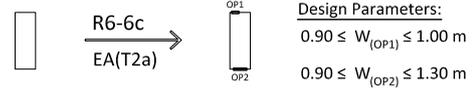


#### Design Parameters:

$$0.90 \leq W_{(OP)} \leq 1.30 \text{ m}$$



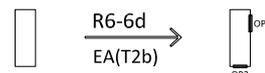
#### Openings for EA(T2): Entry Hall as a Corridor



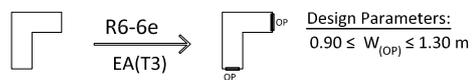
#### Design Parameters:

$$0.90 \leq W_{(OP1)} \leq 1.00 \text{ m}$$

$$0.90 \leq W_{(OP2)} \leq 1.30 \text{ m}$$



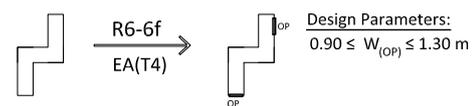
#### Openings for EA(T3): Entry Hall as a L-shape



#### Design Parameters:

$$0.90 \leq W_{(OP)} \leq 1.30 \text{ m}$$

#### Openings for EA(T4): Entry Hall as a Z-shape



#### Design Parameters:

$$0.90 \leq W_{(OP)} \leq 1.30 \text{ m}$$

## Stage (7): Rules for the Configuration of Guest Room (G)

#### Descriptions:

- G: Guest room, which is used dominantly by male visitors
- G: It is a semi-public space (S-Pb)
- G: It is adjacent to the main entry hall

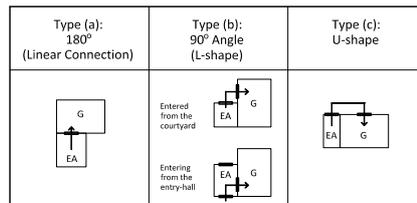
#### Design Parameters:

Movement Pattern from the Main Entry Hall to the Entrance of the Guest Room  
Location of the Guest Room in relation to the Main Entry Hall

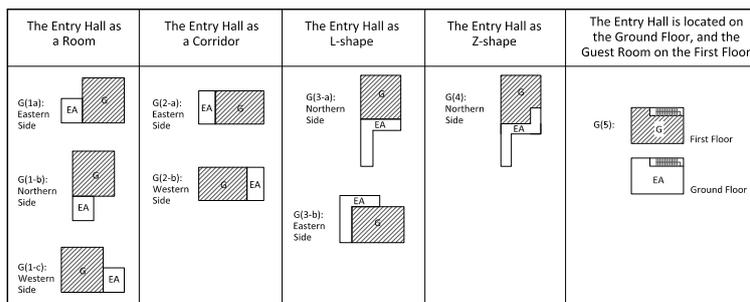
$$(4.5\% * \text{Area}_{(L)}) \leq (W_{(G)} * L_{(G)}) \leq (13.1\% * \text{Area}_{(L)})$$

$$0.80 \leq W_{(G)} / L_{(G)} \leq 3.77$$

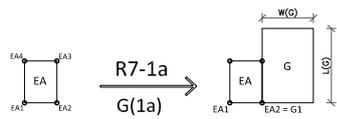
#### Typologies of Movement Patterns from the Main Entry Hall (EA) to the Entrance of the Guest Room



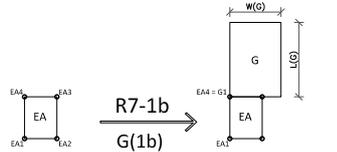
#### Typologies of Guest Rooms according to their Location in relation to the Main Entry Hall



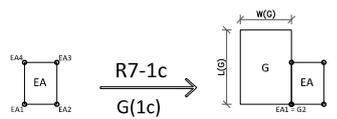
**Rules for Generating a Guest Room (G - Type1), which is attached to a Room Entry-Hall**



**Design Parameters:**  
 $4.10 \leq W_{(G)} \leq 10.95$  m  
 $3.20 \leq L_{(G)} \leq 5.00$  m  
 $1.15 \leq W_{(G)}/L_{(G)} \leq 3.00$   
 $(x,y)_{EA2} = (x,y)_{G1}$

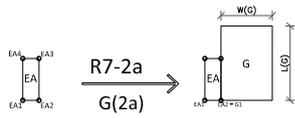


**Design Parameters:**  
 $5.75 \leq W_{(G)} \leq 10.75$  m  
 $2.75 \leq L_{(G)} \leq 5.60$  m  
 $1.30 \leq W_{(G)}/L_{(G)} \leq 3.77$   
 $(x,y)_{EA4} = (x,y)_{G1}$

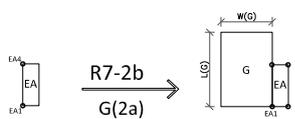


**Design Parameters:**  
 $4.45 \leq W_{(G)} \leq 10.30$  m  
 $2.50 \leq L_{(G)} \leq 6.75$  m  
 $1.43 \leq W_{(G)}/L_{(G)} \leq 3.26$   
 $(x,y)_{EA1} = (x,y)_{G2}$

**Rules for Generating a Guest Room (G - Type 2), which is attached to a Corridor Entry-Hall**

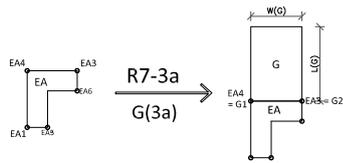


**Design Parameters:**  
 $4.70 \leq W_{(G)} \leq 11.45$  m  
 $3.35 \leq L_{(G)} \leq 4.70$  m  
 $1.00 \leq W_{(G)}/L_{(G)} \leq 3.42$   
 $(x,y)_{EA2} = (x,y)_{G1}$

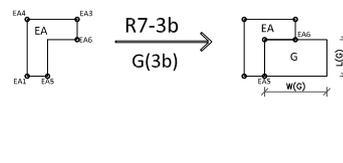


**Design Parameters:**  
 $5.30 \leq W_{(G)} \leq 9.65$  m  
 $2.75 \leq L_{(G)} \leq 6.75$  m  
 $1.06 \leq W_{(G)}/L_{(G)} \leq 2.09$   
 $(x,y)_{EA1} = (x,y)_{G2}$

**Rules for Generating a Guest Room (G - Type 3), which is attached to L-shape Entry-Hall**

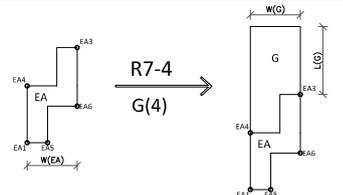


**Design Parameters:**  
 $5.20 \leq W_{(G)} \leq 7.25$  m  
 $4.10 \leq L_{(G)} \leq 6.45$  m  
 $0.80 \leq W_{(G)}/L_{(G)} \leq 1.77$   
 $(x,y)_{EA4} = (x,y)_{G1}$   
 $(x,y)_{EA3} = (x,y)_{G2}$



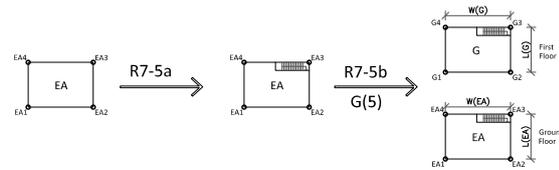
**Design Parameters:**  
 $5.20 \leq W_{(G)} \leq 7.25$  m  
 $4.10 \leq L_{(G)} \leq 6.45$  m  
 $0.80 \leq W_{(G)}/L_{(G)} \leq 1.77$   
 $(x,y)_{EA5} = (x,y)_{G1}$   
 $(x)_{G4} = (x)_{EA5}$   
 $(y)_{G4} = (y)_{EA6}$

**Rules for Generating a Guest Room (G - Type 4), which is attached to Z-shape Entry-Hall**



**Design Parameters:**  
 $W_{(G)} = W_{EA}$   
 $W_{(G)}/L_{(G)} = 0.40$   
 $(x,y)_{EA4} = (x,y)_{G1}$

**Rules for Generating a Guest Room (G - Type 5), which is located on the First Floor**



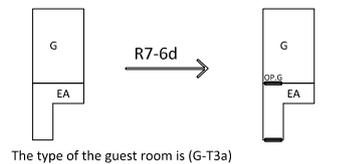
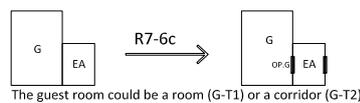
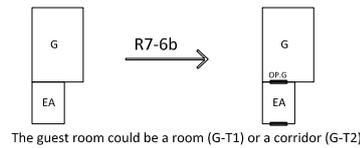
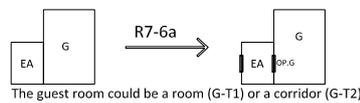
**Design Parameters:**  
 $W_{(G)} = W_{EA}$   
 $L_{(G)} = L_{EA}$   
 $(x,y)_{EA1} = (x,y)_{G1}$   
 $(x,y)_{EA3} = (x,y)_{G3}$   
 $6.10 \leq W_{(G)} \leq 9.00$   
 $2.70 \leq L_{(G)} \leq 3.20$   
 $2.25 \leq W_{(G)}/L_{(G)} \leq 2.80$

**Rules for Generating Doors for the Guest Room (in relation to the Main Entrance)**

**Type (a): a Linear Pattern of Movement (180°), and entered directly from the entry-hall**

**Design Parameters:**  
 $0.90 \leq W_{(OP,G)} \leq 1.30$  m

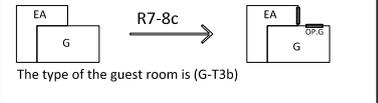
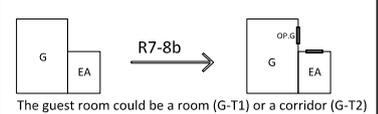
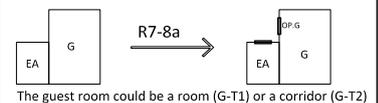
where  
 OP.G: the main entry point for the guest room



**Type (b2): 90° Pattern of Movement, and entered from the courtyard**

**Design Parameters:**  
 $0.90 \leq W_{(OP,G)} \leq 1.30$  m

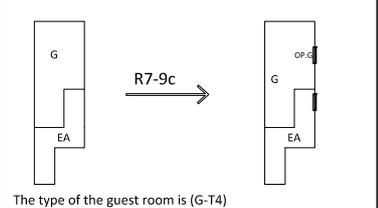
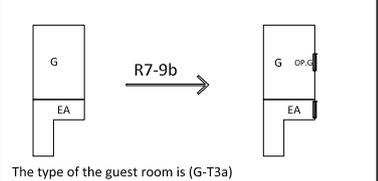
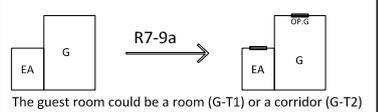
where  
 OP.G: the main entry point for the guest room



**Type (c): U-shape Pattern of Movement, and entered from the courtyard**

**Design Parameters:**  
 $0.90 \leq W_{(OP,G)} \leq 1.30$  m

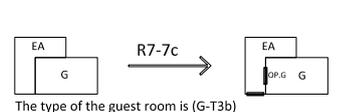
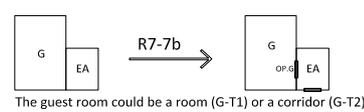
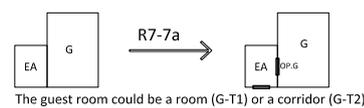
where  
 OP.G: the main entry point for the guest room



**Type (b1): 90° Pattern of Movement, and entered directly from the entry-hall**

**Design Parameters:**  
 $0.90 \leq W_{(OP,G)} \leq 1.30$  m

where  
 OP.G: the main entry point for the guest room



## Stage (8): Rules for the Configuration of Living Spaces (LV) and Bedrooms (B) in Single-Floor Houses

### Descriptions:

LV: Living Room(s) / Multi-purpose Hall  
(Private Spaces)

P: Paths/Corridors (Transitional Spaces)  
(Private Spaces)

B: Bedrooms (Intimate Spaces)

Area of Each Living Room = 4% - 12% (AVG = 8.5%)

Area of Each Bedroom = 4% - 7% (AVG = 5.5%)

$$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25 \quad (\text{AVG} = 1.88)$$

$$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$$

### Design Parameters:

- Number of Bedrooms and Living Rooms.
- Location of Bedrooms in relation to Guest Rooms and Living Rooms.
- Location of Private/Intimate Spaces in relation to Semi-private Spaces (IW, GL, MC).



Court



Living Room is located opposite to Bedrooms (for achieving acoustical privacy)



EA



In most cases, the Guest Room and the Main Entry Hall are located adjacent to the Living Room, as it is used by female visitors



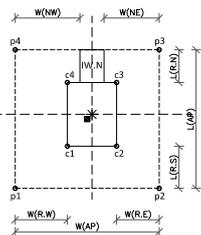
Court



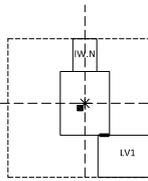
In some cases, there are two living rooms: one is for female visitors (adjacent to the Guest Room), and the other is for the family (adjacent to Bedrooms)

### Rules for Houses that have one *Iwan* located on the Northern Side of the Courtyard:

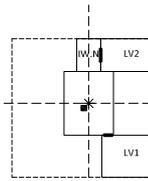
Conditions: MC: Center, IW: North



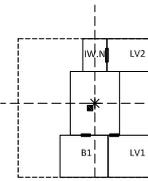
R8-1a  
(1 LV)



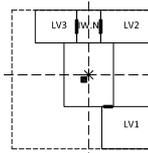
R8-1b  
(2 LV)



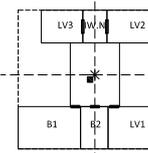
R8-1c  
1 Bedroom



R8-1d  
(3 LV)



R8-1e  
2 Bedrooms



Living Rooms are accessed from Iwan

Area of Each Living Room = 4% - 12% (AVG = 8.5%)

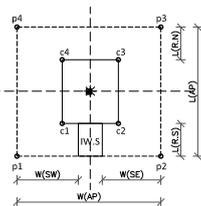
Area of Each Bedroom = 4% - 7% (AVG = 5.5%)

$$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25 \quad (\text{AVG} = 1.88)$$

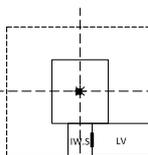
$$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$$

### Rules for Houses that have one *Iwan* located on the Southern or Western Sides of the Courtyard:

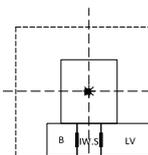
Conditions: MC: Center, IW: South,  $L(R,S) < 8$  m



R8-2a  
(1 LV)

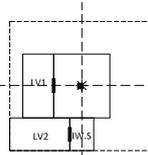


R8-2b  
1 Bedroom

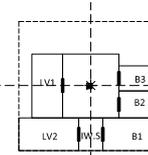


Living Room and Bedrooms are accessed from Iwan, and Bedrooms are opposite to Living Room

R8-2c  
(2 LV)

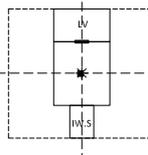


R8-2d  
3 Bedrooms

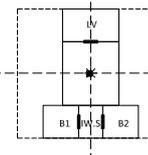


Living Room and Bedrooms are accessed from Iwan/Courtyard, and Bedrooms are opposite to Living Room

R8-2e  
(1 LV)



R8-2f  
2 Bedrooms



Bedrooms are accessed from Iwan, and Bedrooms are opposite to Living Room

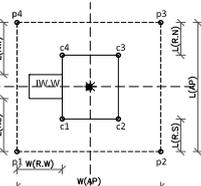
Area of Each Living Room = 4% - 12% (AVG = 8.5%)

Area of Each Bedroom = 4% - 7% (AVG = 5.5%)

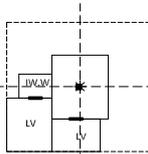
$$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25 \quad (\text{AVG} = 1.88)$$

$$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$$

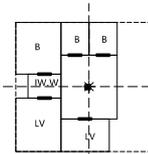
Conditions: MC: Center, IW: West,  $L(R,W) < 8$  m



R8-3a  
(2 LV)



R8-3b  
3 Bedrooms



Bedrooms are accessed from Iwan/Courtyard, and Bedrooms are opposite to Living Room

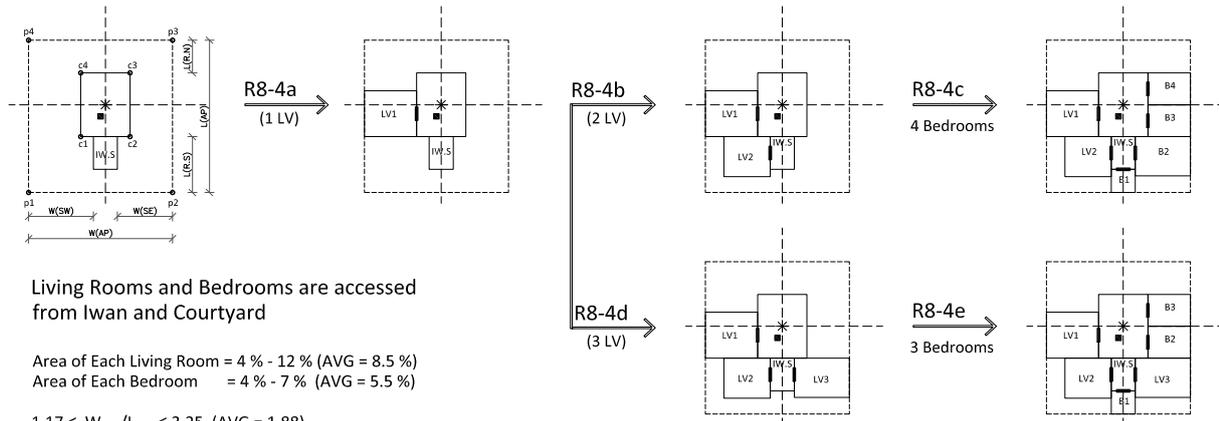
Area of Each Living Room = 4% - 12% (AVG = 8.5%)

Area of Each Bedroom = 4% - 7% (AVG = 5.5%)

$$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25 \quad (\text{AVG} = 1.88)$$

$$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$$

Conditions: MC: Center, IW: South, L(R.S) > 8 m



Living Rooms and Bedrooms are accessed from Iwan and Courtyard

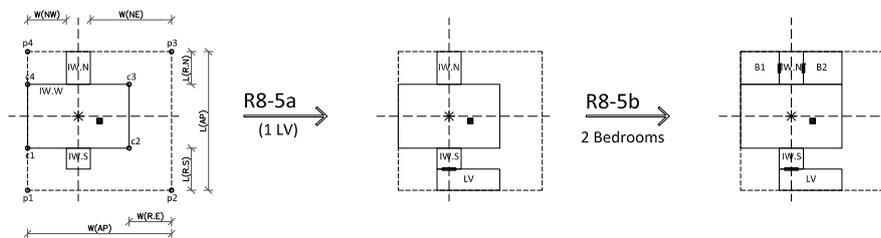
Area of Each Living Room = 4% - 12% (AVG = 8.5%)  
 Area of Each Bedroom = 4% - 7% (AVG = 5.5%)

$$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25 \text{ (AVG = 1.88)}$$

$$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$$

### Rules for Houses that have two Iwans located on the Southern/Northern Sides of the Courtyard:

Conditions: MC: West, IW: North and South, L(R.S) > 8 m



Living Rooms and Bedrooms are accessed from Iwans

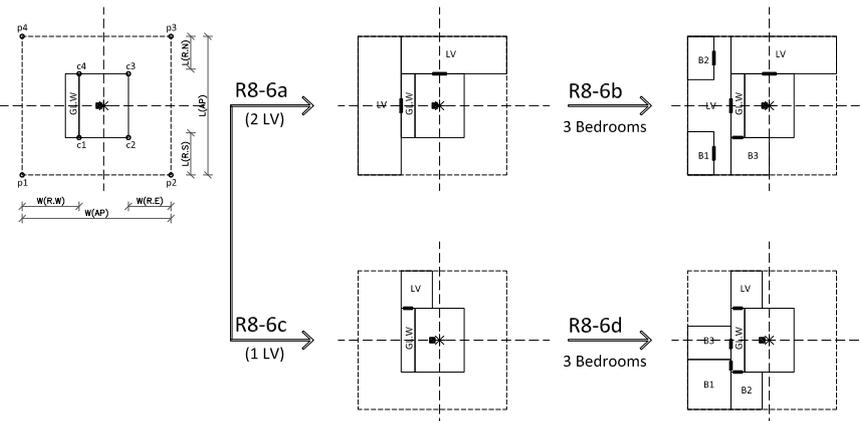
Area of Each Living Room = 4% - 12% (AVG = 8.5%)  
 Area of Each Bedroom = 4% - 7% (AVG = 5.5%)

$$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25 \text{ (AVG = 1.88)}$$

$$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$$

### Rules for Houses that have Galleries:

Conditions: MC: Center, GL: West



Living Room is accessed from Gallery, and Bedrooms are accessed from Living Room/Gallery

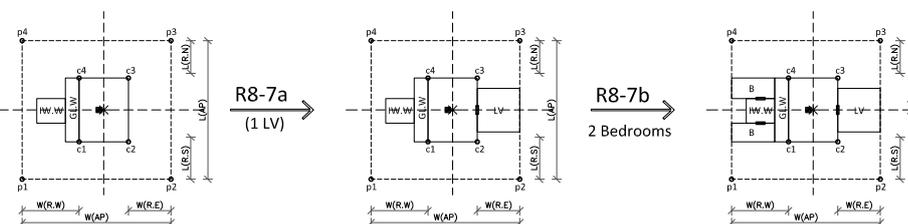
Living Room and Bedrooms are accessed from Gallery

Area of Each Living Room = 4% - 12% (AVG = 8.5%)  
 Area of Each Bedroom = 4% - 7% (AVG = 5.5%)

$$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25 \text{ (AVG = 1.88)}$$

$$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$$

Conditions: MC: Center, IW: West, GL: West



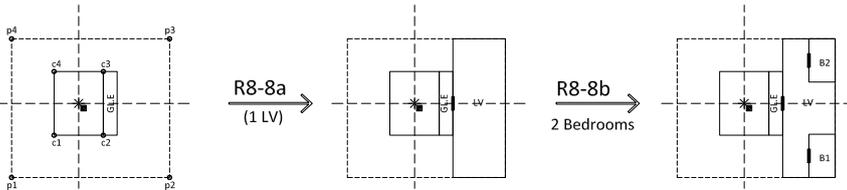
Living Room is accessed from courtyard, and Bedrooms are accessed from Iwan

Area of Each Living Room = 4% - 12% (AVG = 8.5%)  
 Area of Each Bedroom = 4% - 7% (AVG = 5.5%)

$$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25 \text{ (AVG = 1.88)}$$

$$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$$

Conditions: MC: Center, GL: West



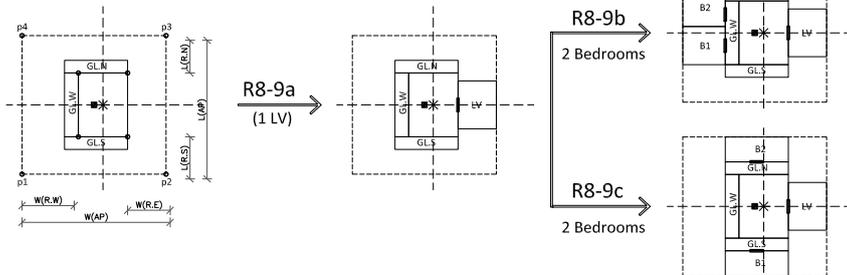
Living Room is accessed from Gallery, and Bedrooms are accessed from Living Room

Area of Each Living Room = 4% - 12% (AVG = 8.5%)  
Area of Each Bedroom = 4% - 7% (AVG = 5.5%)

$$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25 \text{ (AVG = 1.88)}$$

$$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$$

Conditions: MC: Center, GL: U-shape (West, North, South)



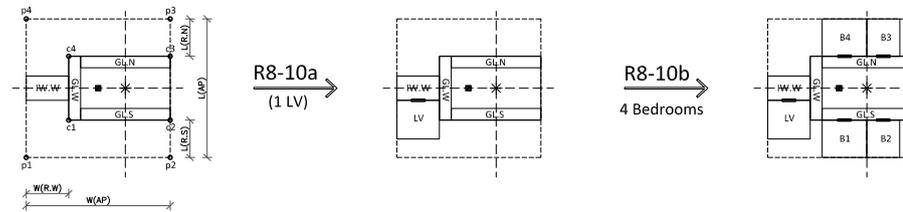
Bedrooms are accessed from Gallery, and opposite to Living Room

Area of Each Living Room = 4% - 12% (AVG = 8.5%)  
Area of Each Bedroom = 4% - 7% (AVG = 5.5%)

$$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25 \text{ (AVG = 1.88)}$$

$$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$$

Conditions: MC: East, IW: West, GL: U-shape (North, South, West)



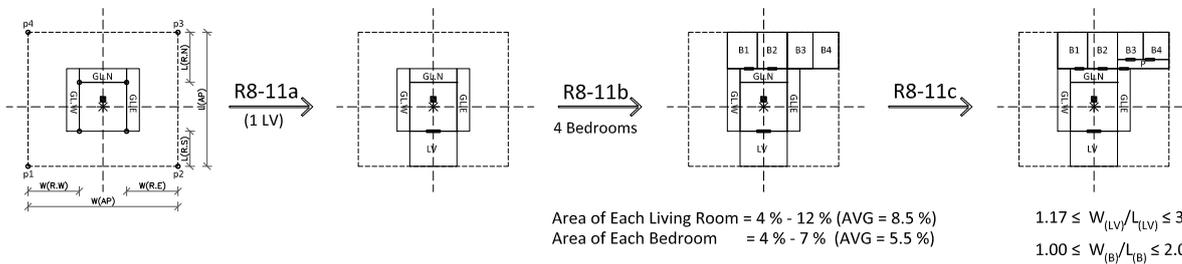
Living Room is accessed from Iwan, and Bedrooms are accessed from Gallery

Area of Each Living Room = 4% - 12% (AVG = 8.5%)  
Area of Each Bedroom = 4% - 7% (AVG = 5.5%)

$$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25 \text{ (AVG = 1.88)}$$

$$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$$

Conditions: MC: Center, GL: U-shape (North, East, West)



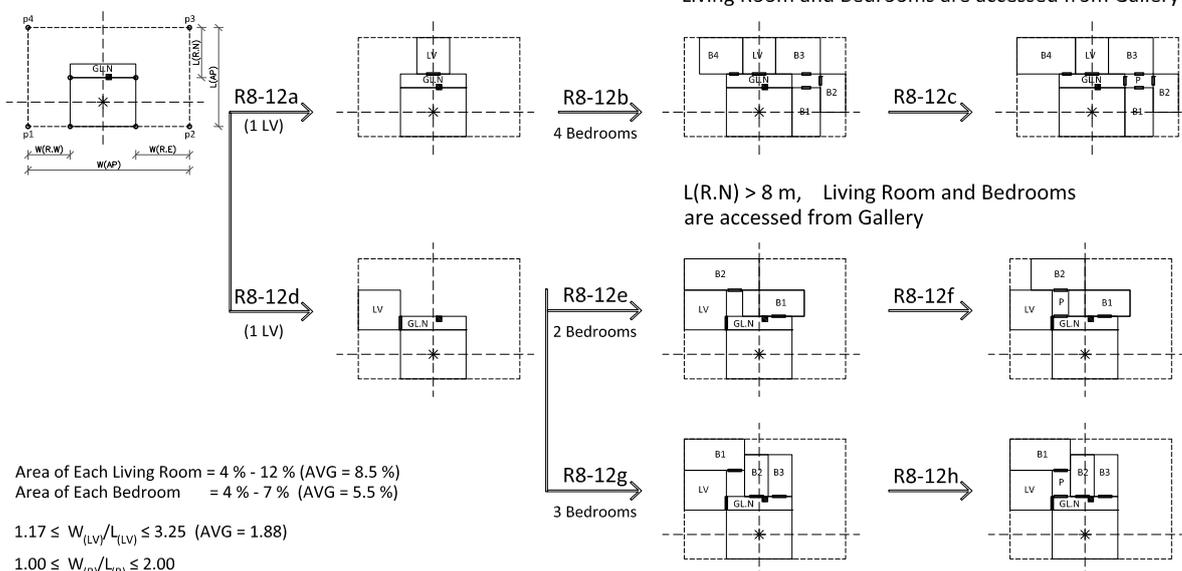
Bedrooms are accessed from Gallery, and opposite to Living Room

Area of Each Living Room = 4% - 12% (AVG = 8.5%)  
Area of Each Bedroom = 4% - 7% (AVG = 5.5%)

$$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25 \text{ (AVG = 1.88)}$$

$$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$$

Conditions: MC: South, GL: North



$L(R.N) < 8 \text{ m}$ ,  $L(R.N) < 8 \text{ m}$ ,  
Living Room and Bedrooms are accessed from Gallery

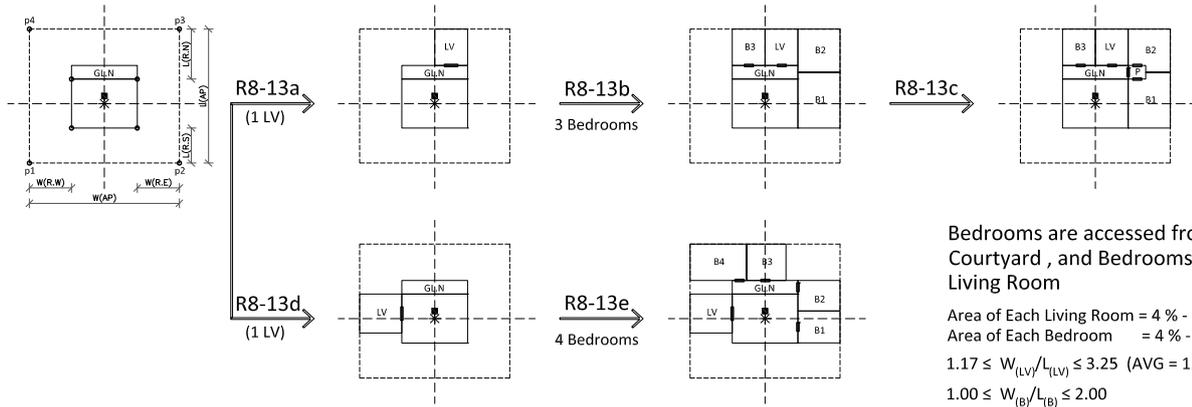
$L(R.N) > 8 \text{ m}$ , Living Room and Bedrooms  
are accessed from Gallery

Area of Each Living Room = 4% - 12% (AVG = 8.5%)  
Area of Each Bedroom = 4% - 7% (AVG = 5.5%)

$$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25 \text{ (AVG = 1.88)}$$

$$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$$

Conditions: MC: Center, GL: North

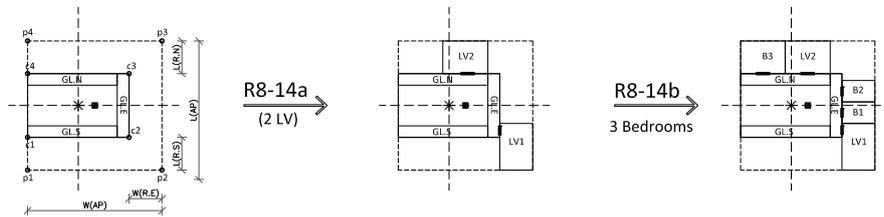


Living Room and Bedrooms are accessed from Gallery

Bedrooms are accessed from Gallery and Courtyard, and Bedrooms are opposite to Living Room

Area of Each Living Room = 4% - 12% (AVG = 8.5%)  
 Area of Each Bedroom = 4% - 7% (AVG = 5.5%)  
 $1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$  (AVG = 1.88)  
 $1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$

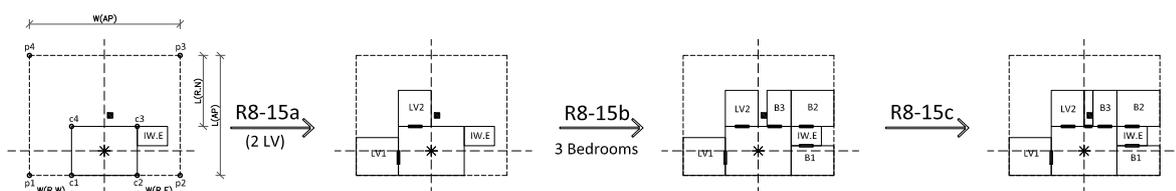
Conditions: MC: West, GL: U-shape (North, South, East)



Living Rooms are located opposite and adjacent to the Guest Room, and Bedrooms are accessed from the Gallery

Area of Each Living Room = 4% - 12% (AVG = 8.5%)  
 Area of Each Bedroom = 4% - 7% (AVG = 5.5%)  
 $1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$  (AVG = 1.88)  
 $1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$

Conditions: MC: South, IW: East, L(R.N) > 10 m

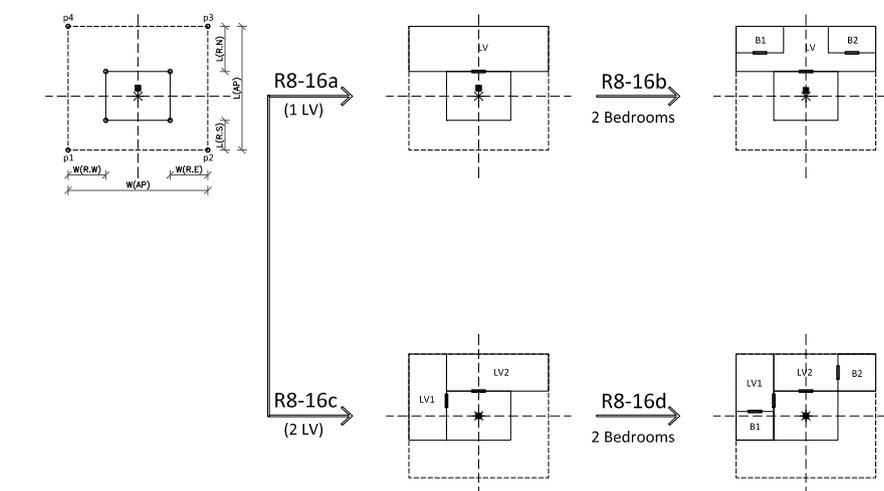


Bedrooms are accessed from Iwan/Courtyard

Area of Each Living Room = 4% - 12% (AVG = 8.5%)  
 Area of Each Bedroom = 4% - 7% (AVG = 5.5%)  
 $1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$  (AVG = 1.88)  
 $1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$

**Rules for Houses that have no Iwan/Gallery:**

Conditions: MC: Center



Living Room is located opposite to the Guest Room, and Bedrooms are accessed from the Living Room

Area of Each Living Room = 4% - 12% (AVG = 8.5%)  
 Area of Each Bedroom = 4% - 7% (AVG = 5.5%)  
 $1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$  (AVG = 1.88)  
 $1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$

Bedrooms are accessed from Living Rooms

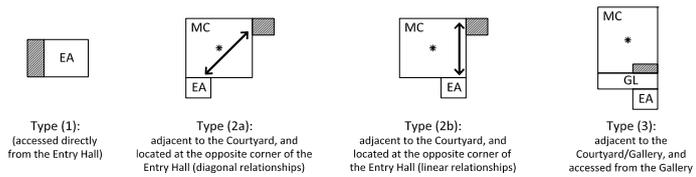
Area of Each Living Room = 4% - 12% (AVG = 8.5%)  
 Area of Each Bedroom = 4% - 7% (AVG = 5.5%)  
 $1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$  (AVG = 1.88)  
 $1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$

## Stage (9): Rules for the Configuration of Vertical Circulation Elements (Stairs) in Two-Floor Houses

### Descriptions:

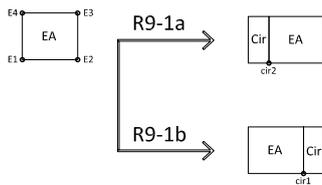
Cir: Stairs leading to upper floors are private spaces that are used by family members.  
 Cir: On the ground floor, stairs could be attached to: Main Entry Hall (EA), Courtyard (MC), Gallery (GL).  
 On upper floor(s), stairs are attached to Gallery (GL), Terraces (T), or Paths/Transitional Spaces (P).

### Typologies for the location of Stairs in relation to Courtyards, Galleries, and Entry Hall



### Rules for Allocating Stairs (Cir) Type 1 (Attached to EA)

Conditions: EA is located on the Southern or Northern sides of the courtyard



#### Design Parameters:

$$X_{(cir2)} = X_{(E1)}$$

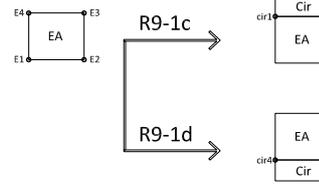
$$Y_{(E1)} \leq Y_{(cir2)} \leq Y_{(E4)}$$

#### Design Parameters:

$$X_{(cir1)} = X_{(E2)}$$

$$Y_{(E2)} \leq Y_{(cir1)} \leq Y_{(E3)}$$

Conditions: EA is located on the Eastern or Western sides of the courtyard



#### Design Parameters:

$$X_{(E4)} \leq X_{(cir1)} \leq X_{(E3)}$$

$$Y_{(cir1)} = Y_{(E3)}$$

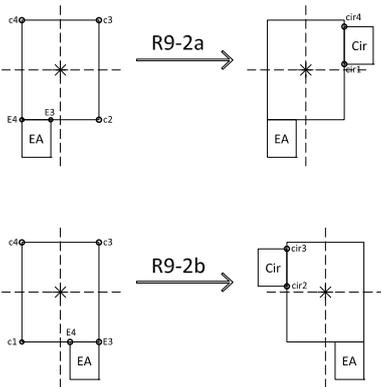
#### Design Parameters:

$$X_{(E1)} \leq X_{(cir4)} \leq X_{(E2)}$$

$$Y_{(cir4)} = Y_{(E2)}$$

### Rules for Allocating Stairs (Cir) Type 2-a (Diagonal Relationship with EA)

Conditions: EA is located on the Southern side of the courtyard



#### Design Parameters:

If  $Y_{(E4)} = Y_{(E3)} = Y_{(c2)}$ , then

$$X_{(cir1)} = X_{(cir4)} = X_{(c2)}$$

$$(Y_{(c2)} + Y_{(c3)})/2 \leq Y_{(cir1)}$$

$$Y_{(cir4)} \leq Y_{(c3)}$$

#### Design Parameters:

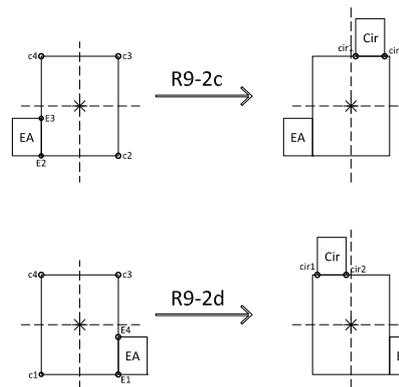
If  $Y_{(E3)} = Y_{(E4)} = Y_{(c1)}$ , then

$$X_{(cir2)} = X_{(cir3)} = X_{(c1)}$$

$$(Y_{(c1)} + Y_{(c4)})/2 \leq Y_{(cir2)}$$

$$Y_{(cir3)} \leq Y_{(c4)}$$

Conditions: EA is located on the Eastern or Western sides of the courtyard



#### Design Parameters:

If  $X_{(E2)} = X_{(E3)} = X_{(c4)}$ , then

$$Y_{(cir2)} = Y_{(cir1)} = Y_{(c3)}$$

$$(X_{(c3)} + X_{(c4)})/2 \leq X_{(cir1)}$$

$$X_{(cir2)} \leq X_{(c3)}$$

#### Design Parameters:

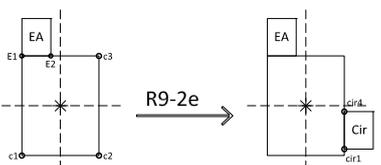
If  $X_{(E1)} = X_{(E4)} = Y_{(c3)}$ , then

$$Y_{(cir2)} = Y_{(cir1)} = Y_{(c3)}$$

$$X_{(cir2)} \leq (X_{(c3)} + X_{(c4)})/2$$

$$X_{(c4)} \leq X_{(cir1)}$$

Conditions: EA is located on the Northern side of the courtyard



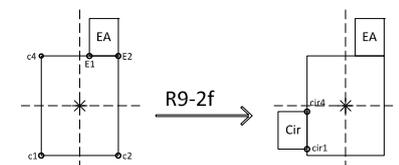
#### Design Parameters:

If  $Y_{(E1)} = Y_{(E2)} = Y_{(c3)}$ , then

$$X_{(cir1)} = X_{(cir4)} = X_{(c2)}$$

$$Y_{(cir4)} \leq (Y_{(c2)} + Y_{(c3)})/2$$

$$Y_{(cir1)} \leq Y_{(c2)}$$



#### Design Parameters:

If  $Y_{(E1)} = Y_{(E2)} = Y_{(c4)}$ , then

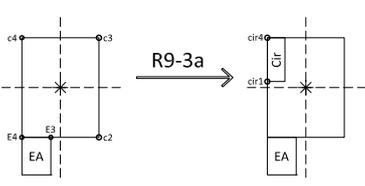
$$X_{(cir1)} = X_{(cir4)} = X_{(c1)}$$

$$Y_{(cir4)} \leq (Y_{(c1)} + Y_{(c4)})/2$$

$$Y_{(cir1)} \leq Y_{(c1)}$$

### Rules for Allocating Stairs (Cir) Type 2-b (Linear Relationship with EA)

Conditions: EA is located on the Southern side of the courtyard



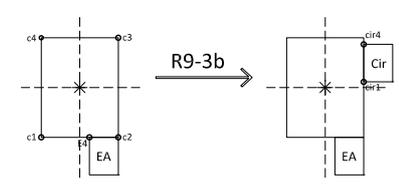
#### Design Parameters:

If  $Y_{(E4)} = Y_{(E3)} = Y_{(c3)}$ , then

$$X_{(cir1)} = X_{(cir4)} = X_{(c4)}$$

$$(Y_{(c1)} + Y_{(c4)})/2 \leq Y_{(cir1)}$$

$$Y_{(cir4)} \leq Y_{(c4)}$$



#### Design Parameters:

If  $Y_{(E4)} = Y_{(E3)} = Y_{(c1)}$ , then

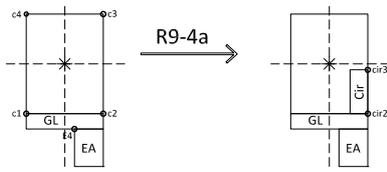
$$X_{(cir1)} = X_{(cir4)} = X_{(c3)}$$

$$(Y_{(c2)} + Y_{(c3)})/2 \leq Y_{(cir1)}$$

$$Y_{(cir4)} \leq Y_{(c3)}$$

## Rules for Allocating Stairs (Cir) Type 3 (accessed from the Gallery)

Conditions: EA and GL are located on the Southern side of the courtyard

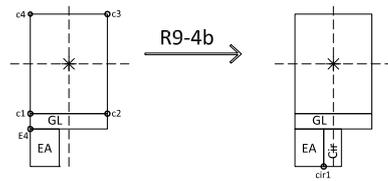


Design Parameters:

$$(x,y)_{(cir2)} = (x,y)_{(c2)}$$

$$x_{(cir3)} = x_{(cir2)}$$

$$(y_{(c2)} + y_{(c3)})/2 \leq y_{(cir3)}$$

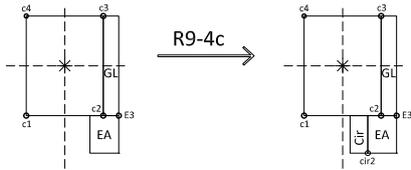


Design Parameters:

$$(x,y)_{(cir1)} = (x,y)_{(E2)}$$

$$(x,y)_{(cir4)} = (x,y)_{(E3)}$$

Conditions: EA is located on the Southern side of the courtyard/gallery, and the Gallery is located on the Eastern side of the courtyard

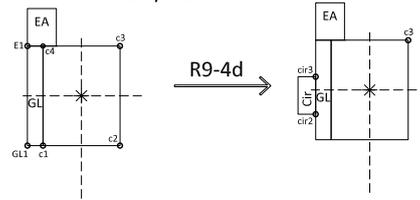


Design Parameters:

$$(x,y)_{(cir2)} = (x,y)_{(E1)}$$

$$(x,y)_{(cir3)} = (x,y)_{(E4)}$$

Conditions: EA is located on the Northern side of the courtyard/gallery, and the Gallery is located on the Western side of the courtyard



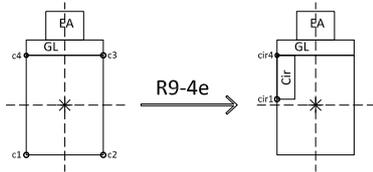
Design Parameters:

$$x_{(cir2)} \leq x_{(cir2)} \leq x_{(GL1)}$$

$$y_{(GL1)} \leq y_{(cir2)} \leq y_{(GL4)}$$

$$y_{(cir3)} = y_{(cir2)}$$

Conditions: EA and GL are located on the Northern side of the courtyard



Design Parameters:

$$(x,y)_{(cir4)} = (x,y)_{(c4)}$$

$$x_{(cir1)} = x_{(cir4)}$$

$$(y_{(c1)} + y_{(c4)})/2 \leq y_{(cir1)}$$

# Stage (10): Rules for the Configuration of Living Spaces (LV) and Bedrooms (B) in Two-Floor Houses

## Descriptions:

In most cases, guest room and living room (which could be used by female visitors) are located on the ground floor. Bedrooms and a family living room are located on the first floor.

In addition, a guest bedroom and/or master bedroom could be located on the ground floor.

## Design Parameters:

- Number of Bedrooms and Living Rooms.
- The Layout of Ground/First Floors.
- Location of Bedrooms in relation to Guest Rooms and Living Rooms.
- Location of Private/Intimate Spaces in relation to Semi-private Spaces (IW, GL, MC)

## Typologies for the First Floor Layout:

- . U-shape 
- . I-shape 
- . L-shape 
- . O-shape 

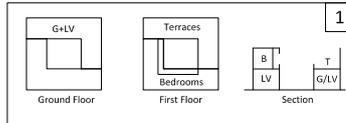
| The Layout of the Ground Floor                            | For MC-S  |   | For MC-C  |  |   |   |   |   | For MC-E  |
|---|---|---|---|--|---|---|---|---|---|
|   | Type S1   | Type S2   | Type C1   | Type C2  | Type C3   | Type C4   | Type C5   | Type C6   | Type E  |
| The Layout of the First Floor                             |  |  |  |  |  |  |  |  |  |
| % of the 1 <sup>st</sup> Floor Area from the Ground Floor | 87%   | 36%   | 73% ↔ 93%<br>(AVG = 83%)  | 34% ↔ 65%<br>(AVG = 47%)   | 26% ↔ 46%<br>(AVG = 36%)  | 47%   | 70%   | 40%   | 73%   |
| No. of Bedrooms   | 4   | 3   | 4, 5, 6, 7  | 1, 3, 4  | 2, 3  | 3   | 2   | 3   | 3, 4  |

## Typologies for the Layout of the First Floor

In L-shape layout for the first floor, the following strategies are used for achieving visual privacy:

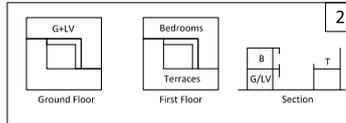
### Strategy (1):

- Bedrooms are located opposite to guest/living rooms (with a gallery in front of it)
- Terraces are located above guest rooms



### Strategy (2):

- Bedrooms are located above guest/living rooms (with a gallery in front of it)
- Terraces are located opposite to guest rooms (with a gallery in front of it)



Both strategies are applicable for O-shape layout.

In some cases, there are two living rooms: one is for female visitors (adjacent to the Guest Room), and the other is for the family (adjacent to Bedrooms)



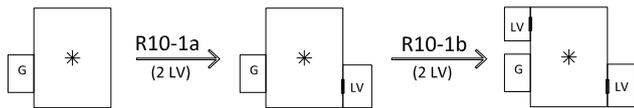
Area of Each Living Room = 3.25% - 10.3% (AVG = 6.65%)  
Area of Each Bedroom = 2.1% - 10.3% (AVG = 4.7%)

$$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25 \quad (AVG = 1.88)$$

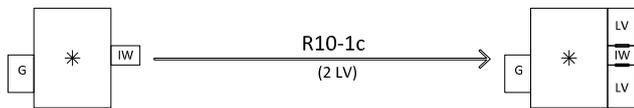
$$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$$

## Rules for Houses that have a Guest Room, which is located on the Western Side of the Courtyard:

### Conditions: G: West



### Conditions: G: West, IW: East



Area of Each Living Room = 3.25% - 10.3% (AVG = 6.65%)  
Area of Each Bedroom = 2.1% - 10.3% (AVG = 4.7%)

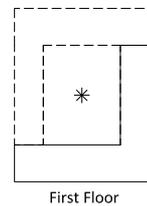
$$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25 \quad (AVG = 1.88)$$

$$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$$

Applicable Solutions

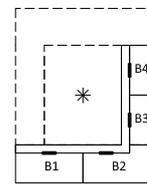
R10-2a

(1<sup>st</sup> Floor)  
Type C2



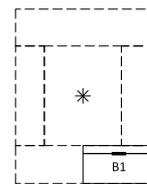
R10-2b

(4 B)  
L-shape



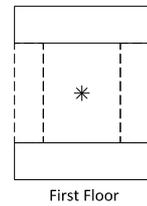
R10-2c

(1 B)  
I-shape



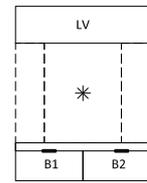
R10-2d

(1<sup>st</sup> Floor)  
Type C5



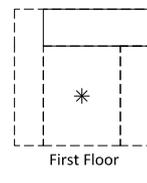
R10-2e

(1 LV + 2 B)  
I-shape



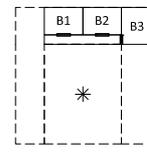
R10-2f

(1<sup>st</sup> Floor)  
Type S2



R10-2g

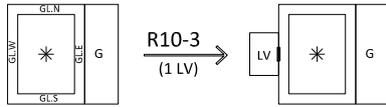
(3 B)  
I-shape



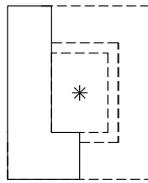
← First Floor →

## Rules for Houses that have a Guest Room, which is located on the Eastern Side of the Courtyard:

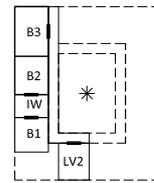
Conditions: G: East, and  
GL: East, West, North, South



R10-4a  
(1<sup>st</sup> Floor)  
Type C3



R10-4b  
(3 B + 1 LV)  
L-shape



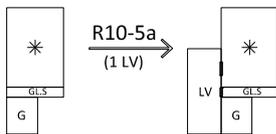
Area of Each Living Room = 3.25 % - 10.3 % (AVG = 6.65 %)  
Area of Each Bedroom = 2.1 % - 10.3 % (AVG = 4.7 %)

$$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25 \text{ (AVG = 1.88)}$$

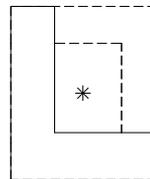
$$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$$

## Rules for Houses that have a Guest Room, which is located on the Southern Side of the Courtyard:

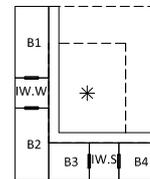
Conditions: G: South,  
GL: South



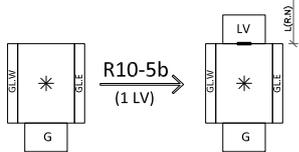
R10-6a  
(1<sup>st</sup> Floor)  
Type C3



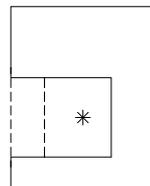
R10-6b  
(4 B)  
L-shape



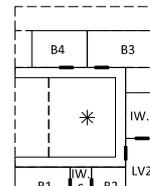
Conditions: G: South, L(R.N) > 8 m  
GL: East, West



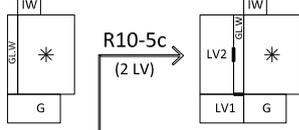
R10-6c  
(1<sup>st</sup> Floor)  
Type C4



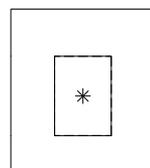
R10-6d  
(4 B + 1 LV)  
U-shape



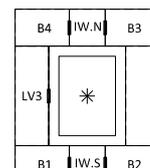
Conditions: G: South,  
GL: West



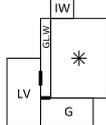
R10-6e  
(1<sup>st</sup> Floor)  
Type C1



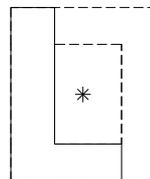
R10-6f  
(4 B + 1 LV)  
O-shape



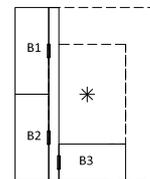
R10-5d  
(1 LV)



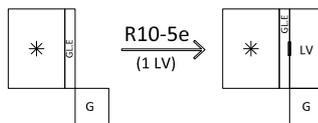
R10-6g  
(1<sup>st</sup> Floor)  
Type E



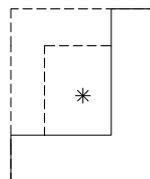
R10-6h  
(3 B)  
L-shape



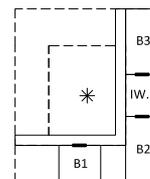
Conditions: G: South,  
GL: East



R10-6i  
(1<sup>st</sup> Floor)  
Type C2



R10-6j  
(3 B)  
L-shape



Area of Each Living Room = 3.25 % - 10.3 % (AVG = 6.65 %)  
Area of Each Bedroom = 2.1 % - 10.3 % (AVG = 4.7 %)

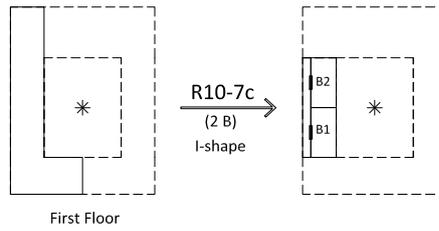
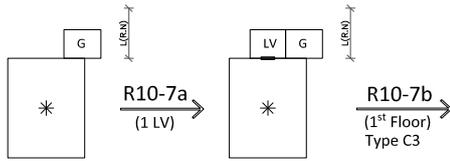
$$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25 \text{ (AVG = 1.88)}$$

$$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$$

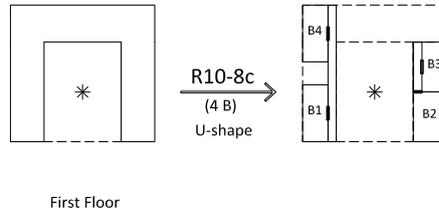
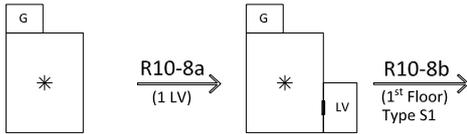
← First Floor →

## Rules for Houses that have a Guest Room, which is located on the Northern Side of the Courtyard:

Conditions: G: North,  $L(R.N) > 8\text{ m}$



Conditions: G: North



Area of Each Living Room = 3.25 % - 10.3 % (AVG = 6.65 %)  
 Area of Each Bedroom = 2.1 % - 10.3 % (AVG = 4.7 %)

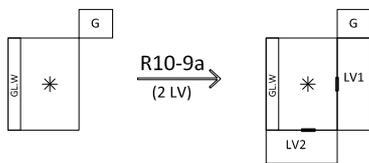
$$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25 \text{ (AVG = 1.88)}$$

$$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$$

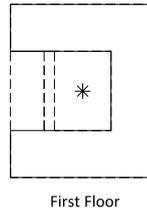
← First Floor →

## Rules for Houses that have 5+ Bedrooms:

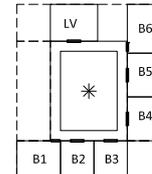
Conditions: MC: Center  
 G: North, GL: West



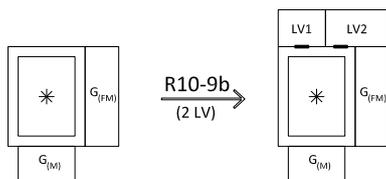
R10-10a (1<sup>st</sup> Floor) Type C4



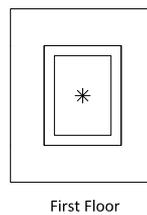
R10-10b (6 B + 1 LV) O-shape



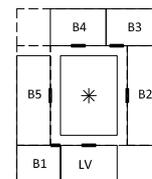
Conditions: MC: Center, G(M): South, G(FM): East  
 GL: West, East, North, South



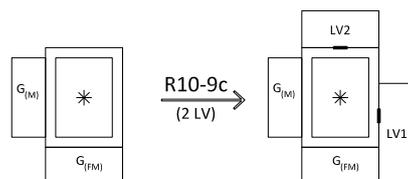
R10-10c (1<sup>st</sup> Floor) Type C1



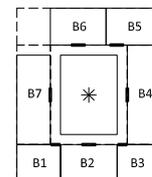
R10-10d (5 B + 1 LV) O-shape



Conditions: MC: Center, G(FM): South, G(M): West  
 GL: West, East, North, South



R10-10e (7 B) O-shape



← First Floor →

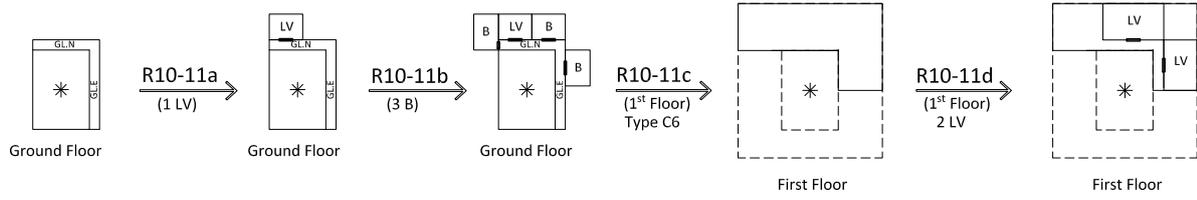
Area of Each Living Room = 3.25 % - 10.3 % (AVG = 6.65 %)  
 Area of Each Bedroom = 2.1 % - 10.3 % (AVG = 4.7 %)

$$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25 \text{ (AVG = 1.88)}$$

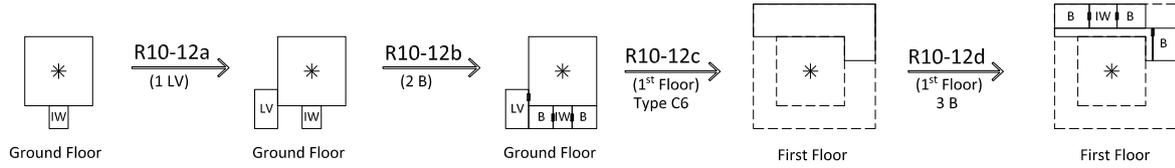
$$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$$

## Rules for Houses with Bedrooms located on Ground & First Floors:

Conditions: GL: North + East



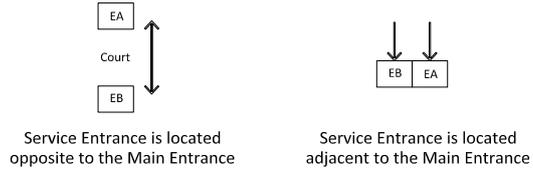
Conditions: IW: South



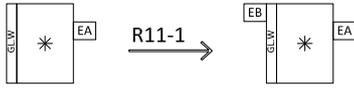
# Stage (11): Rules for the Configuration of Service Entrance (EB)

**Descriptions:**

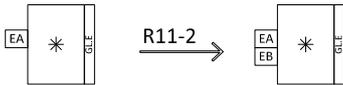
- EB: a service entrance, which is connected with services and/or courtyard/gallery
- EB: it is a semi-private space (S-Pv)
- EB: it has to open to the outside context



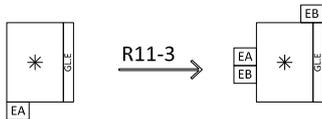
**Conditions:** GL: West, EA: East



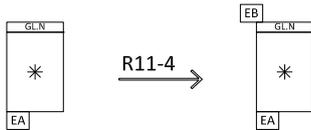
**Conditions:** GL: East, EA: West



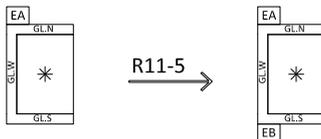
**Conditions:** GL: East, EA: South



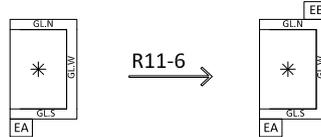
**Conditions:** GL: North, EA: South



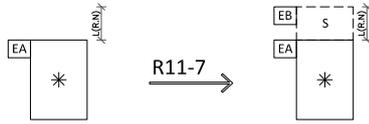
**Conditions:** GL: West+North+South, EA: North



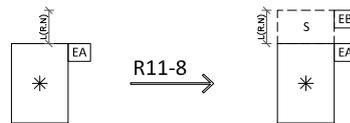
**Conditions:** GL: East+North+South, EA: South



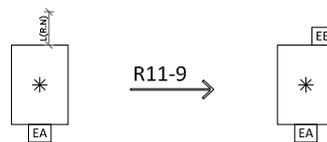
**Conditions:** GL: East+North+South, EA: West,  $L(R.N) \geq 10m$



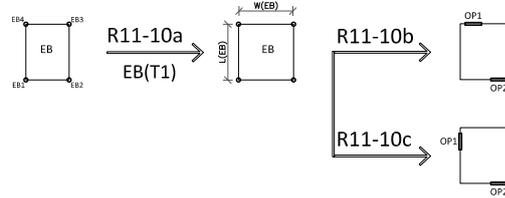
**Conditions:** GL: East+North+South, EA: East,  $L(R.N) \geq 10m$



**Conditions:** GL: East+North+South, EA: East,  $L(R.N) < 10m$



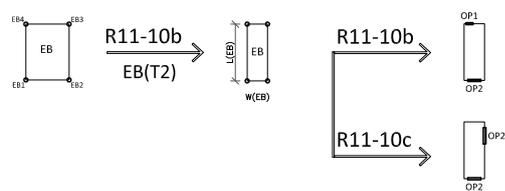
**EB(T1): Service Entrance as a Hall**



**Design Parameters:**

- $2.25 \leq W_{(EB)} \leq 3.60 m$
- $L_{(EB)}$  = length of adjacent room
- $0.90 \leq W_{(OP1)} \leq 1.30 m$
- $0.90 \leq W_{(OP2)} \leq 1.30 m$

**EB(T2): Service Entrance as a Corridor**



**Design Parameters:**

- $1.35 \leq W_{(EB)} \leq 1.90 m$
- $L_{(EB)}$  = length of adjacent room
- $0.90 \leq W_{(OP1)} \leq 1.00 m$
- $0.90 \leq W_{(OP2)} \leq 1.30 m$

## Stage (12): Rules for the Configuration of Services (S) that are located on the Ground Floor

### Descriptions:

S: Services include Toilets, Bathrooms, Kitchen and Storage Areas (Private/Intimate Spaces)

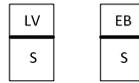
In this grammar, rules indicate the overall layout of services. Subdivisions are not included as they depend on the needs of each design.

Location of services depends on the overall layout of the house, and the location of the courtyard and other rooms specified in previous steps.

Area of Services = 11% - 20% (AVG = 15.5%)

Width of services depends on the width of rooms surrounding the main courtyard.

### Type of Services in relation to Other Spaces



← Shared surface



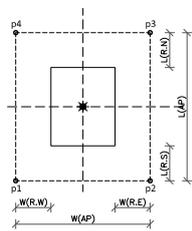
S: Kitchen, Storage Areas, and Toilets (adjacent to living room and/or service entrance)

S: Bathrooms (adjacent to bedrooms)

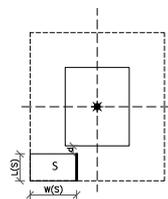
S: Toilets (adjacent to guestroom)

### Rules for Houses that have O-shape Layout:

Conditions: Main Courtyard is located at the center of the Layout



R12-1a  
S: South



$$W_{(S)} \leq W_{(AP)}$$

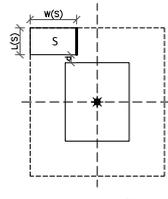
$$L_{(S)} \leq L_{(R,S)}$$

$$0 \leq d \leq W_{(GL)}$$

$$(x_{(p1)} - (W_{(S)}/2)) \leq x_{(S)} \leq (x_{(p2)} - (W_{(S)}/2))$$

$$y_{(S)} = - (y_{(MC)} + (L_{(MC)}/2) + d + (L_{(S)}/2))$$

R12-1b  
S: North



$$W_{(S)} \leq W_{(AP)}$$

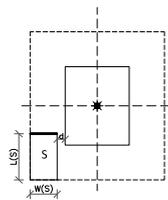
$$L_{(S)} \leq W_{(R,N)}$$

$$0 \leq d \leq W_{(GL)}$$

$$(x_{(p3)} - (W_{(S)}/2)) \leq x_{(S)} \leq (x_{(p4)} - (W_{(S)}/2))$$

$$y_{(S)} = (y_{(MC)} + (L_{(MC)}/2) + d + (L_{(S)}/2))$$

R12-1c  
S: East



$$L_{(S)} \leq L_{(AP)}$$

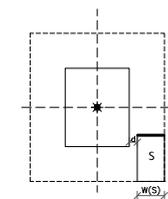
$$W_{(S)} \leq W_{(R,W)}$$

$$0 \leq d \leq W_{(GL)}$$

$$(y_{(p1)} - (L_{(S)}/2)) \leq y_{(S)} \leq (y_{(p4)} - (L_{(S)}/2))$$

$$x_{(S)} = -(x_{(MC)} + (W_{(MC)}/2) + d + (W_{(S)}/2))$$

R12-1d  
S: West



$$L_{(S)} \leq L_{(AP)}$$

$$W_{(S)} \leq W_{(R,E)}$$

$$0 \leq d \leq W_{(GL)}$$

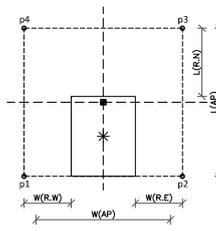
$$(y_{(p2)} - (L_{(S)}/2)) \leq y_{(S)} \leq (y_{(p3)} - (L_{(S)}/2))$$

$$x_{(S)} = (x_{(MC)} + (W_{(MC)}/2) + d + (W_{(S)}/2))$$

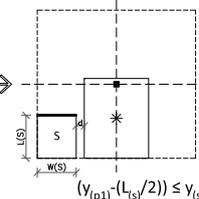
— shared surface with adjacent room

### Rules for Houses that have U-shape Layout:

Conditions: Main Courtyard is located on the Southern Side of the Layout



R12-2a  
S: West



$$L_{(S)} \leq L_{(AP)}$$

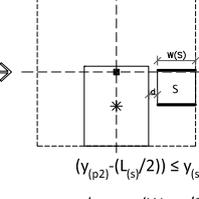
$$W_{(S)} \leq W_{(R,W)}$$

$$0 \leq d \leq W_{(GL)}$$

$$(y_{(p1)} - (L_{(S)}/2)) \leq y_{(S)} \leq (y_{(p4)} - (L_{(S)}/2))$$

$$x_{(S)} = -(x_{(MC)} + (W_{(MC)}/2) + d + (W_{(S)}/2))$$

R12-2b  
S: East



$$L_{(S)} \leq L_{(AP)}$$

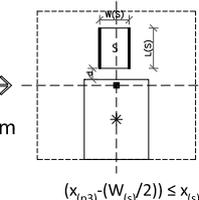
$$W_{(S)} \leq W_{(R,E)}$$

$$0 \leq d \leq W_{(GL)}$$

$$(y_{(p2)} - (L_{(S)}/2)) \leq y_{(S)} \leq (y_{(p3)} - (L_{(S)}/2))$$

$$x_{(S)} = (x_{(MC)} + (W_{(MC)}/2) + d + (W_{(S)}/2))$$

R12-2c  
S: North  
 $L_{(R,N)} < 8m$



$$W_{(S)} \leq W_{(AP)}$$

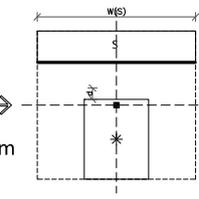
$$L_{(S)} \leq W_{(R,N)}$$

$$0 \leq d \leq W_{(GL)}$$

$$(x_{(p3)} - (W_{(S)}/2)) \leq x_{(S)} \leq (x_{(p4)} - (W_{(S)}/2))$$

$$y_{(S)} = (y_{(MC)} + (L_{(MC)}/2) + d + (L_{(S)}/2))$$

R12-2d  
S: North  
 $L_{(R,N)} \geq 8m$



$$W_{(S)} \leq W_{(AP)}$$

$$L_{(S)} \leq (L_{(R,N)}/2)$$

$$0 \leq d \leq W_{(GL)}$$

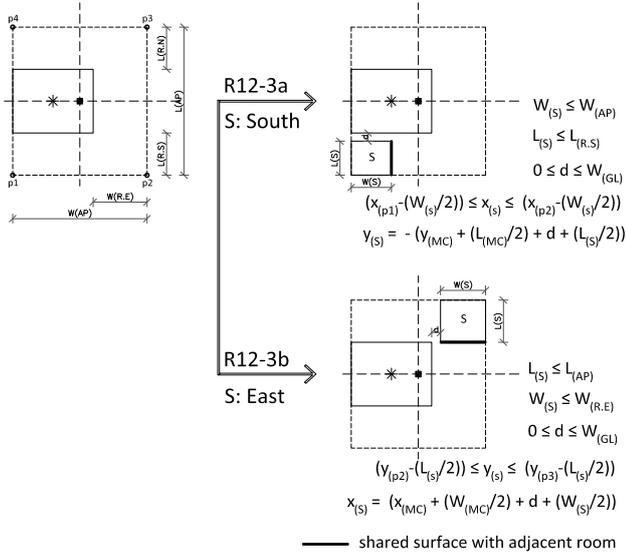
$$(x_{(p3)} - (W_{(S)}/2)) \leq x_{(S)} \leq (x_{(p4)} - (W_{(S)}/2))$$

$$y_{(S)} = (y_{(MC)} + (L_{(MC)}/2) + d + (L_{(S)}/2))$$

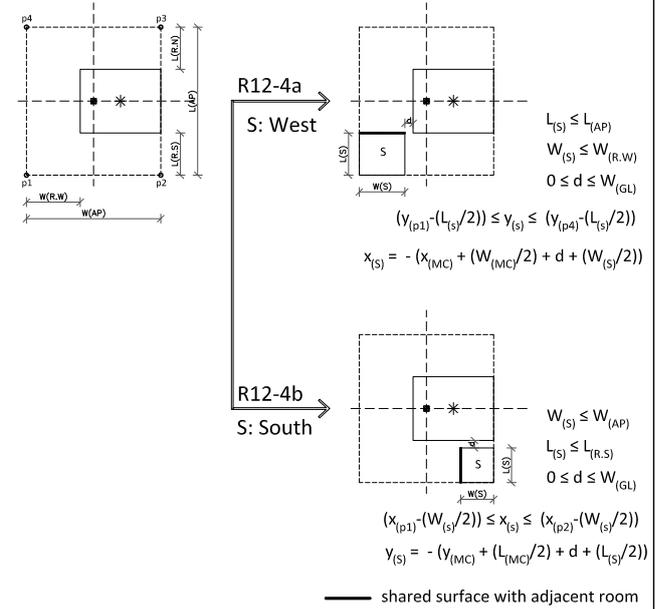
— shared surface with adjacent room

## Rules for Houses that have U-shape Layout:

Conditions: Main Courtyard is located on the Western Side of the Layout



Conditions: Main Courtyard is located on the Eastern Side of the Layout



## Stage (13): Rules for the Configuration of Services (S) that are located on the First Floor

### Descriptions:

S: Services include Bathrooms (Intimate Spaces)

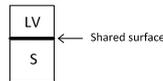
In this grammar, rules indicate the overall layout of services. Subdivisions are not included as they depend on the needs of each design.

Location of services depends on the overall layout of the house, and the location of the courtyard and other rooms specified in previous steps.

Area of Services = 11% - 20% (AVG = 15.5%)

Width of services depends on the width of rooms surrounding the main courtyard.

### Type of Services in relation to Other Spaces

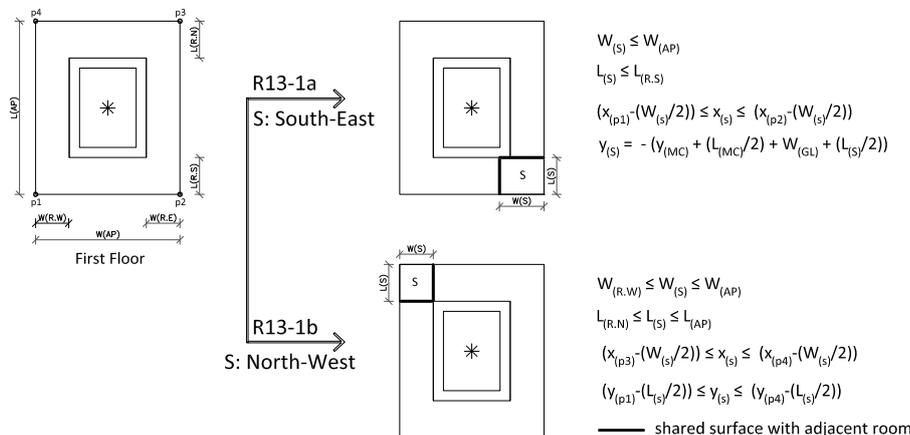


S: Kitchen, Storage Areas, and Toilets  
(adjacent to living room and/or service entrance)

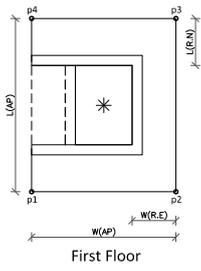


S: Bathrooms  
(adjacent to bedrooms)

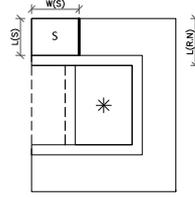
## Rules for a First Floor that has an O-shape Layout:



## Rules for a First Floor that has a U-shape Layout:



R13-2a  
S: North  
 $L_{(R,N)} < 8m$



$$W_{(S)} \leq W_{(AP)}$$

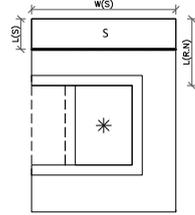
$$L_{(S)} \leq W_{(R,N)}$$

$$(x_{(p3)} - (W_{(S)}/2)) \leq x_{(s)} \leq (x_{(p4)} - (W_{(S)}/2))$$

$$y_{(s)} = (y_{(MC)} + (L_{(MC)}/2) + W_{(GL)} + (L_{(S)}/2))$$

— shared surface with adjacent room

R13-2b  
S: North  
 $L_{(R,N)} \geq 8m$



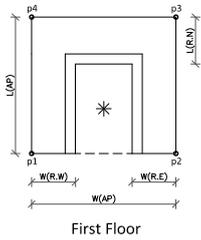
$$W_{(S)} \leq W_{(AP)}$$

$$L_{(S)} \leq (L_{(R,N)}/2)$$

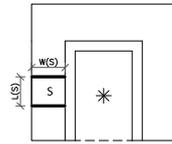
$$(x_{(p3)} - (W_{(S)}/2)) \leq x_{(s)} \leq (x_{(p4)} - (W_{(S)}/2))$$

$$y_{(s)} = (y_{(MC)} + (L_{(MC)}/2) + W_{(GL)} + (L_{(S)}/2))$$

— shared surface with adjacent room



R13-3a  
S: West



$$L_{(S)} \leq L_{(AP)}$$

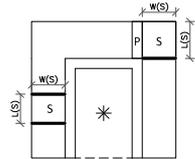
$$W_{(S)} \leq W_{(R,W)}$$

$$(y_{(p1)} - (L_{(S)}/2)) \leq y_{(s)} \leq (y_{(p4)} - (L_{(S)}/2))$$

$$x_{(s)} = -(x_{(MC)} + (W_{(MC)}/2) + d + (W_{(S)}/2))$$

— shared surface with adjacent room

R13-3b  
S: North-East



$$L_{(S)} \leq L_{(AP)}$$

$$W_{(S)} \leq W_{(R,E)}$$

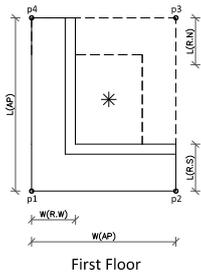
$$(y_{(p2)} - (L_{(S)}/2)) \leq y_{(s)} \leq (y_{(p3)} - (L_{(S)}/2))$$

$$x_{(s)} = (x_{(MC)} + (W_{(MC)}/2) + W_{(GL)} + (W_{(S)}/2))$$

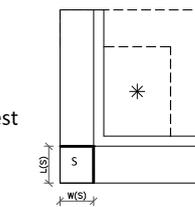
$$W_{(P)} = W_{(GL)}$$

$$L_{(P)} \leq W_{(R,N)}$$

## Rules for a First Floor that has L-shape Layout:



R13-4a  
S: South-West



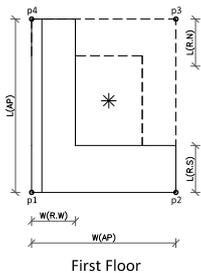
$$L_{(S)} \leq L_{(AP)}$$

$$W_{(S)} \leq W_{(AP)}$$

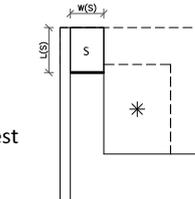
$$(y_{(p2)} - (L_{(S)}/2)) \leq y_{(s)} \leq (y_{(p3)} - (L_{(S)}/2))$$

$$(x_{(p1)} - (W_{(S)}/2)) \leq x_{(s)} \leq (x_{(p4)} - (W_{(S)}/2))$$

— shared surface with adjacent room



R13-4b  
S: North-West



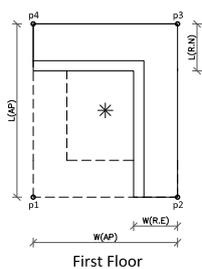
$$W_{(S)} = W_{(R,W)} - W_{(GL)}$$

$$L_{(S)} \leq L_{(AP)}$$

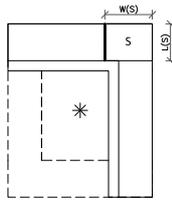
$$x_{(s)} = -(x_{(MC)} + (W_{(MC)}/2) + (W_{(S)}/2))$$

$$(y_{(p1)} - (L_{(S)}/2)) \leq y_{(s)} \leq (y_{(p4)} - (L_{(S)}/2))$$

— shared surface with adjacent room



R13-4c  
S: North



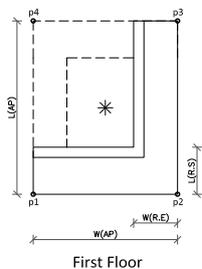
$$W_{(S)} \leq W_{(AP)}$$

$$L_{(S)} \leq W_{(R,N)}$$

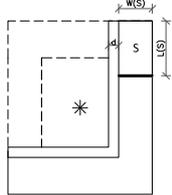
$$(x_{(p3)} - (W_{(S)}/2)) \leq x_{(s)} \leq (x_{(p4)} - (W_{(S)}/2))$$

$$y_{(s)} = (y_{(MC)} + (L_{(MC)}/2) + W_{(GL)} + (L_{(S)}/2))$$

— shared surface with adjacent room



R13-4d  
S: North



$$L_{(S)} \leq L_{(AP)}$$

$$W_{(S)} \leq W_{(R,E)}$$

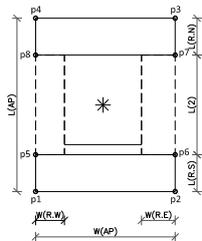
$$0 \leq d \leq W_{(GL)}$$

$$(y_{(p2)} - (L_{(S)}/2)) \leq y_{(s)} \leq (y_{(p3)} - (L_{(S)}/2))$$

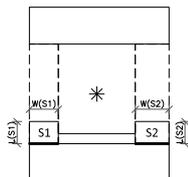
$$x_{(s)} = (x_{(MC)} + (W_{(MC)}/2) + d + (W_{(S)}/2))$$

— shared surface with adjacent room

### Rules for a First Floor that has North/South Rooms:



R13-5  
S: East/West



$$L_{(S1)} \leq L_{(2)}$$

$$W_{(S1)} \leq W_{(R,W)}$$

$$y_{(s1)} = y_{(p6)} + (L_{(S1)}/2)$$

$$x_{(s1)} = - (x_{(MC)} + (W_{(S1)}/2))$$

$$L_{(S2)} \leq L_{(2)}$$

$$W_{(S2)} \leq W_{(R,E)}$$

$$y_{(s2)} = y_{(p7)} + (L_{(S2)}/2)$$

$$x_{(s2)} = - (x_{(MC)} + (W_{(S2)}/2))$$

— shared surface with adjacent room

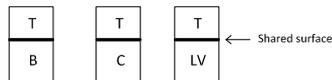
S1 and S2: Bathrooms, connected from North with Terraces, and from South with Bedrooms

# Stage (14): Rules for the Configuration of Terraces that are located on the Ground Floor

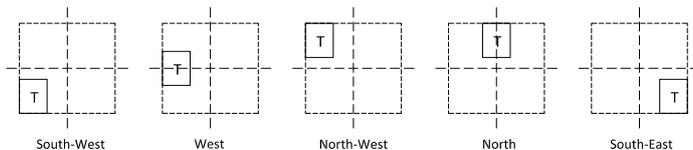
## Descriptions:

T: Terraces/Balconies (Semi-Private Spaces)  
 T: Terraces could be connected with Bedrooms, Living Spaces, or Courtyards

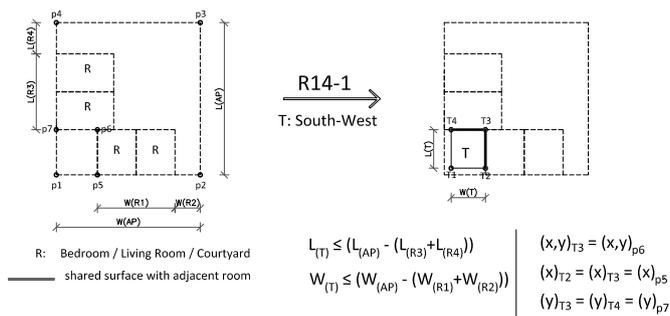
Area of All Terraces = 11 % - 16 % (AVG = 14.3 %) from the total area of the house



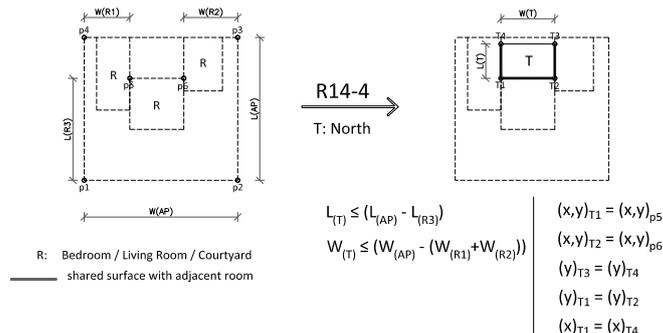
## Location of Terraces in relation to the Layout of the Ground Floor



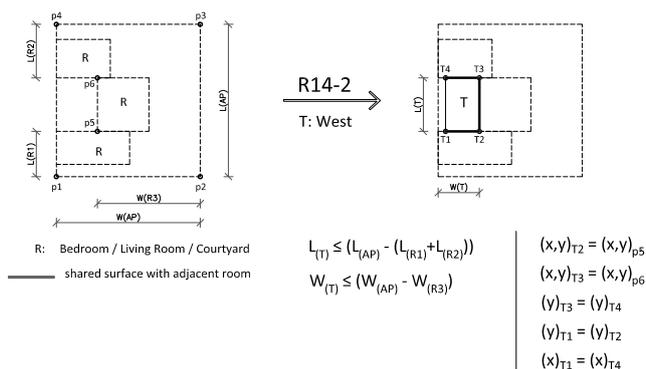
### Terrace is located on the South-West Direction:



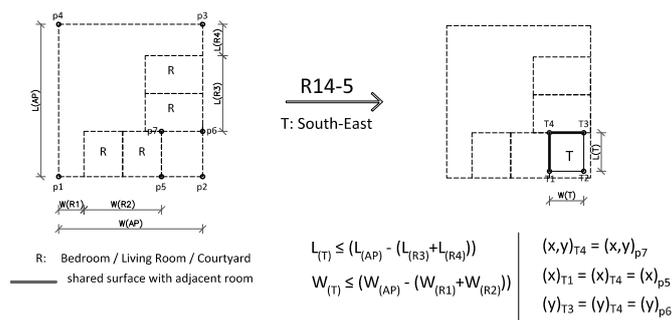
### Terrace is located on the North Direction:



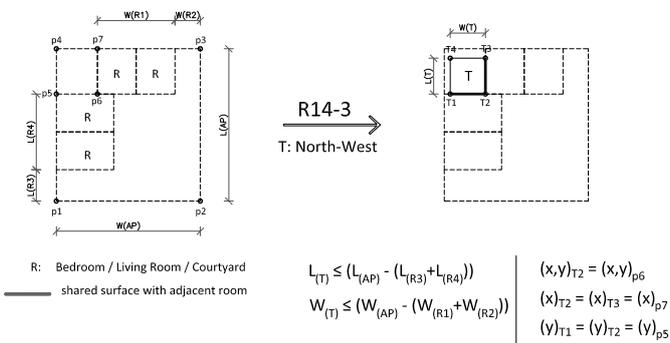
### Terrace is located on the West Direction:



### Terrace is located on the South-East Direction:



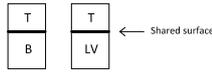
### Terrace is located on the North-West Direction:



# Stage (15): Rules for the Configuration of Terraces that are located on the First Floor

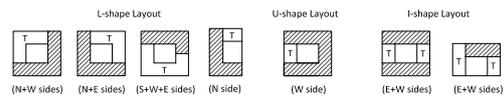
## Descriptions:

T: Terraces/Balconies (Semi-Private Spaces)  
 T: Terraces could be connected with Bedrooms, or Living Spaces

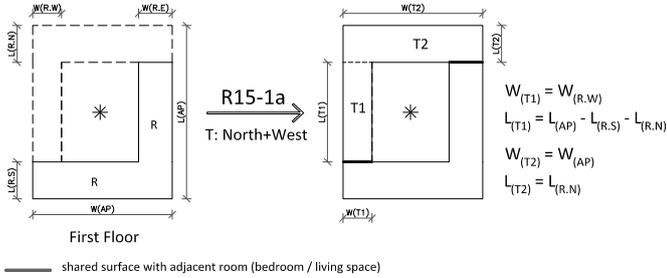


Area of Terraces = 11 % - 16 % (AVG = 14.3 %) from the total area of the house

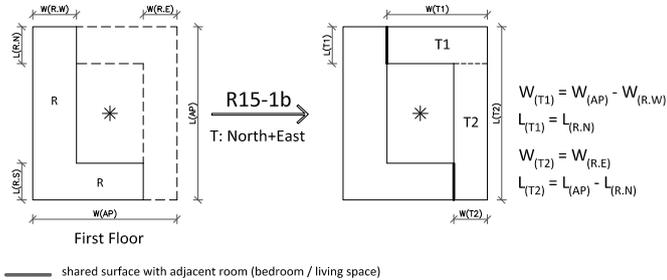
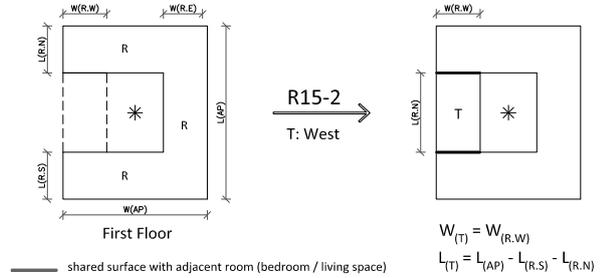
## Location of Terraces in relation to the Layout of the First Floor



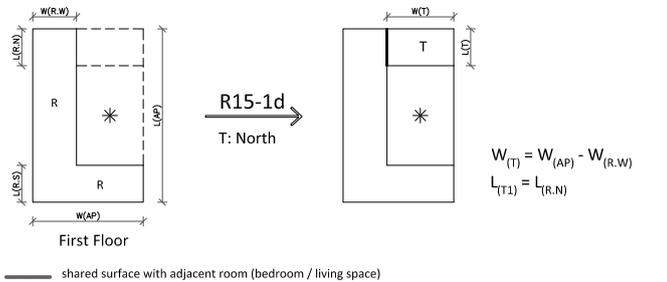
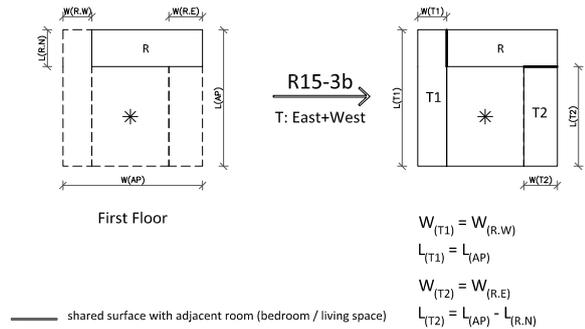
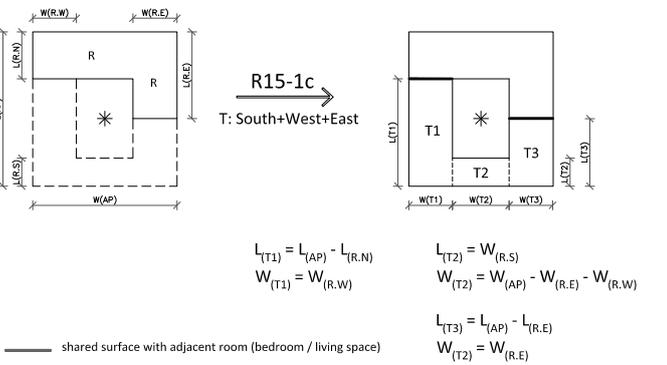
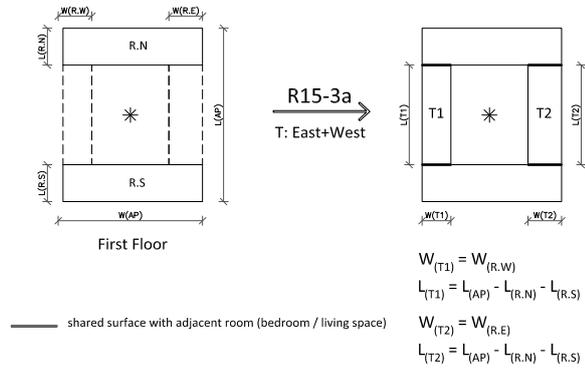
### Terraces for the First Floor that has L-shape Layout:



### Terraces for the First Floor that has U-shape Layout:

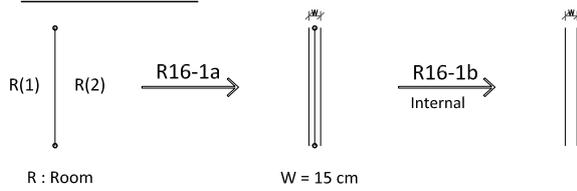


### Terraces for the First Floor that has I-shape Layout:

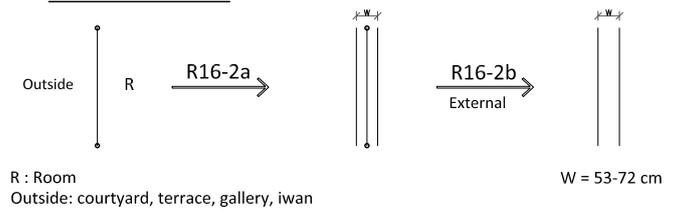


## Stage (16): Rules for Walls Thickness

### Internal Walls

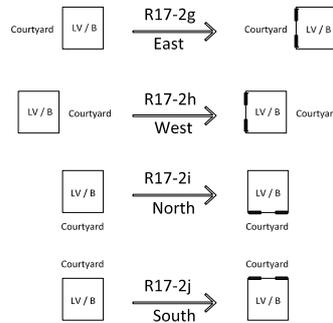
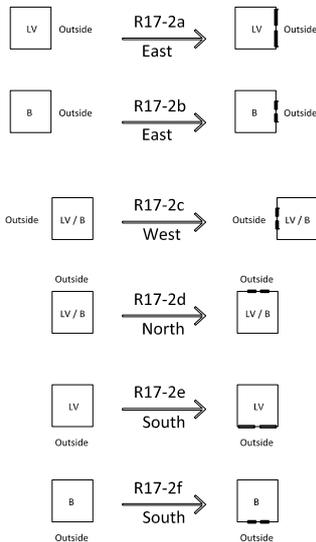
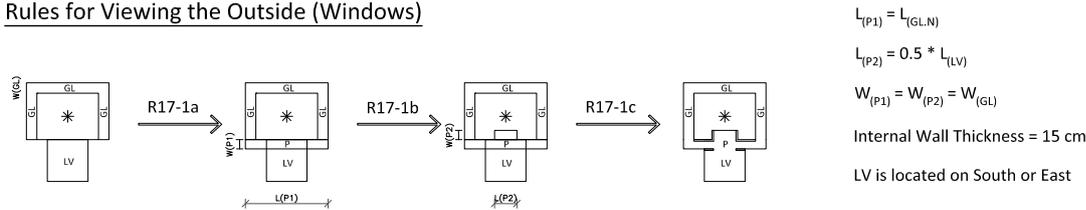


### External Walls



## Stage (17): Rules for Special Treatments

### Rules for Viewing the Outside (Windows)

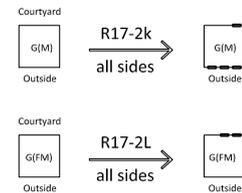


#### Relationship with Courtyard:

**For Living Rooms / Bedrooms:**  
 Windows located on all sides: large windows

**For Guest Rooms (male visitors):**  
 Windows located on all sides: small windows

**For Guest Rooms (female visitors):**  
 Windows located on all sides: large windows with screens



#### Relationship with Outside:

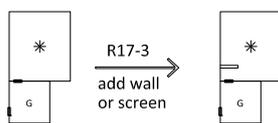
**For Living Rooms:**  
 Windows located on South/East: large windows with screens  
 Windows located on North/West: small windows

**For Bedrooms:**  
 Windows located on all sides: small windows with screens

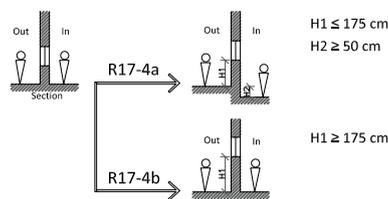
**For Guest Rooms (males visitors):**  
 Windows located on outside edges: small windows

**For Guest Rooms (female visitors):**  
 Windows located on outside edges: no windows

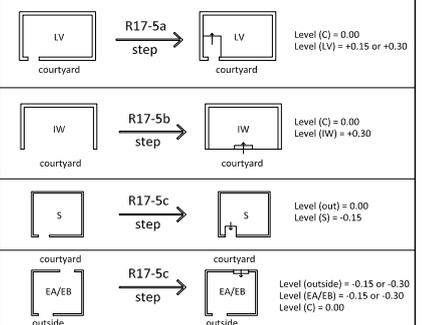
### Rules for Achieving Visual Privacy between Guest Room and Courtyard:



### Rules for Achieving Visual Privacy for the Ground Floor

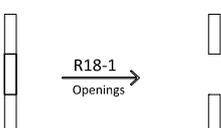


### Rules for Achieving Hygiene:

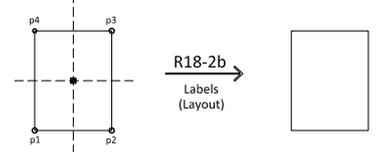
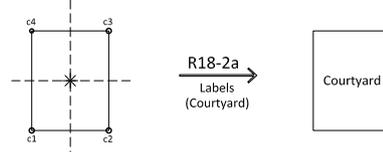


## Stage (18): Termination Rules

### Openings



### Labels and Axes



Appendix (5-A-3)

**Parametric Relationships between Aspects of Social  
Sustainability and Elements of Design at the Scale of  
Neighbourhoods**

# Parametric Relationships between Social Sustainability and Elements of Design at the Scale of Neighborhoods (Clusters of Houses)

## 1. Public/Open Spaces

|  |   |
|--|---|
| <p>1.1. The Percent of Public Spaces relative to the Total Area of the Cluster</p> <p>20%</p> <p>38%</p> <p>             - Social Interaction +<br/>             + Density and Crowding -<br/>             - Human Comfort +           </p>                                  | <p>1.2. The Percent of Private Courtyards relative to the Total Area of Houses</p> <p>18%</p> <p>28%</p> <p>             - Social Interaction +<br/>             + Density and Crowding -<br/>             - Human Comfort +<br/>             - Acoustical Privacy +           </p>                                   |
| <p>1.3. Hierarchy of Open Spaces (from Public to Semi-private to Cul-de-sac)</p> <p>Only a Main Public Space</p> <p>Hierarchy of Open Spaces</p> <p>             - Safety and Security for the Family and Children +<br/>             - Visual Privacy +           </p>      | <p>1.4. Availability of Steps between Public Spaces or Alleys, and Semi-private Open Spaces</p> <p>No Steps</p> <p>5 Steps</p> <p>             - Hygiene +<br/>             + Accessibility -           </p>  |
| <p>1.5. Width of Main Public Spaces</p> <p>3.15 m</p> <p>11.25 m</p> <p>             - Social Interaction +<br/>             + Density and Crowding -<br/>             - Human Comfort +<br/>             + Safety and Security for the Family and Children -           </p> | <p>1.6. Width of Semi-Private Open Spaces</p> <p>1.15 m</p> <p>5.85 m</p> <p>             - Social Interaction +<br/>             + Density and Crowding -<br/>             + Human Comfort -<br/>             + Safety and Security for the Family and Children -<br/>             - Visual Privacy +           </p> |

## 2. Arrangement of Main Entrances

|   |   |
|---|---|
| <p>2.1. Location of Main Entrances</p> <p>connected with Main Public Spaces</p> <p>connected with Alleys, Semi-private Open Spaces</p> <p>             - Safety and Security for the Family and Children +<br/>             - Visual Privacy +           </p> | <p>2.2. Angle between opposite Entrances</p> <p>0°</p> <p>90°</p> <p>             - Visual Privacy +           </p> |
| <p>2.3. Spatial Elements opposite to Main Entrances</p> <p>Door</p> <p>Solid Wall / High Window Sill</p> <p>             - Visual Privacy +           </p>  |   |

## 3. Circulation Pattern

|  |   |
|--|---|
| <p>3.1. Width of Alleys between Houses</p> <p>2.25 m</p> <p>5.45 m</p> <p>             - Social Interaction +<br/>             + Density and Crowding -<br/>             + Human Comfort -<br/>             + Safety and Security for the Family and Children -<br/>             - Visual Privacy +<br/>             - Acoustical Privacy +<br/>             - Accessibility +<br/>             - Hygiene +           </p> | <p>3.2. Changes in Directions between Public Spaces, Alleys, and Entrances of Houses</p> <p>0°</p> <p>90°</p> <p>             - Visual Privacy +<br/>             + Accessibility -<br/>             + Human Comfort -           </p> |
| <p>3.3. Orientation of Alleys between Houses</p> <p>East, South</p> <p>West, North</p> <p>             - Human Comfort +           </p>  |   |
| <p>3.4. Availability of Steps in front of the Main Entrance of the House</p> <p>No Steps</p> <p>5 Steps</p> <p>             - Hygiene +<br/>             + Accessibility -           </p>  | <p>3.5. Outside Corner of Buildings</p> <p>45°</p> <p>90°</p> <p>             + Accessibility and Ease of Movement -           </p>   |

## 4. Configuration of Residential Units

|   |   |
|---|---|
| <p>4.1. Thickness of Shared Walls between Adjacent Houses</p> <p>40 cm</p> <p>90 cm</p> <p>             - Acoustical Privacy +           </p>   | <p>4.2. Number of Floors surrounding Open Spaces</p> <p>1 Floors</p> <p>+4 Floors</p> <p>             + Visual Privacy -<br/>             - Safety and Security +<br/>             - Thermal Comfort +           </p> |
| <p>4.3. Relationships between Adjacent Houses (based on number of shared surfaces)</p> <p>One shared surface</p> <p>Four shared surface</p> <p>             + Viewing the Outside -<br/>             + Thermal Comfort -           </p> |   |

Appendix (5-A-4)

**Parametric Rules for the Configuration of Traditional  
Neighbourhoods (Clusters of Houses) in MENA Region**

## Stage (N1): Rules for the Configuration of Main Public Space (MPS)

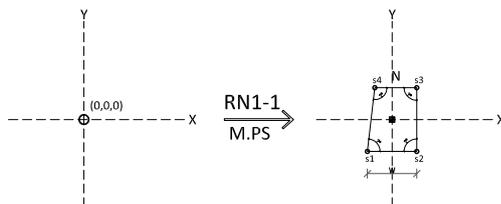
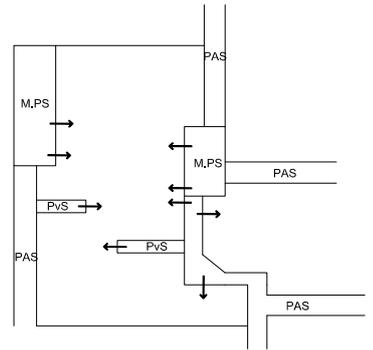
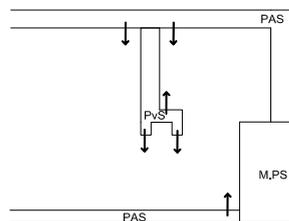
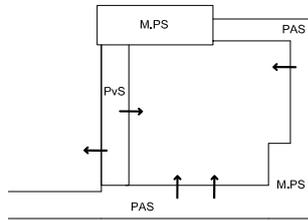
There is a Hierarchy for the Configuration of Public Spaces in Neighbourhoods:

MPS: Main Gathering Area

PvS: A Semi-Private Space between Houses

PAS: Corridors and Passageways connecting MPS with PvS

Total Area of Public Spaces = 21-38%



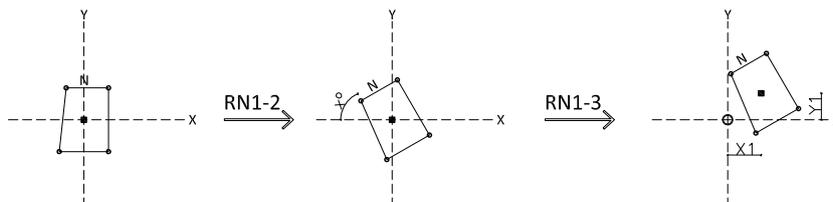
- N : North direction
- : corners of the main public space
- : the centroid of the main public space =  $(x,y,z)_{MPS}$
- : the centroid of the cluster =  $(x,y,z)_{clus}$

Design Parameters:

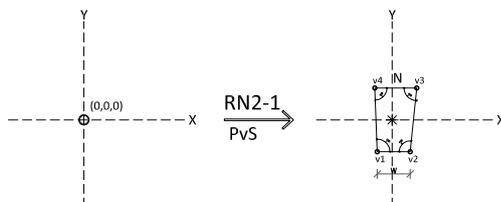
$$3.15 \leq W_{(MPS)} \leq 11.25$$

$$45^\circ \leq X^\circ$$

Number of Public Spaces depends on the Area of the Cluster



## Stage (N2): Rules for the Configuration of Semi-Private Open Space (PvS)



- N : North direction
- : corners of the semi-private space
- \* : the centroid of the semi-private space =  $(x,y,z)_{PvS}$

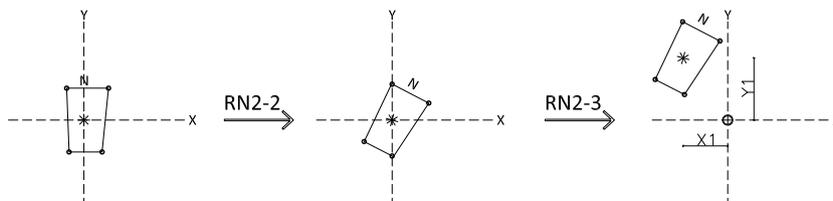
Design Parameters:

$$1.15 \leq W_{(PvS)} \leq 5.85$$

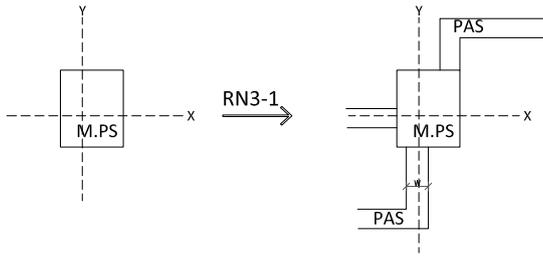
$$(21\% * Area_{(Cluster)}) \leq Area_{(MPS)} + Area_{(PvS)} \leq (28\% * Area_{(Cluster)})$$

$$45^\circ \leq X^\circ$$

Number of Semi-Private Spaces depends on the Area of the Cluster



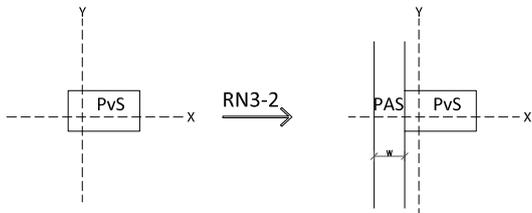
## Stage (N3): Rules for the Configuration of Passageways (PAS)



Design Parameters:

$$2.25 \leq W_{(PAS)} \leq 5.45$$

Passageway could be located on any direction

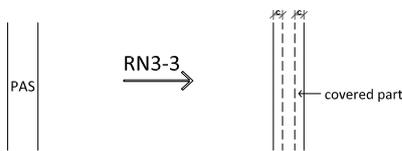


Design Parameters:

$$2.25 \leq W_{(PAS)} \leq 5.45$$

Passageway is perpendicular on Semi-private Spaces

Passageway could be located on any direction



Design Parameters:

$$c \leq 75 \text{ cm}$$

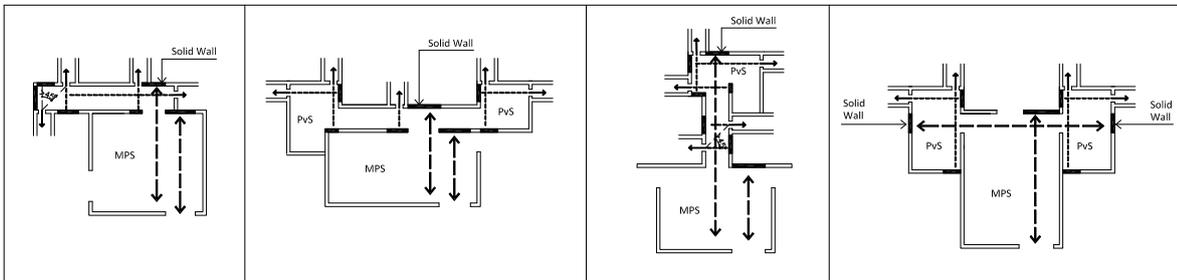
c: is the width of covered part from the passageway. This could be from one side or both sides.

## Stage (N4): Rules for Achieving Visual Privacy between Houses

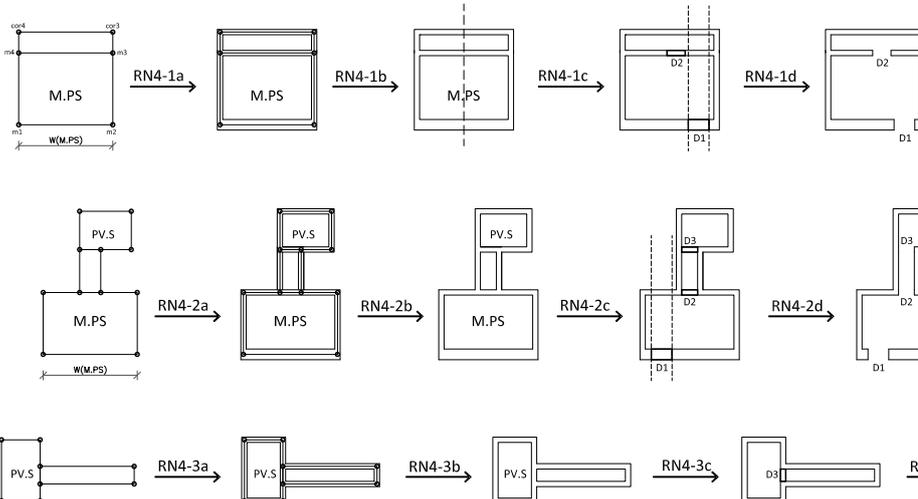
Descriptions:

- Walls in front of main entrances are solid walls.
- Walls in front of the entry of the semi-private spaces are solid walls.
- Houses are connected with corridors or semi-private spaces.
- Entrances for houses are not connected with the main public space.
- Wall that is directly located in front of the entrance of any house is a solid wall.

Strategies for achieving Visual Privacy



## Rules for allocating Openings between Public Spaces



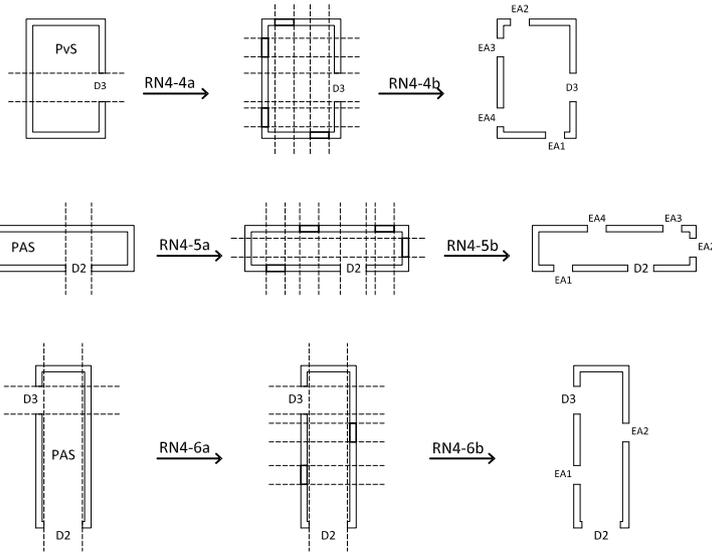
$\begin{matrix} 4 & 3 \\ \hline D \\ \hline 1 & 2 \end{matrix}$ 
 D1: Main Entrance for the Cluster  
 D2: Opening between Passageway and Main Public Space  
 D3: Door between Corridor and Semi-private Space

$$\text{If } (x)_{D1,1} \leq (W_{(M.P.S)}/2), (x)_{D2,1} > (x)_{D1,2}$$

$$\text{If } (x)_{D1,1} > (W_{(M.P.S)}/2), (x)_{D2,2} < (x)_{D1,1}$$

Wall opposite to any door is a solid wall

## Rules for allocating Main Entrances (EA) for Houses

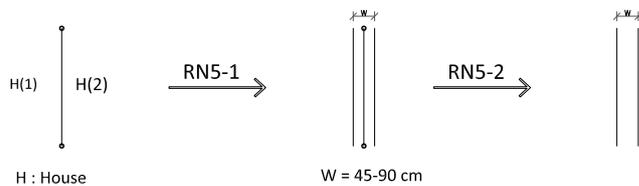


- Wall opposite to any door is a solid wall
- Number of doors depends on the number of houses

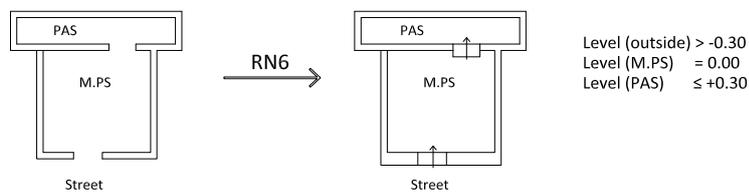
D1: Main Entrance for the Cluster  
 D2: Door between Corridor and Main Public Space  
 D3: Door between Corridor and Semi-private Space  
 EA: Main Entrance for the House

## Stage (N5): Rules for Achieving Acoustical Privacy between Houses

### Shared Wall between Houses



## Stage (N6): Rules for Achieving Hygiene between Public Spaces and Houses



Stage (N7): Rules showing Types of adjacent Houses

Typologies for Houses (based on number and location of shared surfaces)

Houses attached from Three Sides

| Location of Attached Surfaces |                       | North + East + South | North + East + West | South + East + West | South + North + West |
|-------------------------------|-----------------------|----------------------|---------------------|---------------------|----------------------|
| Single-Floor House            |                       |                      |                     |                     |                      |
| Two-Floor House               |                       |                      |                     |                     |                      |
| Two-Floor House               | 1 <sup>st</sup> Level |                      |                     |                     |                      |
|                               | 2 <sup>nd</sup> Level |                      |                     |                     |                      |

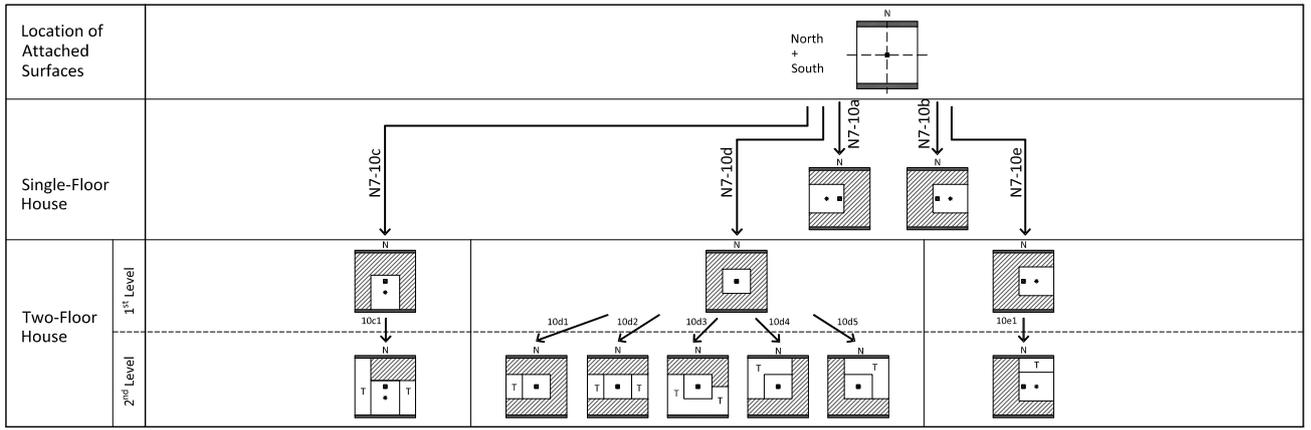
Houses attached from Two Sides

| Location of Attached Surfaces |                       | West + South | East + South | East + North |
|-------------------------------|-----------------------|--------------|--------------|--------------|
| Single-Floor House            |                       |              |              |              |
| Two-Floor House               |                       |              |              |              |
| Two-Floor House               | 1 <sup>st</sup> Level |              |              |              |
|                               | 2 <sup>nd</sup> Level |              |              |              |

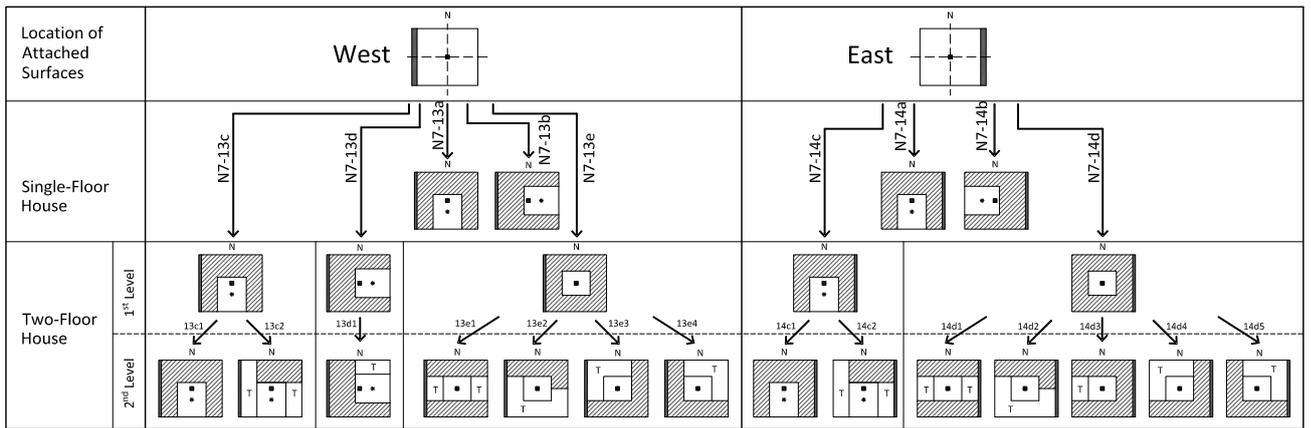
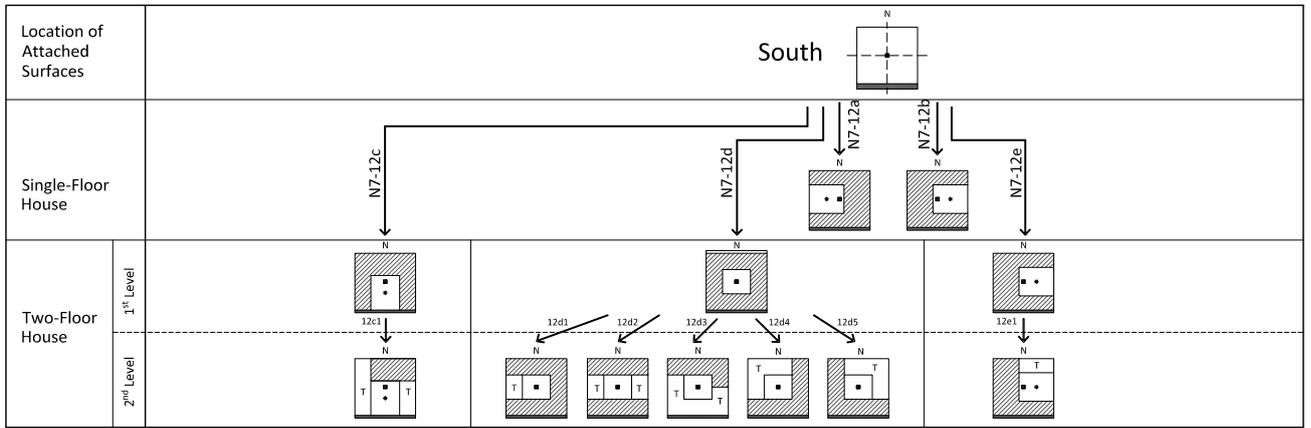
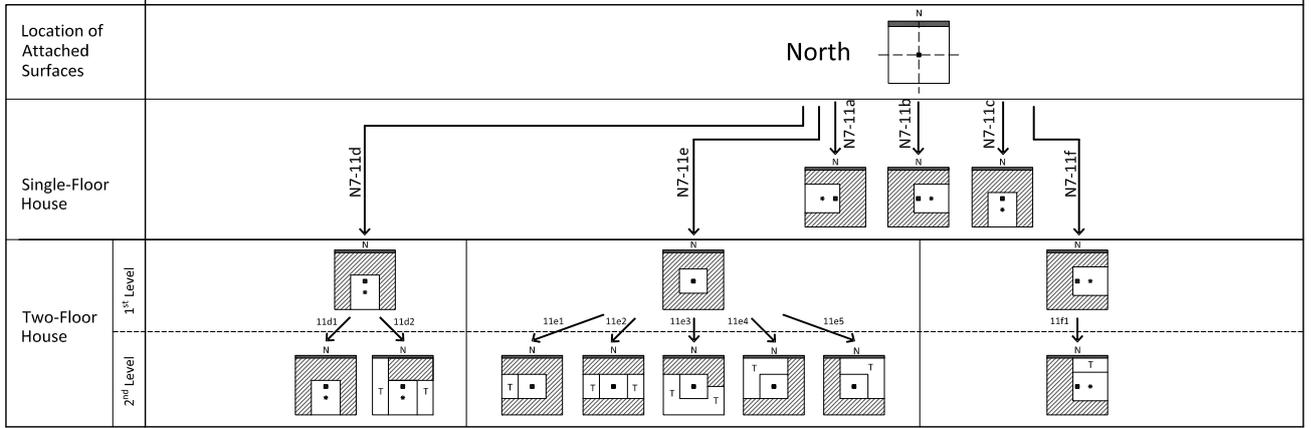
West + North

West + East

| Location of Attached Surfaces |                       | West + North | West + East |
|-------------------------------|-----------------------|--------------|-------------|
| Single-Floor House            |                       |              |             |
| Two-Floor House               |                       |              |             |
| Two-Floor House               | 1 <sup>st</sup> Level |              |             |
|                               | 2 <sup>nd</sup> Level |              |             |



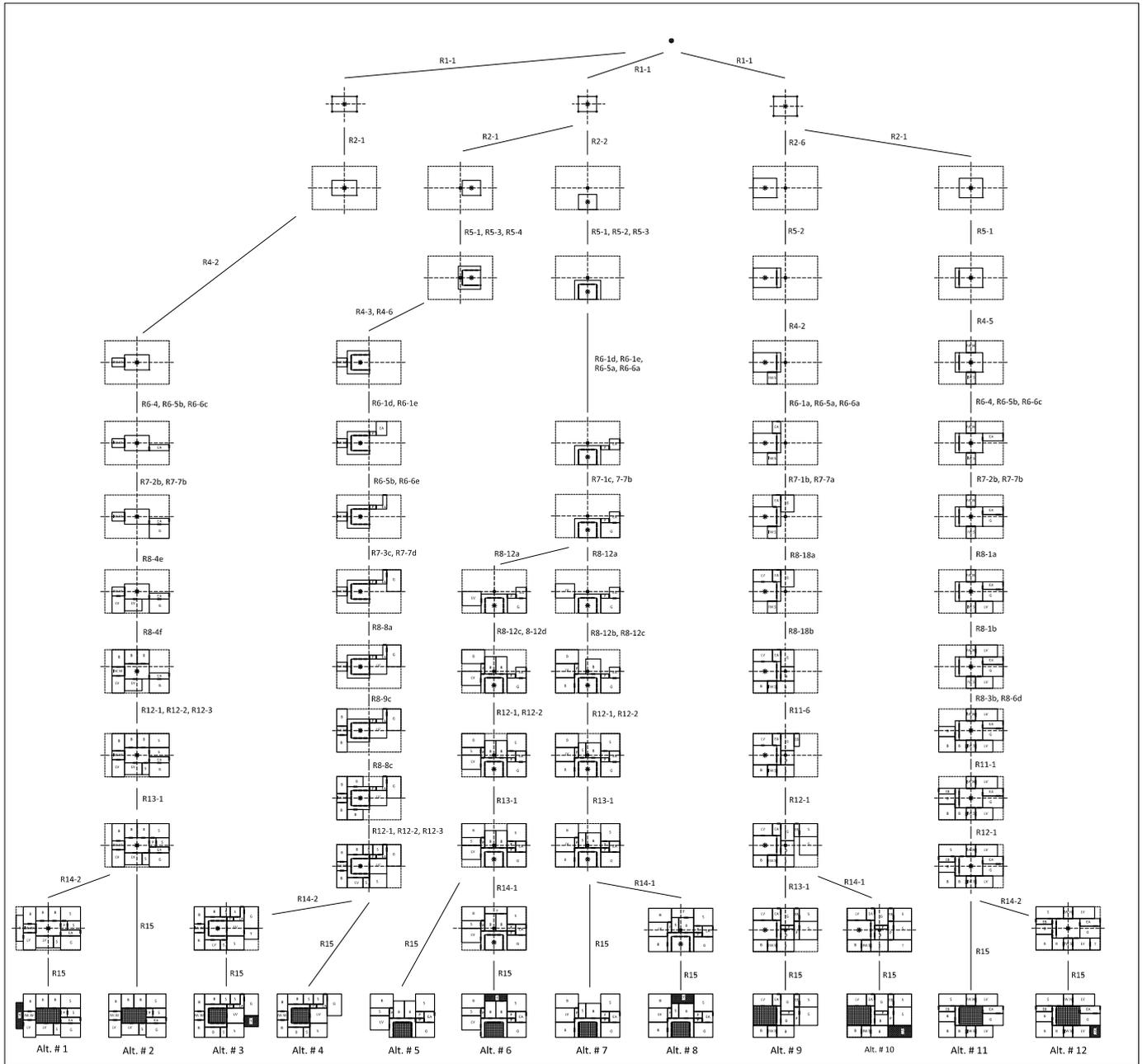
House attached from One Side



Appendix (5-A-5)

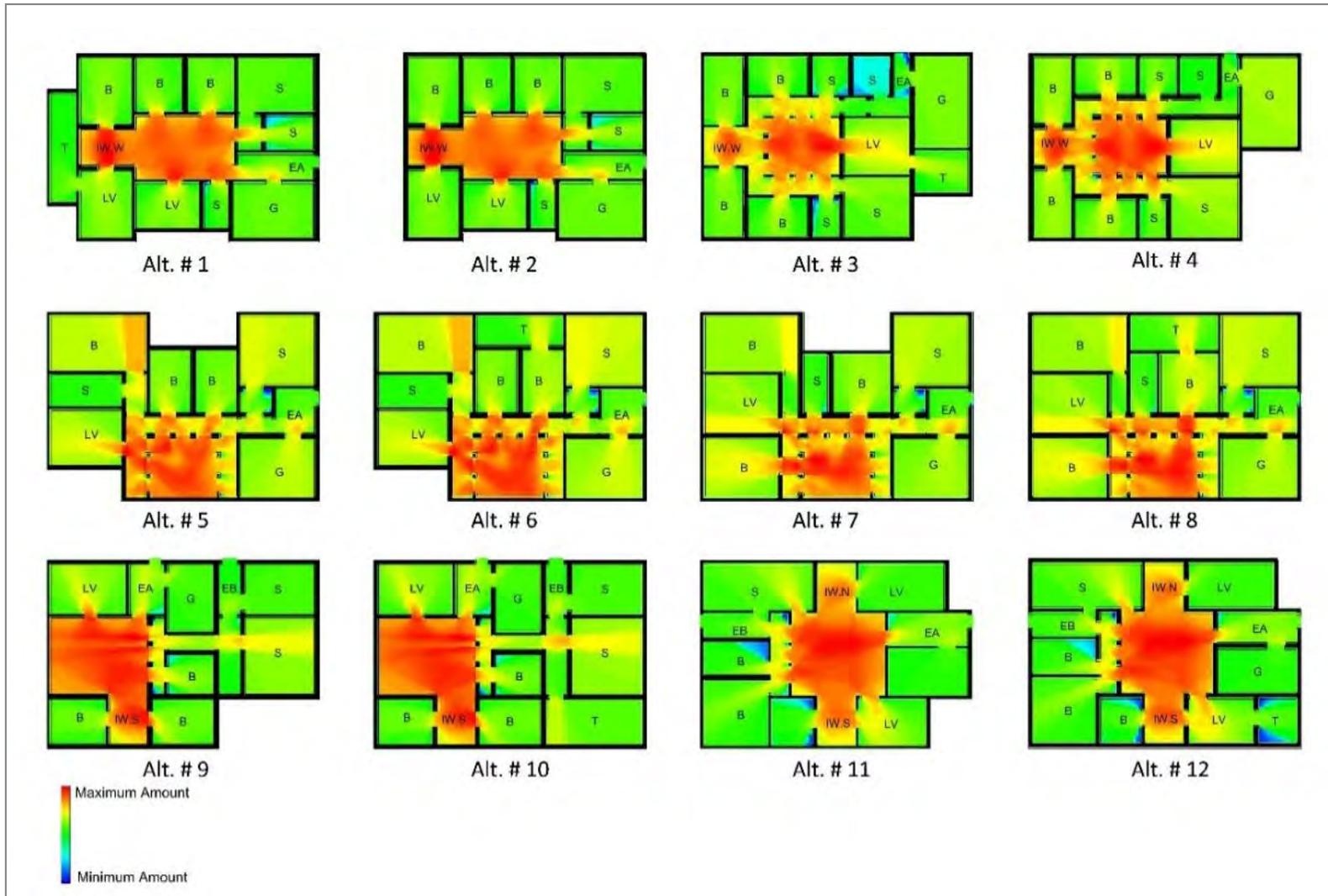
**New Solutions for Courtyard Houses  
generated by the Constructed Grammar**

# The generation process of 12 new solutions for courtyard houses





Evaluating the visual privacy between public and private zones for the new alternatives  
 (Produced by the Researcher, using Syntax2D software)

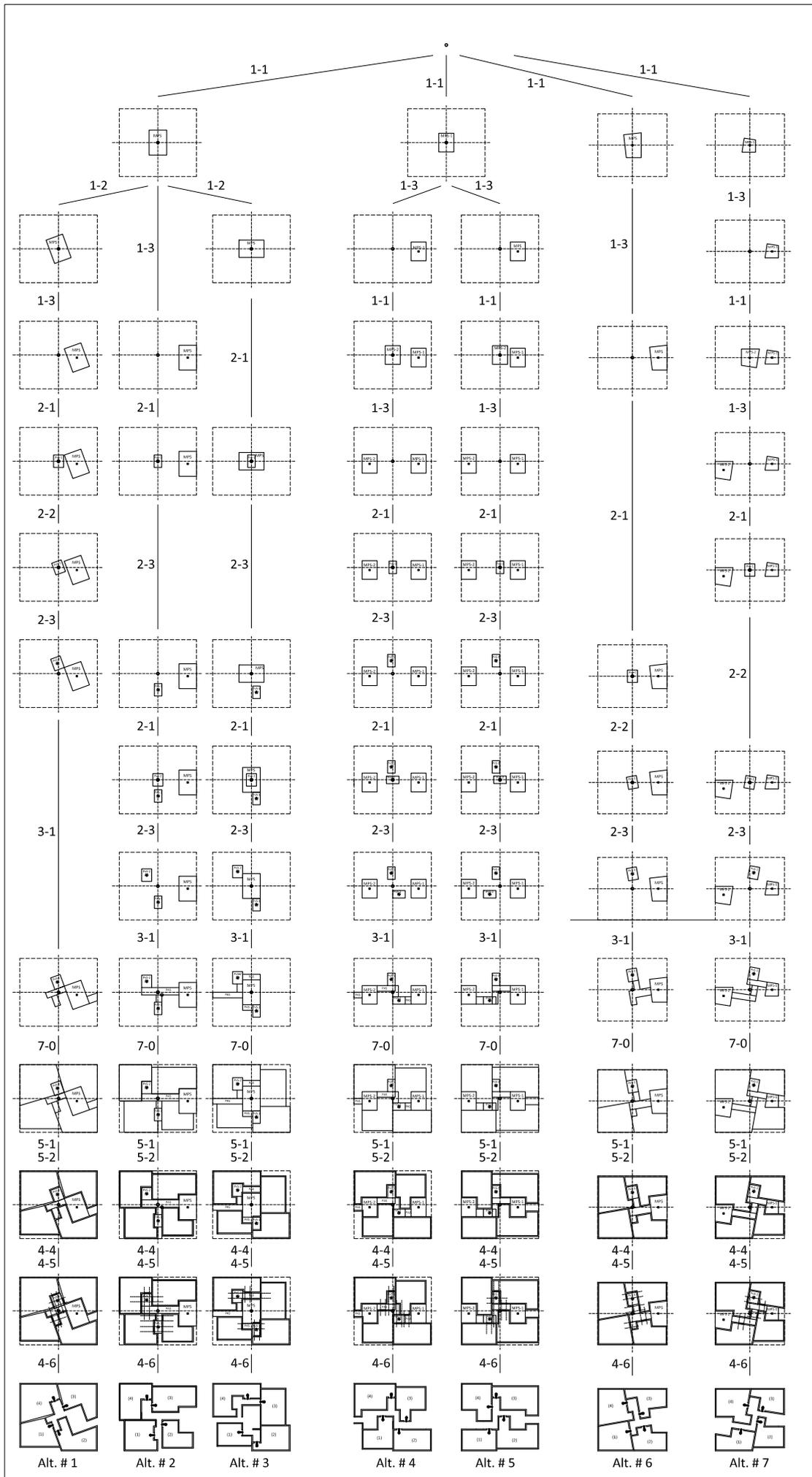


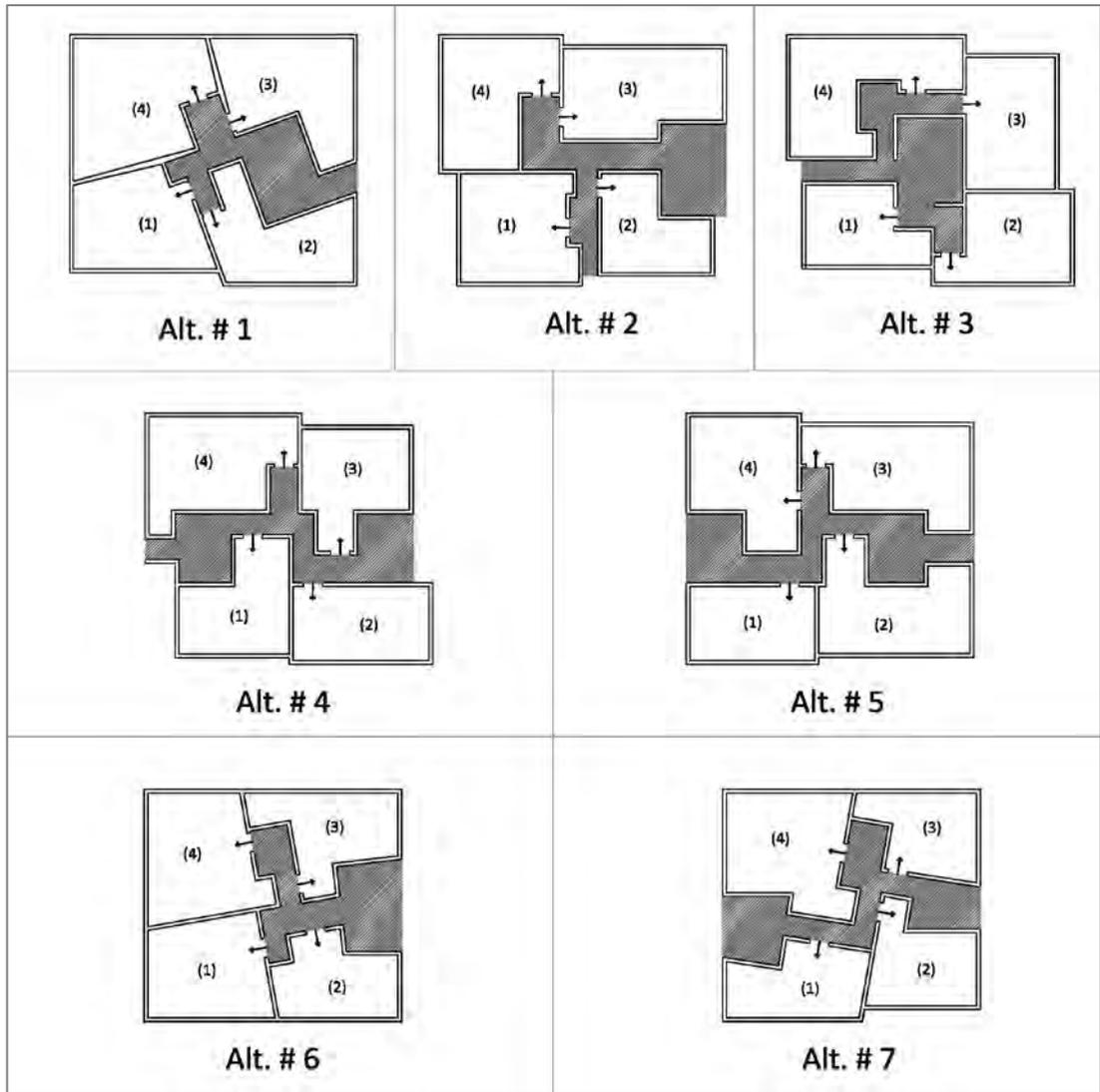
Visibility graph analysis for the new solutions showing the connectivity value for each space  
 (Produced by the Researcher, using DepthmapX software)

Appendix (5-A-6)

**New Solutions for Clusters of Houses  
generated by the Constructed Grammar**

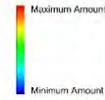
# The generation process of 7 new solutions for clusters of houses





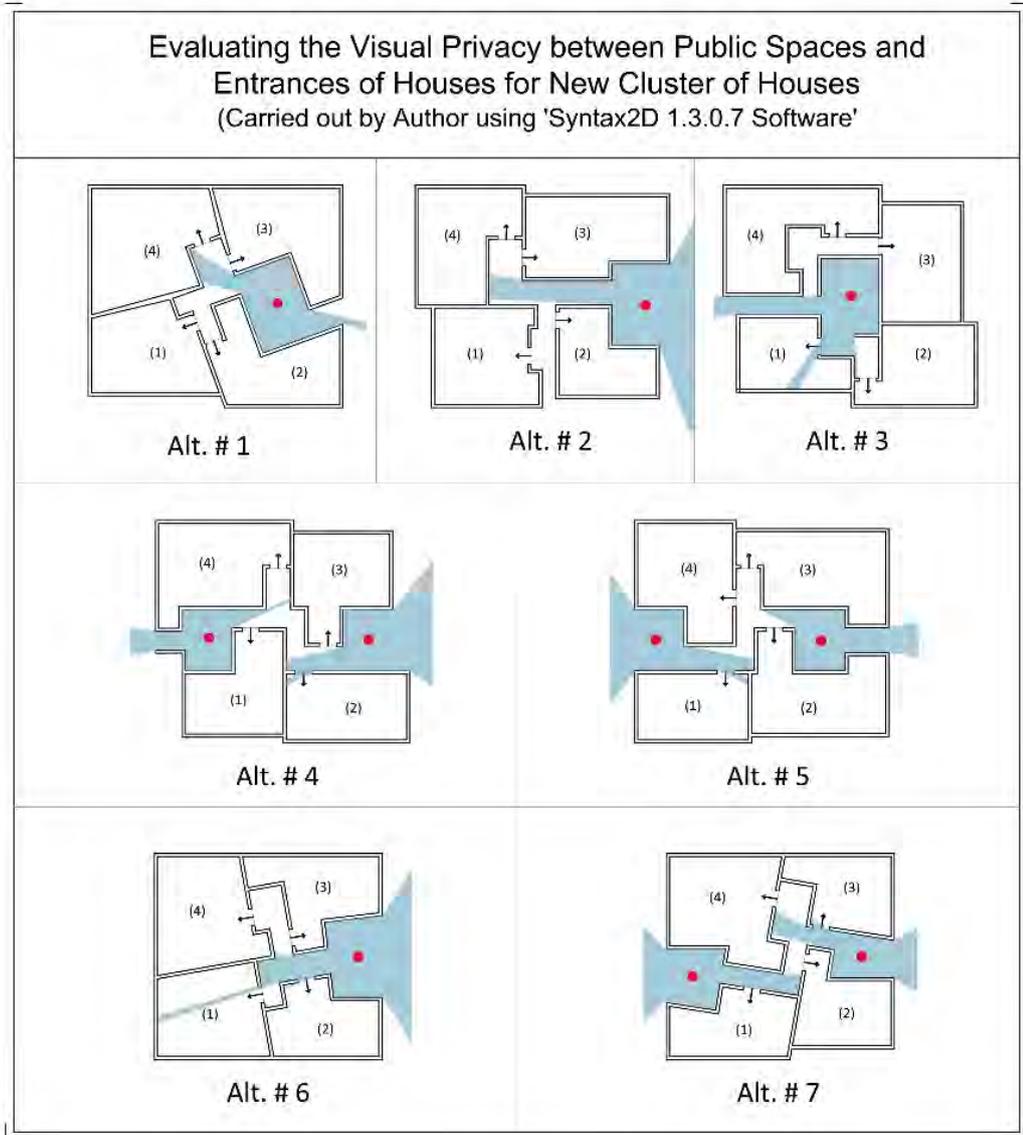
New solutions for clusters of houses generated by the constructed grammar

Visibility Graph Analysis (VGA) for New Cluster of Houses  
(Carried out by Author using 'DepthMapX 0.50 Software')



| Alternative No. | Layout | Connectivity Analysis | Agent Analysis<br>(Pattern of movement and frequent use of spaces, released from the public gathering space) |
|-----------------|--------|-----------------------|--|
| Alt. 1          |        |                       |  |
| Alt. 2          |        |                       |  |
| Alt. 3          |        |                       |  |
| Alt. 4          |        |                       |  |
| Alt. 5          |        |                       |  |
| Alt. 6          |        |                       |  |
| Alt. 7          |        |                       |  |

Visibility graph analysis for the new solutions showing connectivity values for common spaces (Produced by the Researcher, using DepthmapX software)



Appendix (5-B-1)

**Parametric Relationships between Social Sustainability  
and Elements of Design in Residential Buildings**

# Parameters controlling the Design of Main Elements in Residential Buildings, and How they affect Qualities of Social Sustainability

## 1. Public/Open Spaces

|   |  |
|---|--|
| <p>1.1. Area of the Entry Hall relative to the Area of the Ground Floor</p> <p>3% — Social Interaction — + — Density and Crowding — - — Accessibility — +</p>                       | <p>1.2. Area of the Vertical Circulation Core relative to the Area of the Ground Floor</p> <p>5% — Accessibility — + — Density and Crowding — -</p>  |
| <p>1.3. Area of the Main Public Space relative to the Area of the Ground Floor</p> <p>5% — Social Interaction — + — Density and Crowding — - — Human Comfort — +</p>                | <p>1.4. Area of Private Courtyards relative to the Area of the Apartment</p> <p>18% — Social Interaction — + — Density and Crowding — - — Human Comfort — +</p>  |
| <p>1.5. Width of Main Public Spaces</p> <p>5.85 m — Social Interaction — + — Density and Crowding — - — Human Comfort — + — Safety and Security for the Family and Children — -</p> | <p>1.6. Width of Semi-Private Open Spaces</p> <p>2.25 m — Social Interaction — + — Density and Crowding — - — Human Comfort — + — Safety and Security for the Family and Children — - — Visual Privacy — +</p> |

## 2. Configuration of Residential Units

|   |   |
|---|---|
| <p>2.1. Thickness of Shared Walls between Adjacent Apartments</p> <p>30 cm — Acoustical Privacy — +</p> | <p>2.2. Number of Floors surrounding Open Spaces</p> <p>1 Floors — Visual Privacy — - — Safety and Security — + — Thermal Comfort — +</p> |
|---|---|

## 3. Circulation Pattern

|   |   |
|---|---|
| <p>3.1. Width of Alleys between Apartments</p> <p>1.15 m — Social Interaction — + — Density and Crowding — - — Human Comfort — - — Safety and Security for the Family and Children — + — Visual Privacy — + — Accessibility — +</p> | <p>3.2. Changes in Directions between Public Spaces, Alleys, &amp; Entrances of Apartments</p> <p>0° — Visual Privacy — + — Accessibility — - — Human Comfort — +</p> |
|---|---|

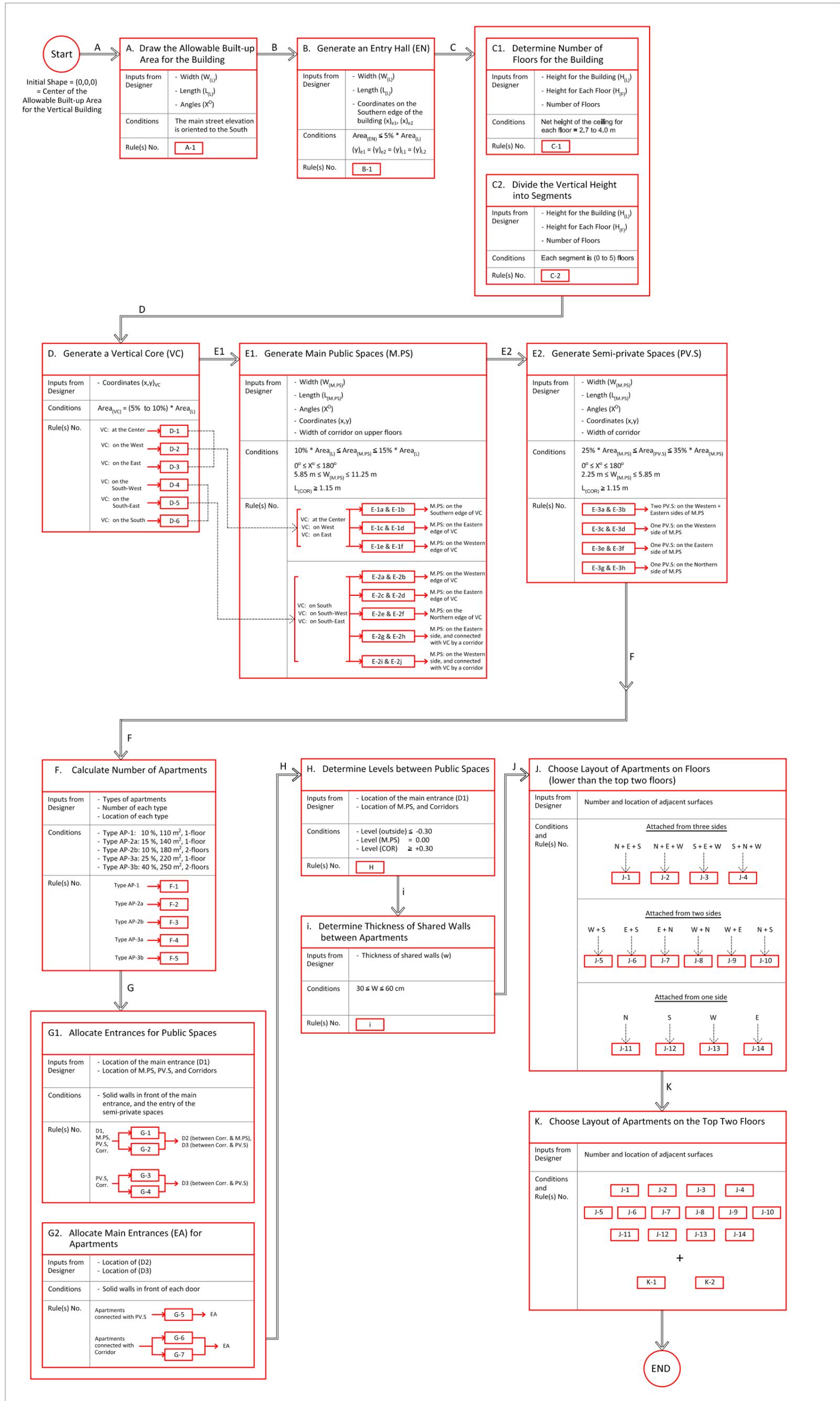
## 4. Arrangement of Entrances for Apartments

|   |   |
|---|---|
| <p>4.1. Location of Entrances</p> <p>connected with Main Public Spaces — Safety and Security for the Family and Children — - — Visual Privacy — +</p> <p>connected with Alleys, Semi-private Open Spaces — Safety and Security for the Family and Children — + — Visual Privacy — -</p> | <p>4.2. Angle between opposite Entrances</p> <p>0° — Visual Privacy — +</p> <p>90° — Visual Privacy — -</p> |
| <p>4.3. Spatial Elements opposite to Entrances</p> <p>Door — Visual Privacy — -</p> <p>Solid Wall / High Window Sill — Visual Privacy — +</p>   |   |

Appendix (5-B-2)

**Groups of Parametric Rules for generating  
a High-rise Residential Building**

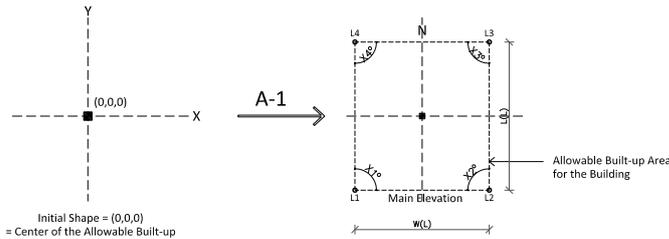
# Groups of Parametric Rules for Generating a High-rise Residential Building



Appendix (5-B-3)

**New Solutions for Clusters of Houses  
generated by the Constructed Grammar**

### Stage (A): Rules for Generating the Allowable Built-up Area for the Building

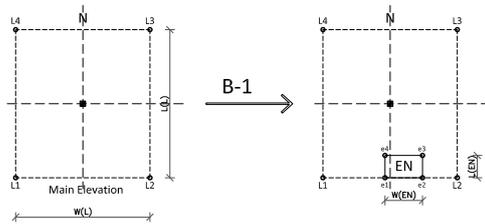


#### Design Parameters:

$$0^\circ \leq X^\circ \leq 180^\circ$$

Main Elevation is oriented to the South

### Stage (B): Rules for the Configuration of an Entry Hall (EN)



#### Design Parameters:

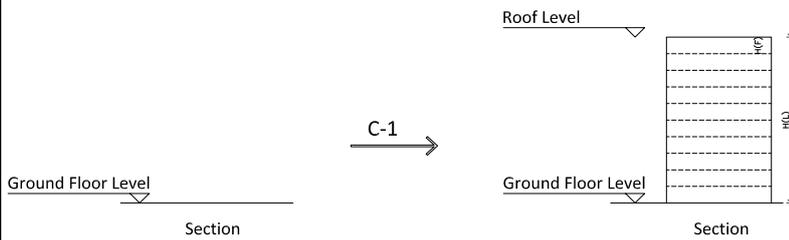
$$(y)_{e1} = (y)_{e2} = (y)_{L1} = (y)_{L2}$$

$$(x)_{L1} \leq (x)_{e1} \leq ((x)_{L2} - W_{(EN)})$$

$$W_{(EN)} \leq W_{(L)}$$

$$\text{Area}_{(EN)} \leq 5\% * \text{Area}_{(L)}$$

### Stage (C): Rules for Dividing the Vertical Building into Segments

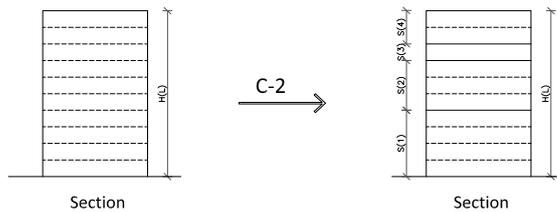


H(L): Allowable Height for the Building  
(which depends on building regulations)

H(F): is the height for each floor

$$H(L) \leq (\text{Number of Floors} * H(F))$$

$$H(F) = (2.7 \text{ to } 4.0 \text{ m}) + \text{Thickness of Slab for each Floor}$$

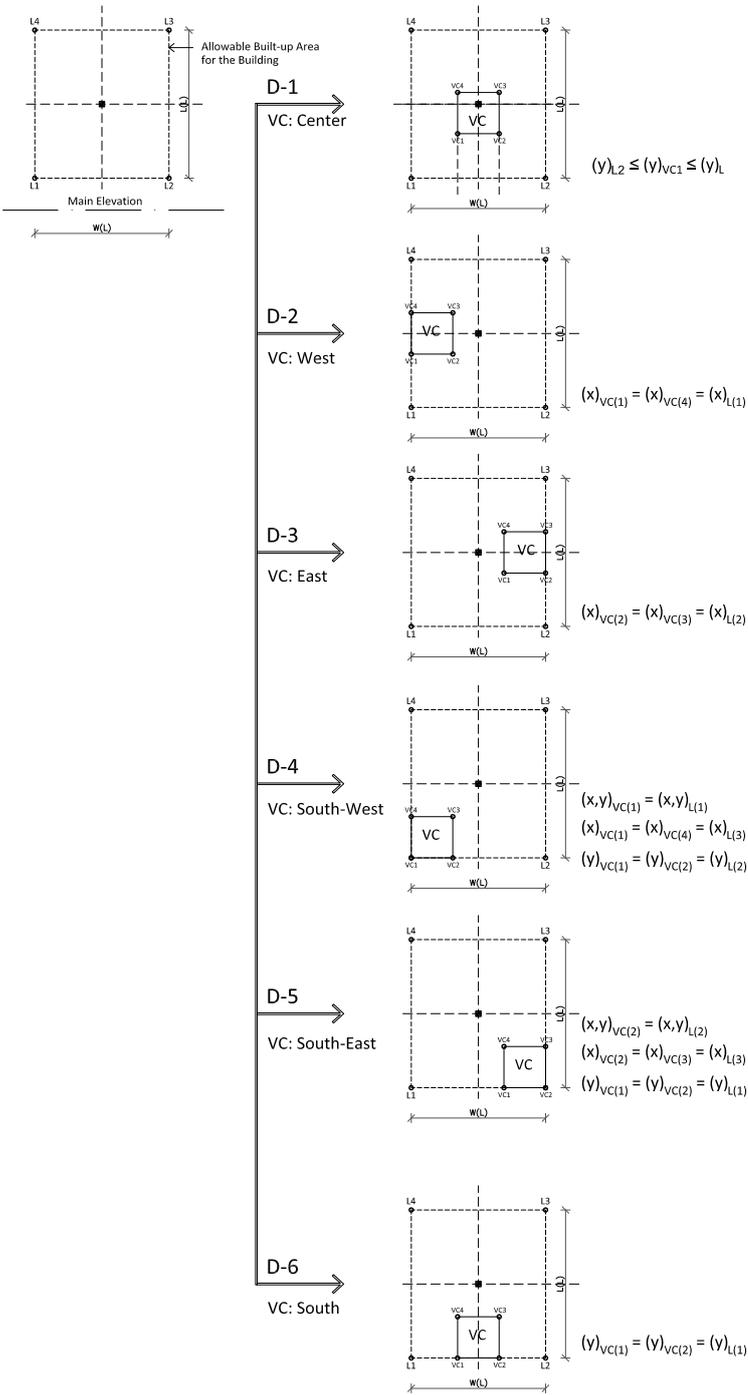


S(n) is a vertical segment, which consists of (0 to 5) floors

## Stage (D): Rules for the Configuration of a Vertical Core

Vertical Core (VC) includes: Elevator, Staircase, and Mechanical Ducts

$$5\% * Area_{(L)} \leq Area_{(VC)} \leq 10\% * Area_{(L)}$$



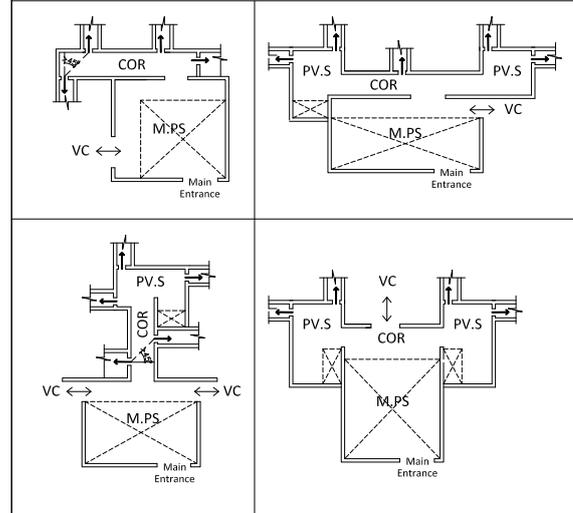
## Stage (E): Rules for the Configuration of Public Spaces for the Building

### Descriptions:

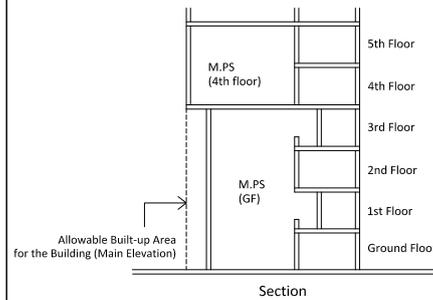
- There is a Hierarchy for the Configuration of Public Spaces on Each Floor
- Public Spaces include:
  - M.P.S: A Main Gathering Area (connected with the vertical circulation and/or the main entrance for the building)
  - PV.S: A Semi-Private Space (connected with the entrance of each Apartment)
  - COR: Corridors (connecting the M.P.S with PV.S). Houses could be directly connected with corridors.

$$10\% * Area_{(L)} \leq Area_{(M.P.S)} \leq 15\% * Area_{(L)}$$

Samples for topological relationships between public spaces and apartments

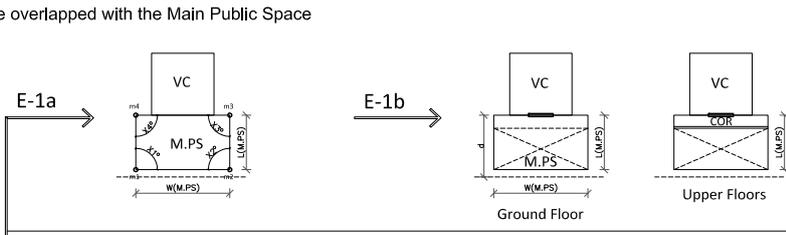
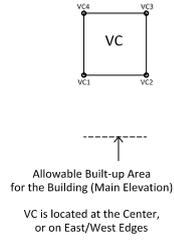


- M.P.S is 1 to 5 storey atrium.
- PVS is 1 to 5 storey atrium.
- Dimensions of MPS and PVS on upper segments could be changed.

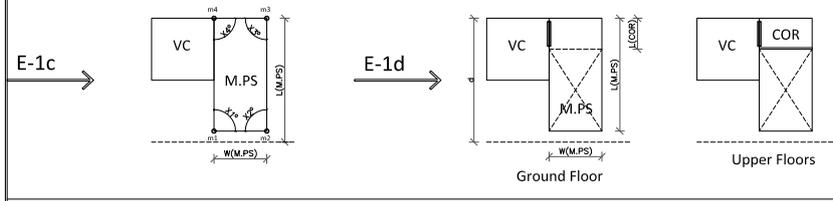


# Rules for Generating Main Public Space (M.P.S)

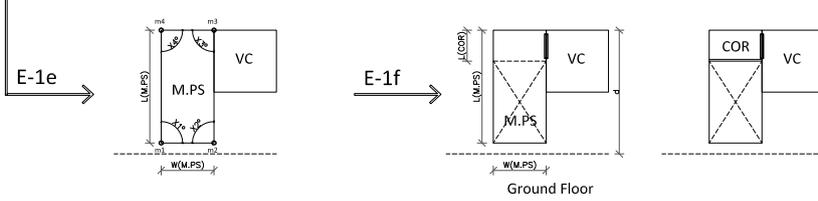
\* The Entry Hall could be overlapped with the Main Public Space



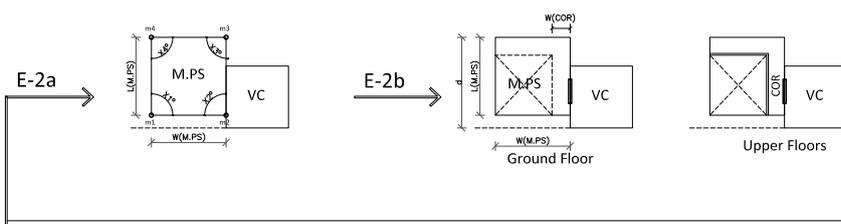
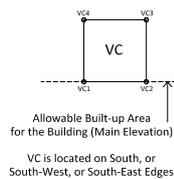
$0^\circ \leq X^\circ \leq 180^\circ$   
 $5.85 \text{ m} \leq W_{(M.P.S)} \leq 11.25 \text{ m}$   
 $(y)_{VC(1)} = (y)_{VC(2)} = (y)_{m4} = (y)_{m3}$   
 $(y)_{L2} \leq (y)_{m2} < (y)_{VC2}$   
 $L_{(M.P.S)} \leq d$   
 On upper floors:  
 $L_{(COR)} \geq 1.15 \text{ m}$



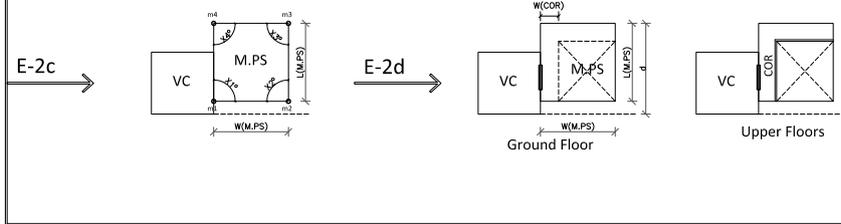
$0^\circ \leq X^\circ \leq 180^\circ$   
 $5.85 \text{ m} \leq W_{(M.P.S)} \leq 11.25 \text{ m}$   
 $(x)_{m1} = (x)_{VC(2)} = (x)_{m4}$   
 $(y)_{L2} \leq (y)_{m2} \leq (y)_{VC2}$   
 $L_{(M.P.S)} \leq d$   
 On upper floors:  
 $L_{(COR)} \geq 1.15 \text{ m}$



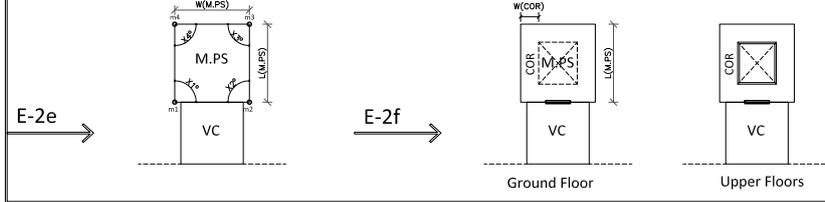
$0^\circ \leq X^\circ \leq 180^\circ$   
 $5.85 \text{ m} \leq W_{(M.P.S)} \leq 11.25 \text{ m}$   
 $(x)_{m2} = (x)_{VC(1)} = (x)_{m3}$   
 $(y)_{L2} \leq (y)_{m2} \leq (y)_{VC1}$   
 $L_{(M.P.S)} \leq d$   
 On upper floors:  
 $L_{(COR)} \geq 1.15 \text{ m}$



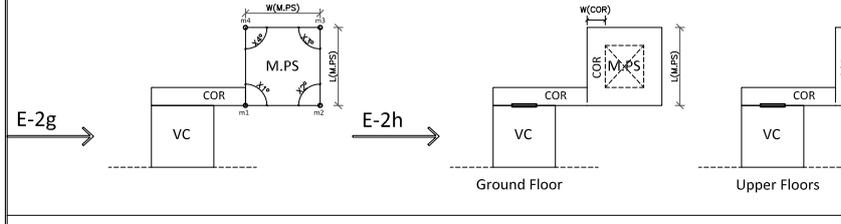
$0^\circ \leq X^\circ \leq 180^\circ$   
 $5.85 \text{ m} \leq W_{(M.P.S)} \leq 11.25 \text{ m}$   
 $(x)_{m2} = (x)_{VC(1)} = (x)_{m3}$   
 $(y)_{L2} \leq (y)_{m2} \leq (y)_{VC}$   
 $L_{(M.P.S)} \leq d$   
 On upper floors:  
 $L_{(COR)} \geq 1.15 \text{ m}$   
 $W_{(COR)} \geq 1.15 \text{ m}$



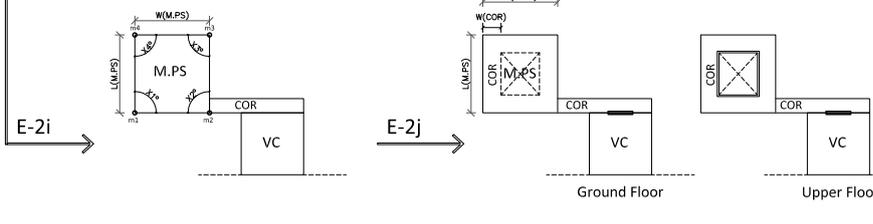
$0^\circ \leq X^\circ \leq 180^\circ$   
 $5.85 \text{ m} \leq W_{(M.P.S)} \leq 11.25 \text{ m}$   
 $(x)_{m1} = (x)_{VC(2)} = (x)_{m4}$   
 $(y)_{L2} \leq (y)_{m2} \leq (y)_{VC}$   
 $L_{(M.P.S)} \leq d$   
 On upper floors:  
 $L_{(COR)} \geq 1.15 \text{ m}$   
 $W_{(COR)} \geq 1.15 \text{ m}$



$0^\circ \leq X^\circ \leq 180^\circ$   
 $5.85 \text{ m} \leq W_{(M.P.S)} \leq 11.25 \text{ m}$   
 $(y)_{m1} = (x)_{VC(3)} = (y)_{m2}$   
 On upper floors:  
 $L_{(COR)} \geq 1.15 \text{ m}$   
 $W_{(COR)} \geq 1.15 \text{ m}$

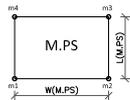


$0^\circ \leq X^\circ \leq 180^\circ$   
 $5.85 \text{ m} \leq W_{(M.P.S)} \leq 11.25 \text{ m}$   
 $(x)_{VC(3)} \leq (x)_{m1}$   
 $(y)_{VC(3)} = (y)_{VC(4)} = (y)_{m1} = (y)_{m2}$   
 On upper floors:  
 $L_{(COR)} \geq 1.15 \text{ m}$   
 $W_{(COR)} \geq 1.15 \text{ m}$

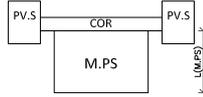


$0^\circ \leq X^\circ \leq 180^\circ$   
 $5.85 \text{ m} \leq W_{(M.P.S)} \leq 11.25 \text{ m}$   
 $(x)_{m2} \leq (x)_{VC(4)}$   
 $(y)_{VC(3)} = (y)_{VC(4)} = (y)_{m1} = (y)_{m2}$   
 On upper floors:  
 $L_{(COR)} \geq 1.15 \text{ m}$   
 $Width_{(COR)} \geq 1.15 \text{ m}$

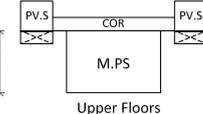
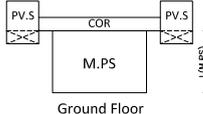
## Rules for Generating Semi-Private Spaces (PV.S)



E-3a

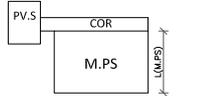


E-3b

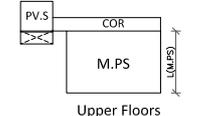
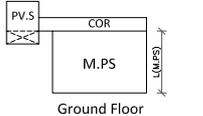


$0^\circ \leq X^\circ \leq 180^\circ$   
 $2.25 \text{ m} \leq W_{(PV.S)} \leq 5.85 \text{ m}$   
 $25\% * \text{Area}_{(M.P.S)} \leq \text{Area}_{(PV.S)} = 35\% * \text{Area}_{(M.P.S)}$   
 $\text{Width}_{(COR)} \geq 1.15 \text{ m}$   
 $(x,y)_{COR,1} = (x,y)_{m4}$   
 $(x,y)_{COR,2} = (x,y)_{m3}$

E-3c

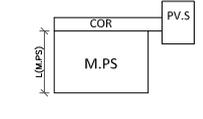


E-3d

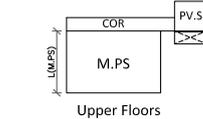
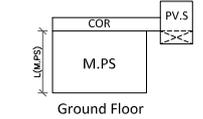


$0^\circ \leq X^\circ \leq 180^\circ$   
 $2.25 \text{ m} \leq W_{(PV.S)} \leq 5.85 \text{ m}$   
 $25\% * \text{Area}_{(M.P.S)} \leq \text{Area}_{(PV.S)} = 35\% * \text{Area}_{(M.P.S)}$   
 $\text{Width}_{(COR)} \geq 1.15 \text{ m}$   
 $(x,y)_{COR,1} = (x,y)_{m4}$   
 $(x,y)_{COR,2} = (x,y)_{m3}$

E-3e

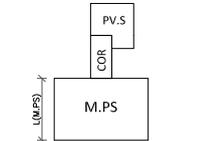


E-3f

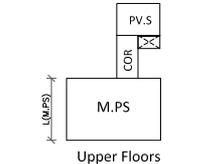
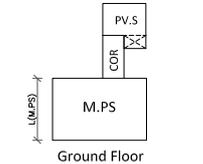


$0^\circ \leq X^\circ \leq 180^\circ$   
 $2.25 \text{ m} \leq W_{(PV.S)} \leq 5.85 \text{ m}$   
 $25\% * \text{Area}_{(M.P.S)} \leq \text{Area}_{(PV.S)} = 35\% * \text{Area}_{(M.P.S)}$   
 $\text{Width}_{(COR)} \geq 1.15 \text{ m}$   
 $(x,y)_{COR,1} = (x,y)_{m4}$   
 $(x,y)_{COR,2} = (x,y)_{m3}$

E-3g



E-3h



$0^\circ \leq X^\circ \leq 180^\circ$   
 $2.25 \text{ m} \leq W_{(PV.S)} \leq 5.85 \text{ m}$   
 $25\% * \text{Area}_{(M.P.S)} \leq \text{Area}_{(PV.S)} = 35\% * \text{Area}_{(M.P.S)}$   
 $\text{Width}_{(COR)} \geq 1.15 \text{ m}$   
 $(y)_{m4} \leq (y)_{COR,1} \leq (y)_{m3}$

## Stage (F): Calculate Number of Apartments

### Descriptions:

There are five types of apartments that could be distributed according to the following percentages:

| Type         | Number of Floors | Total Area               | Area of Each Floor       | % from the Total Number of Apartments | Number of Family Members |
|--------------|------------------|--------------------------|--------------------------|---------------------------------------|--------------------------|
| Type (AP-1)  | Single Floor     | 100 - 110 m <sup>2</sup> | 100 - 110 m <sup>2</sup> | 10 %                                  | 2 - 4                    |
| Type (AP-2a) | Single Floor     | 110 - 140 m <sup>2</sup> | 110 - 140 m <sup>2</sup> | 15 %                                  | 2 - 4                    |
| Type (AP-2b) | Two Floors       | 140 - 180 m <sup>2</sup> | 70 - 90 m <sup>2</sup>   | 10 %                                  | 4 - 6                    |
| Type (AP-3a) | Single Floor     | 180 - 220 m <sup>2</sup> | 180 - 220 m <sup>2</sup> | 25 %                                  | 4 - 6                    |
| Type (AP-3b) | Two Floors       | 220 - 250 m <sup>2</sup> | 110 - 125 m <sup>2</sup> | 40 %                                  | 5 - 8                    |

The maximum number of apartments on each floor is: Five apartments, which could be from the same type, or different types

$$\text{Area of Apartments} = \left( \text{Allowable Built-up Area for the Building} - \text{Area of Vertical Circulation} - \text{Area of Public Spaces and Corridors} \right) * \text{Number of Floors}$$

Rule F-1

$$\begin{aligned} \text{Total Area of (Type AP-1)} &= \text{Area of Apartments} * 10\% \\ \text{Number of Apartments (Type AP-1)} &= \frac{\text{Total Area of (Type AP-1)}}{110} \end{aligned}$$

Rule F-2

$$\begin{aligned} \text{Total Area of (Type AP-2a)} &= \text{Area of Apartments} * 15\% \\ \text{Number of Apartments (Type AP-2a)} &= \frac{\text{Total Area of (Type AP-2a)}}{140} \end{aligned}$$

Rule F-3

$$\begin{aligned} \text{Total Area of (Type AP-2b)} &= \text{Area of Apartments} * 10\% \\ \text{Number of Apartments (Type AP-2b)} &= \frac{\text{Total Area of (Type AP-2b)}}{180} \end{aligned}$$

Rule F-4

$$\begin{aligned} \text{Total Area of (Type AP-3a)} &= \text{Area of Apartments} * 25\% \\ \text{Number of Apartments (Type AP-3a)} &= \frac{\text{Total Area of (Type AP-3a)}}{220} \end{aligned}$$

Rule F-5

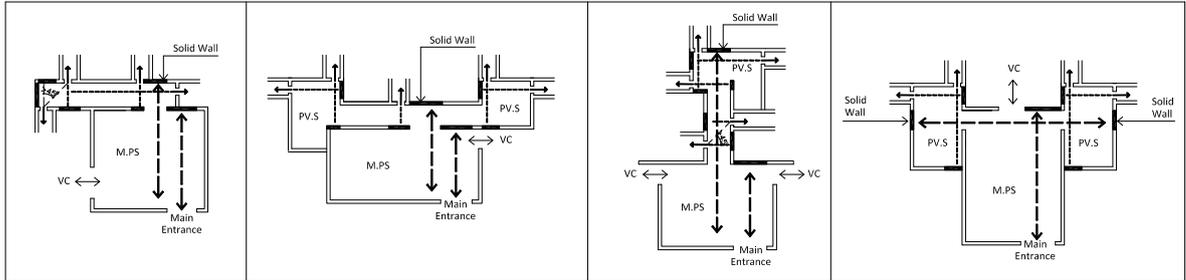
$$\begin{aligned} \text{Total Area of (Type AP-3b)} &= \text{Area of Apartments} * 40\% \\ \text{Number of Apartments (Type AP-3b)} &= \frac{\text{Total Area of (Type AP-3b)}}{250} \end{aligned}$$

## Stage (G): Rules for Allocating Entrances on the Same Floor

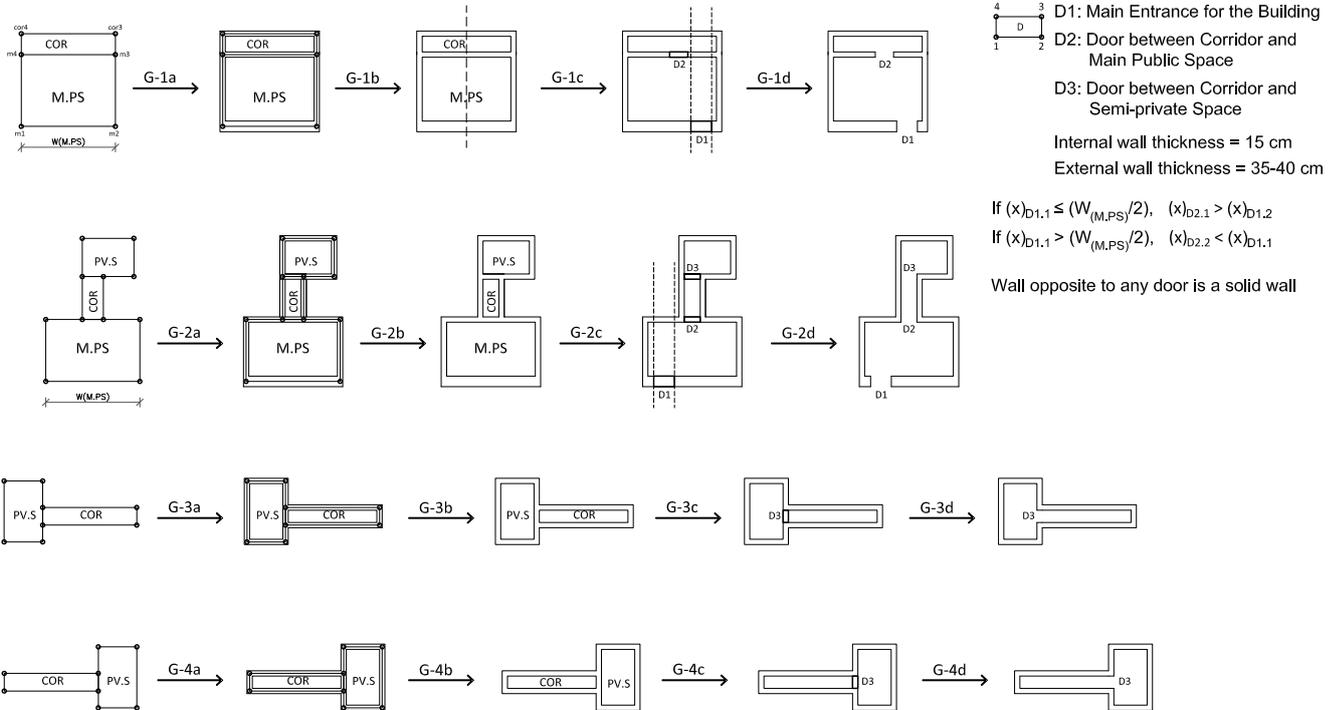
### Descriptions:

- Walls in front of main entrances are solid walls.
- Walls in front of the entry of the semi-private spaces are solid walls.
- Apartments are connected with corridors or semi-private spaces.
- Entrances for apartments are not connected with the main public space.
- Wall that is directly located in front of the entrance of any apartment is a solid wall.

### Strategies for achieving Visual Privacy



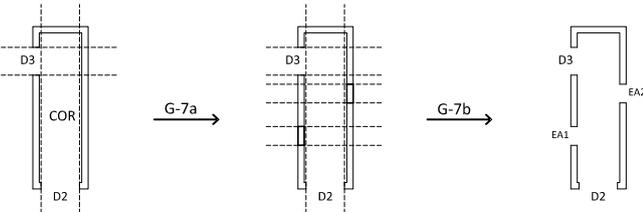
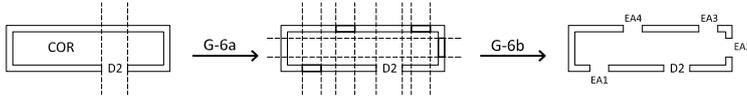
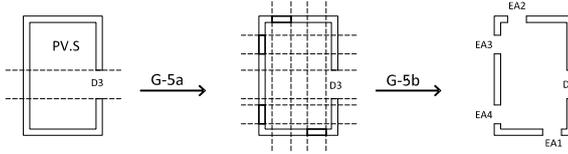
## G1: Rules for Allocating Openings between Public Spaces



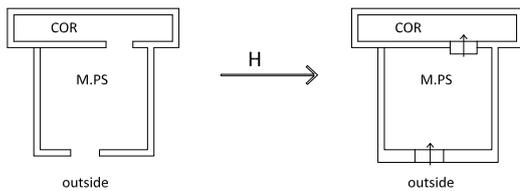
## G2: Rules for Allocating Main Entrances (EA) for Apartments

- Wall opposite to any door is a solid wall
- Number of doors depends on the number of apartments

D1: Main Entrance for the Building  
 D2: Door between Corridor and Main Public Space  
 D3: Door between Corridor and Semi-private Space  
 EA: Main Entrance for the Apartment



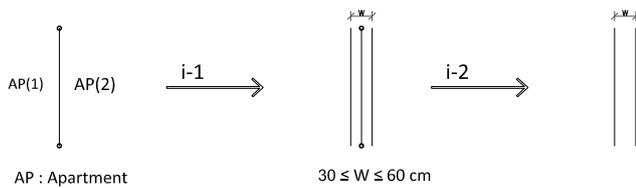
## Stage (H): Rules for Achieving Hygiene between Public Spaces and Apartments



Level (outside)  $\leq -0.30$   
 Level (M.P.S) = 0.00  
 Level (COR)  $\geq +0.30$

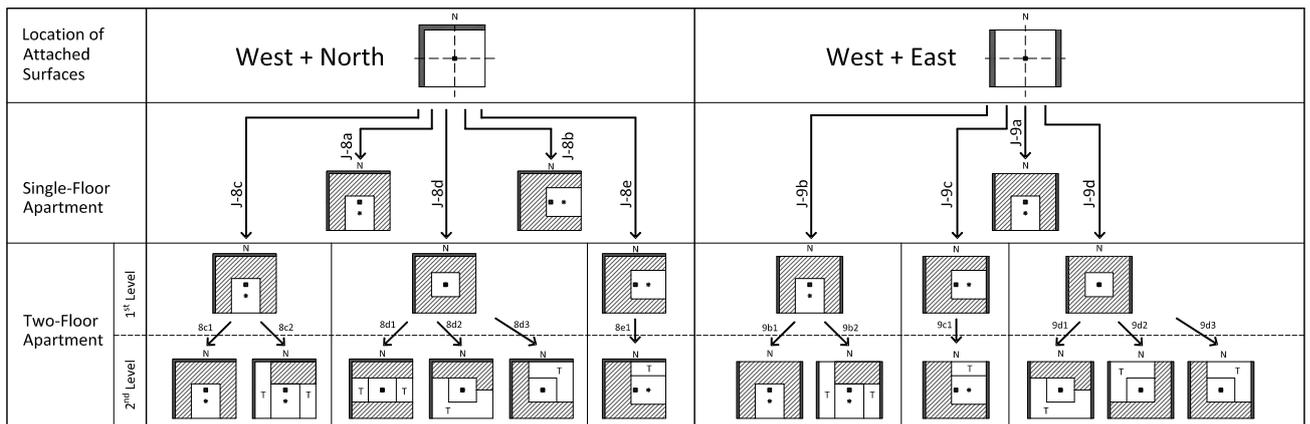
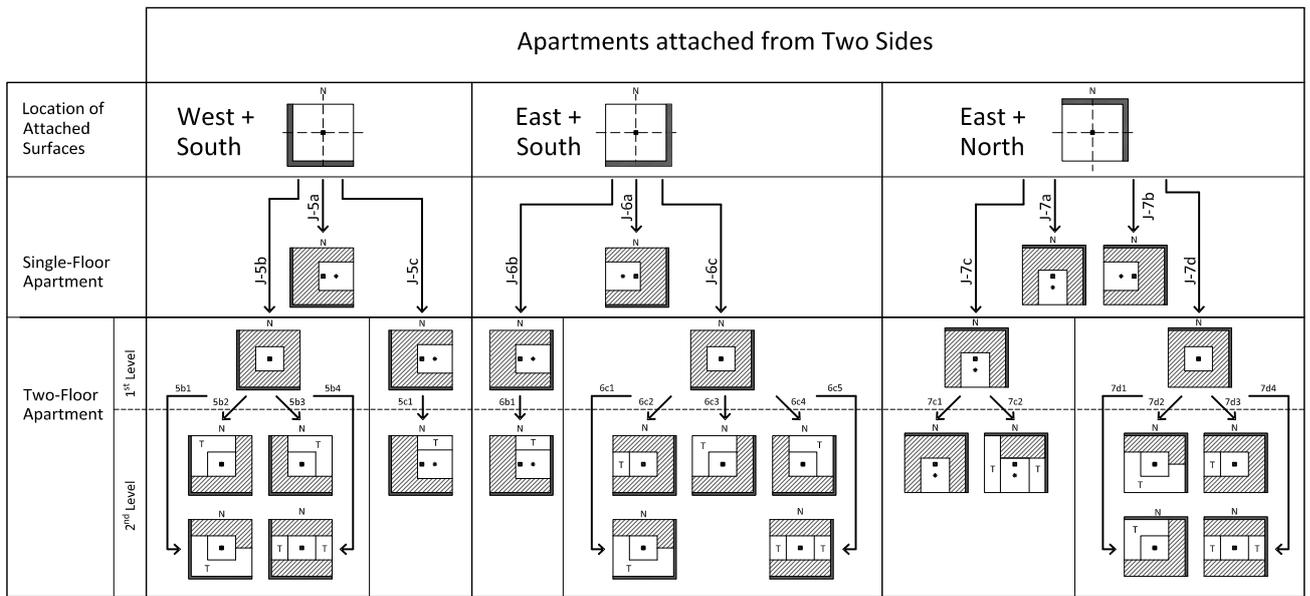
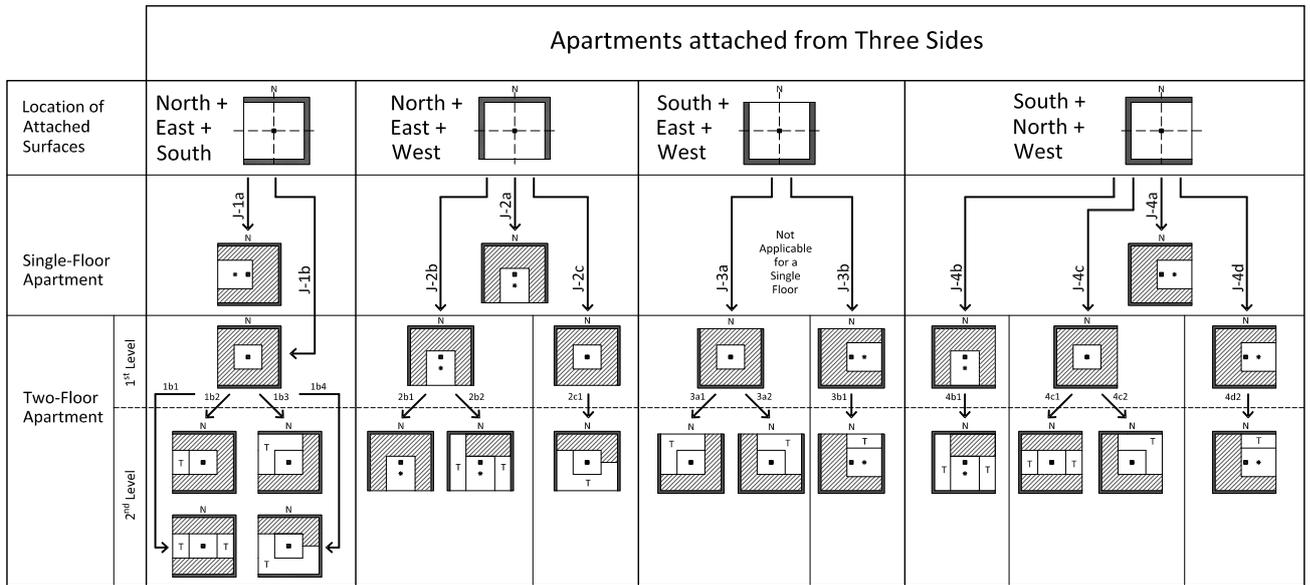
## Stage (i): Rules for Achieving Acoustic Privacy between Apartments

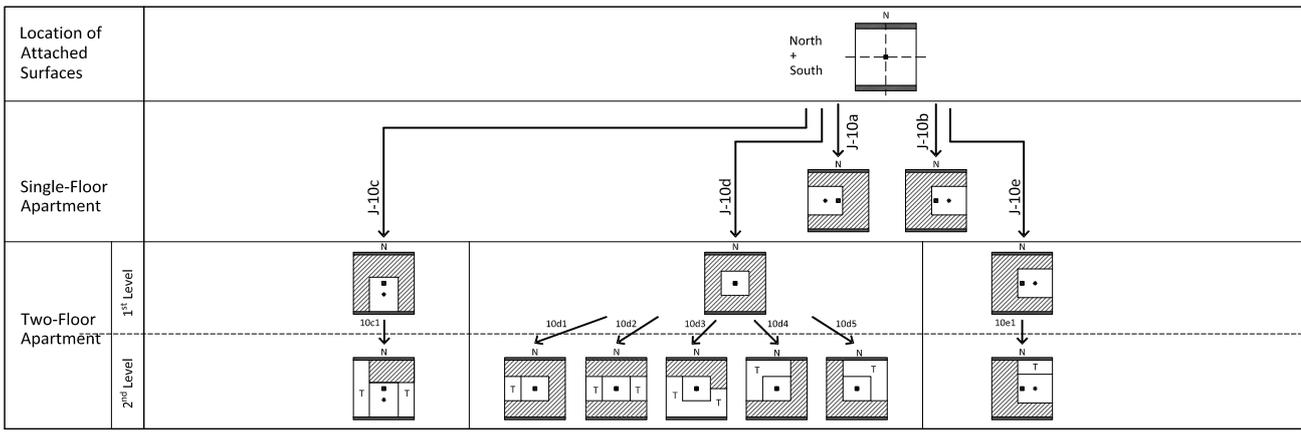
### Shared Wall between Apartments



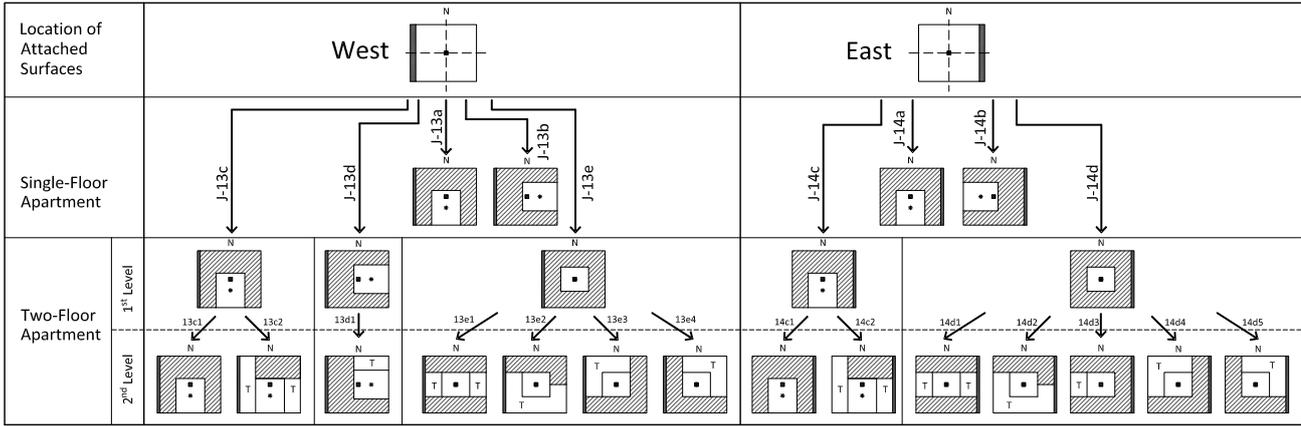
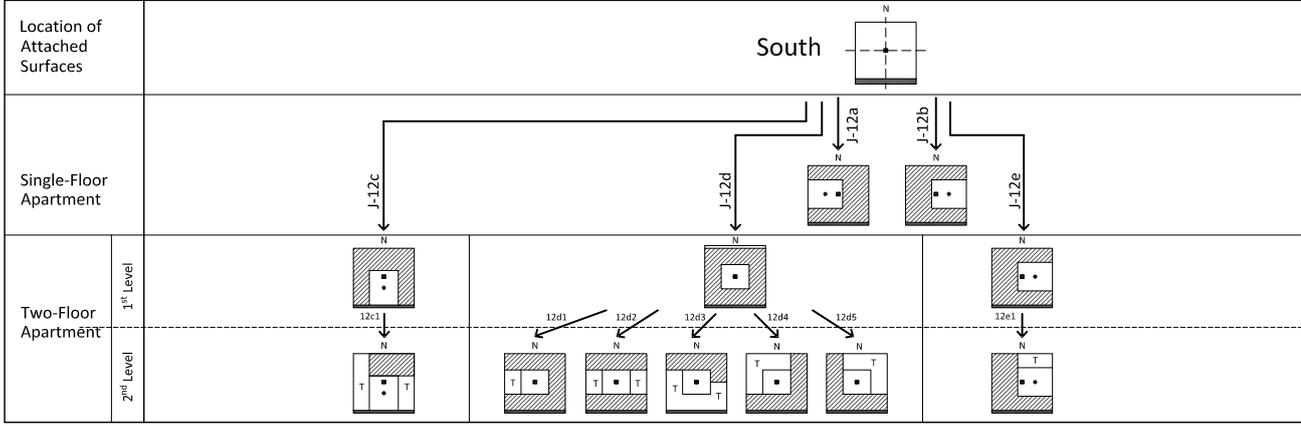
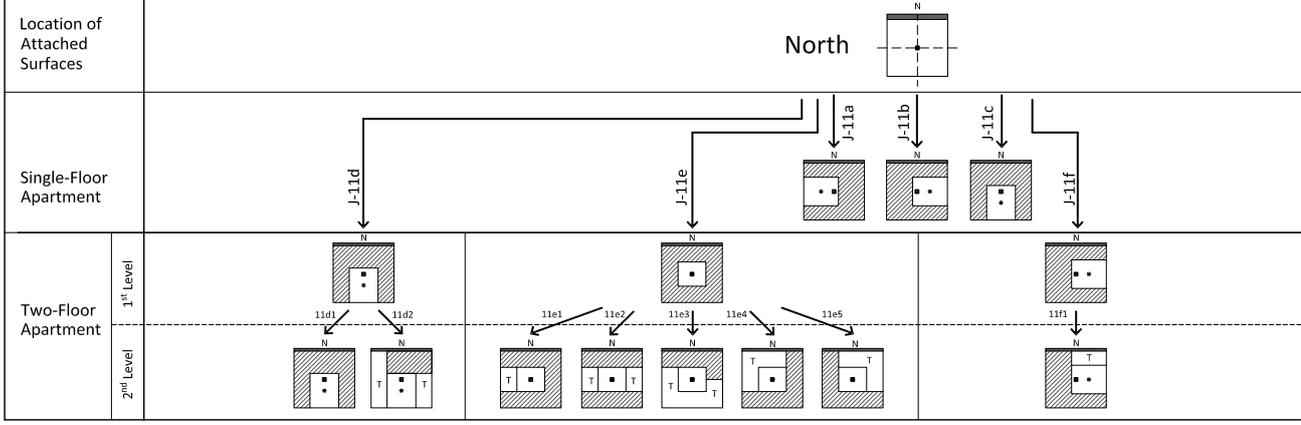
**Stage (J):** Rules showing Layout of Apartments that are located on Floors lower than the Top Two Floors

Typologies of Apartments (based on number and location of shared surfaces with adjacent apartments)





**Apartments attached from One Side**

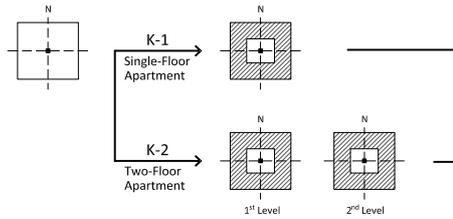


**Stage (K):** Rules showing Layout of Apartments that are located on the Top Two Floors

Prototypes for apartments that are located on the top two floors

| Prototypes for the Layout of the 1st Level | For MC-S                            |                                | For MC-C                          |                                   |                                   |                                     |                                   |                                   | For MC-E                         |
|--|-------------------------------------|--------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-------------------------------------|-----------------------------------|-----------------------------------|----------------------------------|
|  |                                     |                                |                                   |                                   |                                   |                                     |                                   |                                   |                                  |
| Prototypes for the Layout of the 2nd Level | Type S1<br>U-shape<br>(N+E+W sides) | Type S2<br>I-shape<br>(N side) | Type C1<br>O-shape<br>(All sides) | Type C2<br>L-shape<br>(S+E sides) | Type C3<br>L-shape<br>(S+W sides) | Type C4<br>U-shape<br>(N+E+S sides) | Type C5<br>I-shape<br>(N+S sides) | Type C6<br>L-shape<br>(N+E sides) | Type E<br>L-shape<br>(S+W sides) |

All rules that are illustrated in Stage (J) (with the same conditions), in addition to the following rules (K-1, K-2), are applicable for the top two floors.



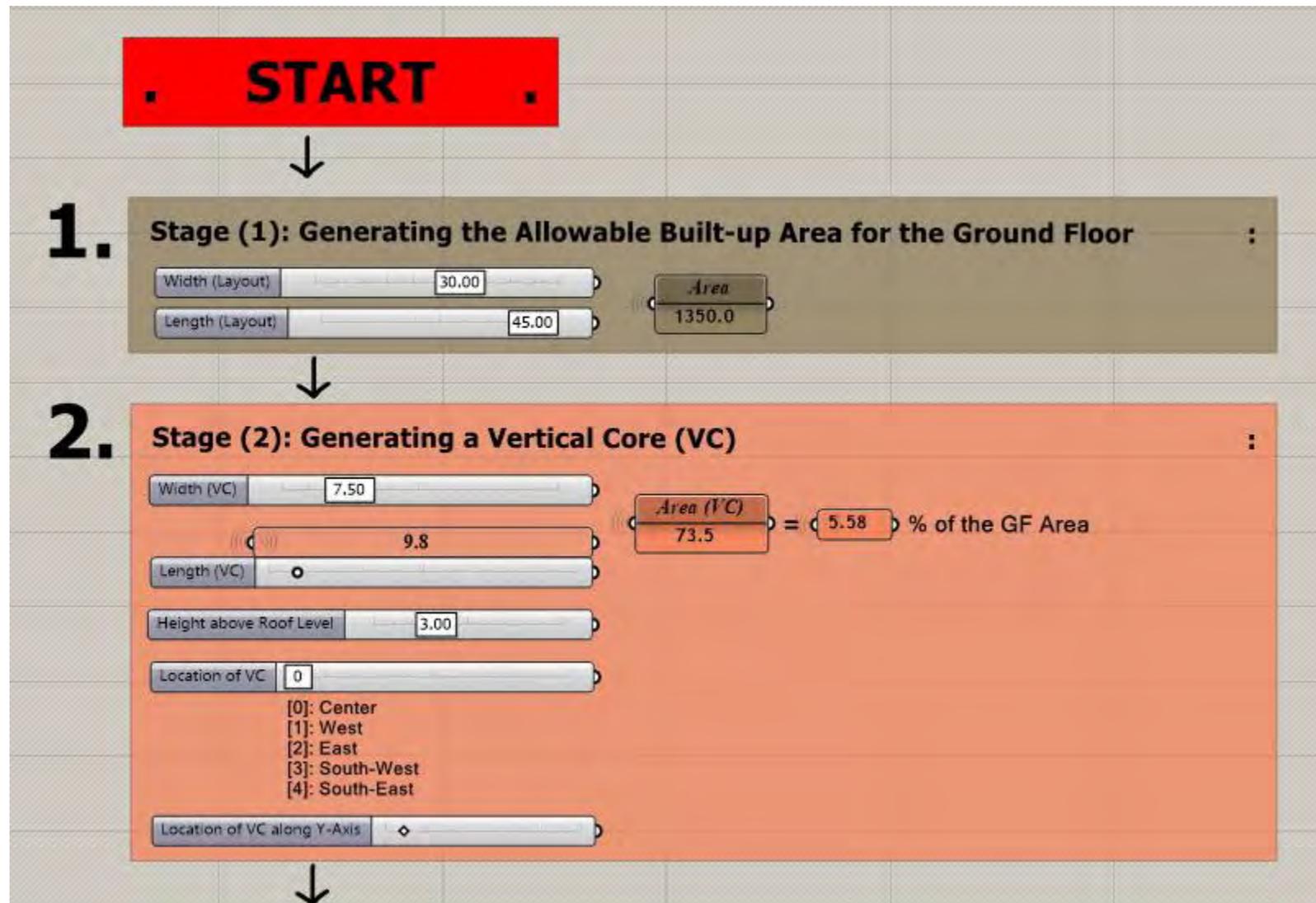
When these rules are applied, NO additional floors could be added above the roof of the apartment.

Appendix (5-B-4)

**Screenshots for Components of the Computational  
Model for the Generation of Socially-Sustainable  
High-rise Buildings, using Rhino/Grasshopper**



A screenshot showing the overall interface for the user for design a high-rise residential building



A screenshot showing inputs to be selected by the user for stages (1 and 2)

**3. Stage (3): Generating the Main Entry Hall (EN)**

Width (EN)    =  % of the GF Area

Length (EN)

Location

If VC is at Center, or East, or West

If VC is on SW, or SE

---

**4. Stage (4): Generating the Main Public Space (MPS) on the Ground Floor**

Width (MPS)    =  % of the Floor Area

Length (MPS)

Location of MPS

[0]: West  
 [1]: East  
 [2]: South-West  
 [3]: South-East  
 [4]: South  
 [5]: North-West  
 [6]: North-East

Location of MPS(East/West) along Y-Axis

Location of MPS(South) along Y-Axis

Location of MPS(South/North) along X-Axis

A screenshot showing inputs to be selected by the user for stages (3 and 4)

**5. Stage (5): Generating a Grid of Structural Columns**

Width & Length of Columns: 0.4

Distances (in meters) between Columns (X-Axis): 5.00

Distances (in meters) between Columns (Y-Axis): 5.00

↓

**6. Stage (6): Generating Corridors on Ground Floor connecting EN, VC, and MPS :**

**6.1. : Corridor along Y-Axis (COR.Y)**

COR. (Y-Axis): 4

[0]: Not Applicable  
 [1]: Connecting VC & the Eastern Side of the MPS  
 [2]: Connecting VC & the Western Side of the MPS  
 [3]: Connecting VC & the Southern Side of the MPS

Location (COR.Y) for Case [3]: [0]

Location (COR.Y) for Case [4]: [0]

Location (COR.Y) for Case [5]: [0]

Location (COR.Y) for Case [6]: [0]

[4]: Connecting VC & EN  
 [5]: Connecting EN & the SE Side of the MPS  
 [6]: Connecting EN & the SW Side of the MPS

Width of (COR.Y): 1.94

**6.2. : Corridor along X-Axis (COR.X)**

Connected with EN: 2

[0]: Not Applicable  
 [1] or [4]: on East  
 [2] or [3]: on West

Connected with MPS: 0

[0]: Not Applicable  
 [1] or [4]: on East  
 [2] or [3]: on West

Width of (COR.X): 2.14

A screenshot showing inputs to be selected by the user for stages (5 and 6)

## 7. Stage (7): Generating Floors

### Stage (7-1): Generating Floors (for the Ground Floor and the 1st Segment of the Building)

Thickness of Slab for All Floors

Height of GF

No. of Floors above GF (1st Segment)

Height of Each Floor for the (1st Segment)

Facades connected with MPS (on the GF)  [0]: East, or West

Facades connected with MPS (1st Segment)  [1]: East and South, or West and South  
[2]: East, South, and West  
[3]: South-East corner, or South-West corner

1st Segment  
(including GF)

### Stage (7-2): Generating Floors (for the 2nd Segment of the Building)

No. of Floors (2nd Segment)

Height of Each Floor (2nd Segment)

% of MPS Length relative to the Length of (MPS) on the 1st Segment  100% 80%

% of Void Length relative to the Length of (MPS) on the 2nd Segment  Max = 50%

Facades connected with MPS (2nd Segment)  [0]: East, or West  
[1]: East and South, or West and South  
[2]: East, South, and West  
[3]: South-East corner, or South-West corner

2nd Segment

Length of MPS =  
 meters

Length of Void =  
 meters

A screenshot showing inputs to be selected by the user for stage (7)

## Stage (8): Generating Semi-Private Spaces (PVS) between Residential Apartments

### Stage (G-1A): Corridors connected with PVS

**Corridor (along Y-Axis) connecting MPS & PVS**

COR.Y Connecting MPS & PVS:  [0]: Not Applicable [1] or [2]: West [3] or [4]: East

Width of (COR.Y):

---

**Corridor (along X-Axis) connected with PVS**

COR.X connected with PVS:  [0]: when MPS is located on N [1]: when MPS is located on E/W/S

Width of (COR.X):

Extension of COR.X (towards West) (for 1st, 3rd, and 5th Segments):

Extension of COR.X (towards East) (for 1st, 3rd, and 5th Segments):

Extension of COR.X (towards West) (for 2nd, 4th, and 6th Segments):

Extension of COR.X (towards East) (for 2nd, 4th, and 6th Segments):

---

**Corridor (along Y-Axis) connected with PVS**

Width of COR.Y:

Applicability on 1st, 3rd, and 5th Segments:  [0]: No [1]: Yes

Length of COR.Y (for 1st, 3rd, and 5th Segments):

Location of COR.Y (along X-Axis) (for 1st, 3rd, and 5th Segments):

Applicability on 2nd, 4th, and 6th Segments:  [0]: No [1]: Yes

Length of COR.Y (for 2nd, 4th, and 6th Segments):

Location of COR.Y (along X-Axis) (for 2nd, 4th, and 6th Segments):

Length of COR.Y (in meter) (for 1st, 3rd, 5th segments) =

Length of COR.Y (in meter) (for 2nd, 4th, 6th segments) =

### Stage (G-2A): Generating Semi-Private Spaces (PVS) (on GF, 1st, 3rd, and 5th Segments)

**Located on the Eastern Side of (COR.X)**

Applicability:  [0]: No [1]: Yes

Width:

Length:

---

**Located on the Western Side of (COR.X)**

Applicability:  [0]: No [1]: Yes

Width:

Length:

---

**Located on the Northern Side of (COR.X)**

Applicability:  [0]: No [1]: Yes

Width:

Length:

Location along X-Axis:

---

**Located on the Northern Side of (COR.Y)**

Applicability:  [0]: No [1]: Yes

Width:

Length:

Location along X-Axis:

### Stage (G-2B): Generating Semi-Private Spaces (PVS) (on 2nd, 4th, and 6th Segments)

**Located on the Eastern Side of (COR.X)**

Applicability:  [0]: No [1]: Yes

Width:

Length:

---

**Located on the Western Side of (COR.X)**

Applicability:  [0]: No [1]: Yes

Width:

Length:

---

**Located on the Northern Side of (COR.X)**

Applicability:  [0]: No [1]: Yes

Width:

Length:

Location along X-Axis:

---

**Located on the Northern Side of (COR.Y)**

Applicability:  [0]: No [1]: Yes

Width:

Length:

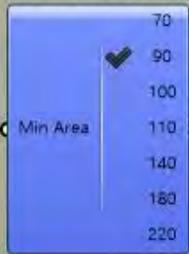
Location along X-Axis:

A screenshot showing inputs to be selected by the user for stage (8)

## 9. Stage (9): Generating the Layout of Residential Apartments :

### Stage (9-1a): Generating the Layout of Residential Apartments (on the Ground Floor)

Min. & Max. Area  
for Each Apartment  
on the Ground Floor



Select Position of  
Lines to divide  
Residential Units,  
OR  
Double-Click on  
the Pink Icon for  
Automatic  
Optimisation

#### Ground Floor

|                          |                      |
|--------------------------|----------------------|
| Position of Divider (S1) | <input type="text"/> |
| Position of Divider (S2) | <input type="text"/> |
| Position of Divider (N1) | <input type="text"/> |
| Position of Divider (N2) | <input type="text"/> |
| Position of Divider (E1) | <input type="text"/> |
| Position of Divider (E2) | <input type="text"/> |
| Position of Divider (W1) | <input type="text"/> |
| Position of Divider (W2) | <input type="text"/> |



A screenshot showing inputs to be selected by the user for stage (9)

# Ground Floor

## Stage (10-1a): Generating Courtyards for Each Apartment (on the Ground Floor)

Apartments located on the Western Side of the Layout

**Ground Floor: Apartment # (1-W)**

Location of Apartment # (1-W):

Not Applicable

Location of Courtyard:  [0]: No Courtyard  
[1]: on West  
[2]: on South  
[3]: at the Center

Width of Courtyard:

Length of Courtyard:

Position of Courtyard along X-Axis:

Position of Courtyard along Y-Axis:

Total Area of Apartment (# 1-W) =

Courtyard Area =  =  %

Area of Apartment (excluding Courtyard) =

Width of Rooms (surrounding the courtyard)

on West:  on East:

on North:  on South:

**Ground Floor: Apartment # (2-W)**

Location of Apartment # (2-W):

Not Applicable

Location of Courtyard:  [0]: No Courtyard  
[1]: on West  
[2]: on South  
[3]: at the Center

Width of Courtyard:

Length of Courtyard:

Position of Courtyard along X-Axis:

Position of Courtyard along Y-Axis:

Total Area of Apartment (# 2-W) =

Courtyard Area =  =  %

Area of Apartment (excluding Courtyard) =

Width of Rooms (surrounding the courtyard)

on West:  on East:

on North:  on South:

Apartments located on the Eastern Side of the Layout

**Ground Floor: Apartment # (1-E)**

Location of Apartment # (1-E):

Not Applicable

Location of Courtyard:  [0]: No Courtyard  
[1]: on East  
[2]: on South  
[3]: at the Center

Width of Courtyard:

Length of Courtyard:

Position of Courtyard along X-Axis:

Position of Courtyard along Y-Axis:

Total Area of Apartment (# 1-E) =

Courtyard Area =  =  %

Area of Apartment (excluding Courtyard) =

Width of Rooms (surrounding the courtyard)

on West:  on East:

on North:  on South:

**Ground Floor: Apartment # (2-E)**

Location of Apartment # (2-E):

Not Applicable

Location of Courtyard:  [0]: No Courtyard  
[1]: on East  
[2]: on South  
[3]: at the Center

Width of Courtyard:

Length of Courtyard:

Position of Courtyard along X-Axis:

Position of Courtyard along Y-Axis:

Total Area of Apartment (# 2-E) =

Courtyard Area =  =  %

Area of Apartment (excluding Courtyard) =

Width of Rooms (surrounding the courtyard)

on West:  on East:

on North:  on South:

A screenshot showing inputs to be selected by the user for stage (10)

## 4th Segment

### Stage (10-4): Generating Courtyards for Each Apartment (on the 4th Segment)

Apartments located on the Western Side of the Layout

#### 4th Segment: Apartment # (1-W)

Location of Apartment # (1-W)

Location of Courtyard  [0]: No Courtyard  
[1]: on West  
[2]: on South  
[3]: at the Center

Width of Courtyard

Length of Courtyard

Position of Courtyard along X-Axis

Position of Courtyard along Y-Axis

Total Area of Apartment (# 1-W) =

Courtyard Area =  =  %

Area of Apartment (excluding Courtyard) =

Width of Rooms (surrounding the courtyard)

on West:  on East:

on North:  on South:

#### 4th Segment: Apartment # (2-W)

Location of Apartment # (2-W)

Location of Courtyard  [0]: No Courtyard  
[1]: on West  
[2]: on South  
[3]: at the Center

Width of Courtyard

Length of Courtyard

Position of Courtyard along X-Axis

Position of Courtyard along Y-Axis

Total Area of Apartment (# 2-W) =

Courtyard Area =  =  %

Area of Apartment (excluding Courtyard) =

Width of Rooms (surrounding the courtyard)

on West:  on East:

on North:  on South:

Apartments located on the Eastern Side of the Layout

#### 4th Segment: Apartment # (1-E)

Location of Apartment # (1-E)

Location of Courtyard  [0]: No Courtyard  
[1]: on East  
[2]: on South  
[3]: at the Center

Width of Courtyard

Length of Courtyard

Position of Courtyard along X-Axis

Position of Courtyard along Y-Axis

Total Area of Apartment (# 1-E) =

Courtyard Area =  =  %

Area of Apartment (excluding Courtyard) =

Width of Rooms (surrounding the courtyard)

on West:  on East:

on North:  on South:

#### 4th Segment: Apartment # (2-E)

Location of Apartment # (2-E)

Location of Courtyard  [0]: No Courtyard  
[1]: on East  
[2]: on South  
[3]: at the Center

Width of Courtyard

Length of Courtyard

Position of Courtyard along X-Axis

Position of Courtyard along Y-Axis

Total Area of Apartment (# 2-E) =

Courtyard Area =  =  %

Area of Apartment (excluding Courtyard) =

Width of Rooms (surrounding the courtyard)

on West:  on East:

on North:  on South:

A screenshot showing inputs to be selected by the user for stage (10)

## Overall Calculations for the Building

|  |          |   |   |
|--|----------|---|---|
| <i>Total Allowable Area for the Building (m<sup>2</sup>)</i> | 24300.0  |   |   |
| <i>Total Designed Area for the Building (m<sup>2</sup>)</i>  | 22517.51 |   |   |
| <i>Total Number of Floors</i>                                | 18       | <i>Total Area of Common Spaces on All Floors (m<sup>2</sup>)</i>          | 3877.23 = 17.22 % of the Total Designed Area  |
| <i>Total Height of the Building (meter)</i>                  | 70.4     | <i>Total Area of Residential Apartments on All Floors (m<sup>2</sup>)</i> | 18359.02 = 81.53 % of the Total Designed Area |

|              | Number of Floors | Total Number of Apartments | Number of Apartments on Each Floor | Designed Area of Each Floor on the Segment (m <sup>2</sup> ) | Total Designed Area for All Floors on Each Segment (m <sup>2</sup> ) | % from the Total Designed Area of the Building |
|--------------|------------------|----------------------------|------------------------------------|--|--|--|
| Ground Floor | 1                | 6                          | 6                                  | 1317.79  | 1317.79  | 5.85 %   |
| 1st Segment  | 3                | 18                         | 6                                  | 1161.9   | 3485.7   | 15.4 %   |
| 2nd Segment  | 2                | 10                         | 5                                  | 1317.79  | 2635.58  | 11.7 %   |
| 3rd Segment  | 3                | 15                         | 5                                  | 1317.79  | 3953.37  | 17.5 %   |
| 4th Segment  | 4                | 20                         | 5                                  | 1134.03  | 4536.12  | 20.1 %   |
| 5th Segment  | 2                | 10                         | 5                                  | 1317.79  | 2635.58  | 11.7 %   |
| 6th Segment  | 3                | 15                         | 5                                  | 1317.79  | 3953.37  | 17.5 %   |
| <b>TOTAL</b> | <b>18</b>        | <b>94</b>                  |                                    |  | <b>22517.51</b>  | <b>100 %</b>                                   |

A screenshot showing outputs carried out by the system for calculating the overall areas for the building

## Detailed Spatial Calculations

|              | Private Courtyards<br>inside Apartments |  |   |   |   | Area of Apartments<br>(including Courtyards) |                                     |   |   |
|--------------|---|--|---|---|---|--|-------------------------------------|---|---|
|              | Area on<br>Each Floor<br>(m2)           | % from the<br>Area of<br>Apartments<br>on Each Floor | % from the<br>Total Area of<br>Each Floor | Area on<br>All Floors of<br>the Segment | % from the<br>Total Designed<br>Area of<br>the Building | Area on<br>Each Floor<br>(m2)                | % from the<br>Area of<br>Each Floor | Area on<br>All Floors of<br>the Segment | % from the<br>Total Designed<br>Area of<br>the Building |
| Ground Floor | 100.3                                   | 9.94 %   | 7.61 %                                    | 100.3                                   | 0.45 %  | 1008.9                                       | 74.73 %                             | 1008.9                                  | 4.48 %  |
| 1st Segment  | 106.0                                   | 11.52 %  | 9.12 %                                    | 318.0                                   | 1.41 %  | 920.03                                       | 68.15 %                             | 2760.0                                  | 12.26 %   |
| 2nd Segment  | 107.2                                   | 9.69 %   | 8.13 %                                    | 214.4                                   | 0.95 %  | 1106.7                                       | 81.98 %                             | 2213.52                                 | 9.83 %  |
| 3rd Segment  | 119.5                                   | 11.11 %  | 9.07 %                                    | 358.5                                   | 1.59 %  | 1075.9                                       | 79.7 %                              | 3227.75                                 | 14.33 %   |
| 4th Segment  | 96.1                                    | 10.46 %  | 8.47 %                                    | 384.4                                   | 1.71 %  | 919.16                                       | 68.09 %                             | 3676.64                                 | 16.33 %   |
| 5th Segment  | 121.4                                   | 10.98 %  | 9.21 %                                    | 242.8                                   | 1.08 %  | 1105.6                                       | 81.9 %                              | 2211.29                                 | 9.82 %  |
| 6th Segment  | 122.8                                   | 11.3 %   | 9.32 %                                    | 368.4                                   | 1.64 %  | 1086.9                                       | 80.51 %                             | 3260.82                                 | 14.48 %   |
| TOTAL        |   |  |   | 1987                                    | 8.83 %  |  |                                     | 18359.02                                | 81.53 %   |
|              |   |  |   | = 10.82 %                               |   |  |                                     |   |   |
|              |   |  |   | from the Total Area<br>of Apartments    |   |  |                                     |   |   |

A screenshot showing outputs carried out by the system for calculating areas of apartments

### Common Spaces inside the Building

|              | TOTAL Area of Common Spaces |                               |                                   |                                       | Main Public Space (MPS) |                               |                                   |                                       | Semi-Private Spaces (PVS) |                               |                                   |                                       |
|--------------|-----------------------------|-------------------------------|-----------------------------------|---------------------------------------|-------------------------|-------------------------------|-----------------------------------|---------------------------------------|---------------------------|-------------------------------|-----------------------------------|---------------------------------------|
|              | Area on Each Floor (m2)     | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area on Each Floor (m2) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area on Each Floor (m2)   | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building |
| Ground Floor | 308.88                      | 23.44 %                       | 308.88                            | 1.38 %                                | 79.28                   | 6.02 %                        | 79.28                             | 0.35 %                                | 39.64                     | 3.01 %                        | 39.64                             | 0.18 %                                |
| 1st Segment  | 241.88                      | 20.82 %                       | 725.64                            | 3.23 %                                | 79.28                   | 6.82 %                        | 237.84                            | 1.06 %                                | 39.64                     | 3.41 %                        | 118.92                            | 0.53 %                                |
| 2nd Segment  | 193.56                      | 14.69 %                       | 387.12                            | 1.72 %                                | 30.09                   | 2.28 %                        | 60.18                             | 0.27 %                                | 39.61                     | 3.01 %                        | 79.22                             | 0.35 %                                |
| 3rd Segment  | 212.34                      | 16.11 %                       | 637.02                            | 2.83 %                                | 49.74                   | 3.77 %                        | 149.22                            | 0.66 %                                | 39.64                     | 3.01 %                        | 118.92                            | 0.53 %                                |
| 4th Segment  | 201.96                      | 17.8 %                        | 807.84                            | 3.58 %                                | 38.49                   | 3.39 %                        | 153.96                            | 0.68 %                                | 39.61                     | 3.49 %                        | 158.44                            | 0.7 %                                 |
| 5th Segment  | 194.4                       | 14.75 %                       | 388.8                             | 1.72 %                                | 31.8                    | 2.41 %                        | 63.6                              | 0.28 %                                | 39.64                     | 3.01 %                        | 79.28                             | 0.35 %                                |
| 6th Segment  | 207.31                      | 15.74 %                       | 621.93                            | 2.76 %                                | 43.84                   | 3.33 %                        | 131.52                            | 0.58 %                                | 39.61                     | 3.01 %                        | 118.83                            | 0.53 %                                |
| <b>TOTAL</b> |                             |                               | 3877.23                           | 17.22 %                               |                         |                               | 875.6                             | 3.88 %                                |                           |                               | 713.25                            | 3.17 %                                |

A screenshot showing outputs carried out by the system for calculating areas of common spaces (part 1)

File Edit View Display Solution Help Space Syntax Test [1]

100%

### Common Spaces inside the Building

|              | Entry Hall (EN) |                              |                                       | Corridors (COR)         |                               |                                   |                                       | Vertical Core (VC)      |                               |                                   |                                       |
|--------------|-----------------|------------------------------|---------------------------------------|-------------------------|-------------------------------|-----------------------------------|---------------------------------------|-------------------------|-------------------------------|-----------------------------------|---------------------------------------|
|              | Area (m2)       | % from the Area of the Floor | % from the Total Area of the Building | Area on Each Floor (m2) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area on Each Floor (m2) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building |
| Ground Floor | 45.0            | 3.41 %                       | 0.2 %                                 | 71.46                   | 5.42 %                        | 71.46                             | 0.32 %                                | 73.5                    | 5.58 %                        | 73.5                              | 0.33 %                                |
| 1st Segment  |                 |                              |                                       | 49.46                   | 4.26 %                        | 148.38                            | 0.66 %                                | 73.5                    | 6.33 %                        | 220.5                             | 0.98 %                                |
| 2nd Segment  |                 |                              |                                       | 50.36                   | 3.82 %                        | 100.72                            | 0.45 %                                | 73.5                    | 5.58 %                        | 147.0                             | 0.65 %                                |
| 3rd Segment  |                 |                              |                                       | 49.46                   | 3.75 %                        | 148.38                            | 0.66 %                                | 73.5                    | 5.58 %                        | 220.5                             | 0.98 %                                |
| 4th Segment  |                 |                              |                                       | 50.36                   | 4.44 %                        | 201.44                            | 0.89 %                                | 73.5                    | 6.48 %                        | 294.0                             | 1.31 %                                |
| 5th Segment  |                 |                              |                                       | 49.46                   | 3.75 %                        | 98.92                             | 0.44 %                                | 73.5                    | 5.58 %                        | 147.0                             | 0.65 %                                |
| 6th Segment  |                 |                              |                                       | 50.36                   | 3.82 %                        | 151.08                            | 0.67 %                                | 73.5                    | 5.58 %                        | 220.5                             | 0.98 %                                |
| <b>TOTAL</b> | <b>45.0</b>     | <b>3.41 %</b>                | <b>0.2 %</b>                          |                         |                               | <b>920.38</b>                     | <b>4.09 %</b>                         |                         |                               | <b>1323.0</b>                     | <b>5.88 %</b>                         |

A screenshot showing outputs carried out by the system for calculating areas of common spaces (part 2)



File Edit View Curve Surface Solid Mesh Dimension Transform Tools Analyze Render Panels Help

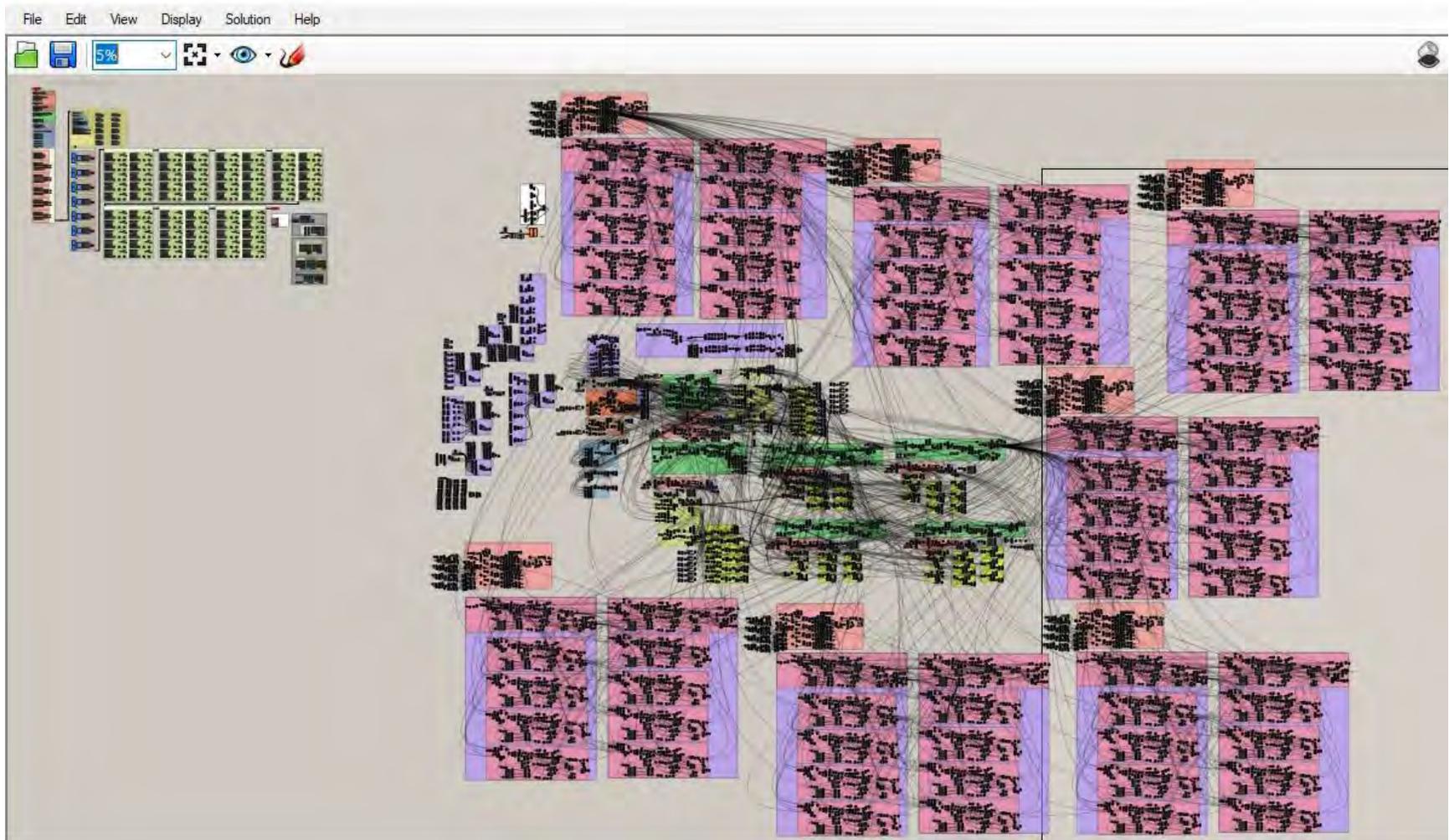
File "D:\Documents\Amer Files\06. UKIPhD Cardiff [Amer] 2015-2016\04. PHD Progress [2015-2017]\12. Analysing Plans\Grasshopper Works [01.09.2017]\Presentation 01.12.17\Vertical Building Nov.17 .3dm" successfully read

Command: [

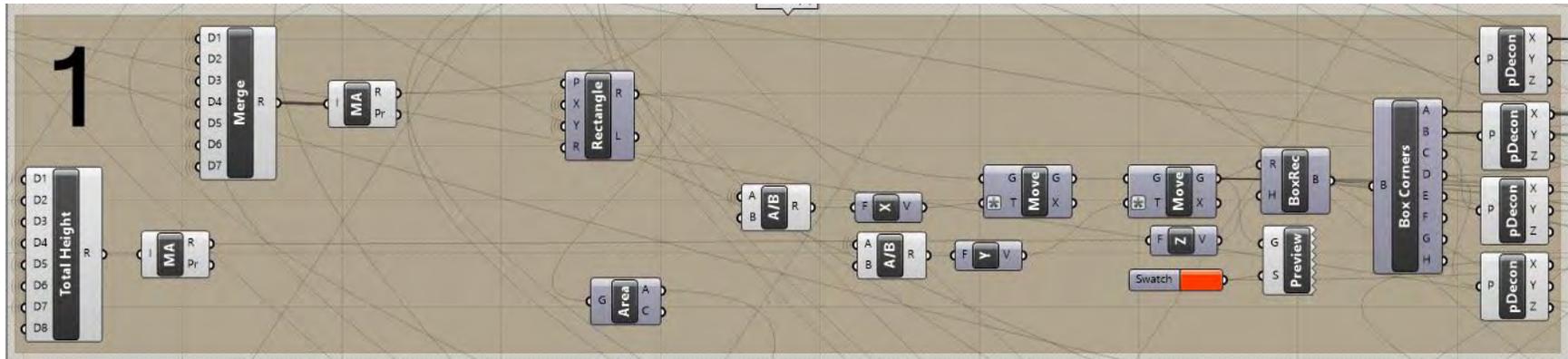
Parallel ▾



A screenshot showing the generated three-dimensional views for the building and for each segment carried out by the system

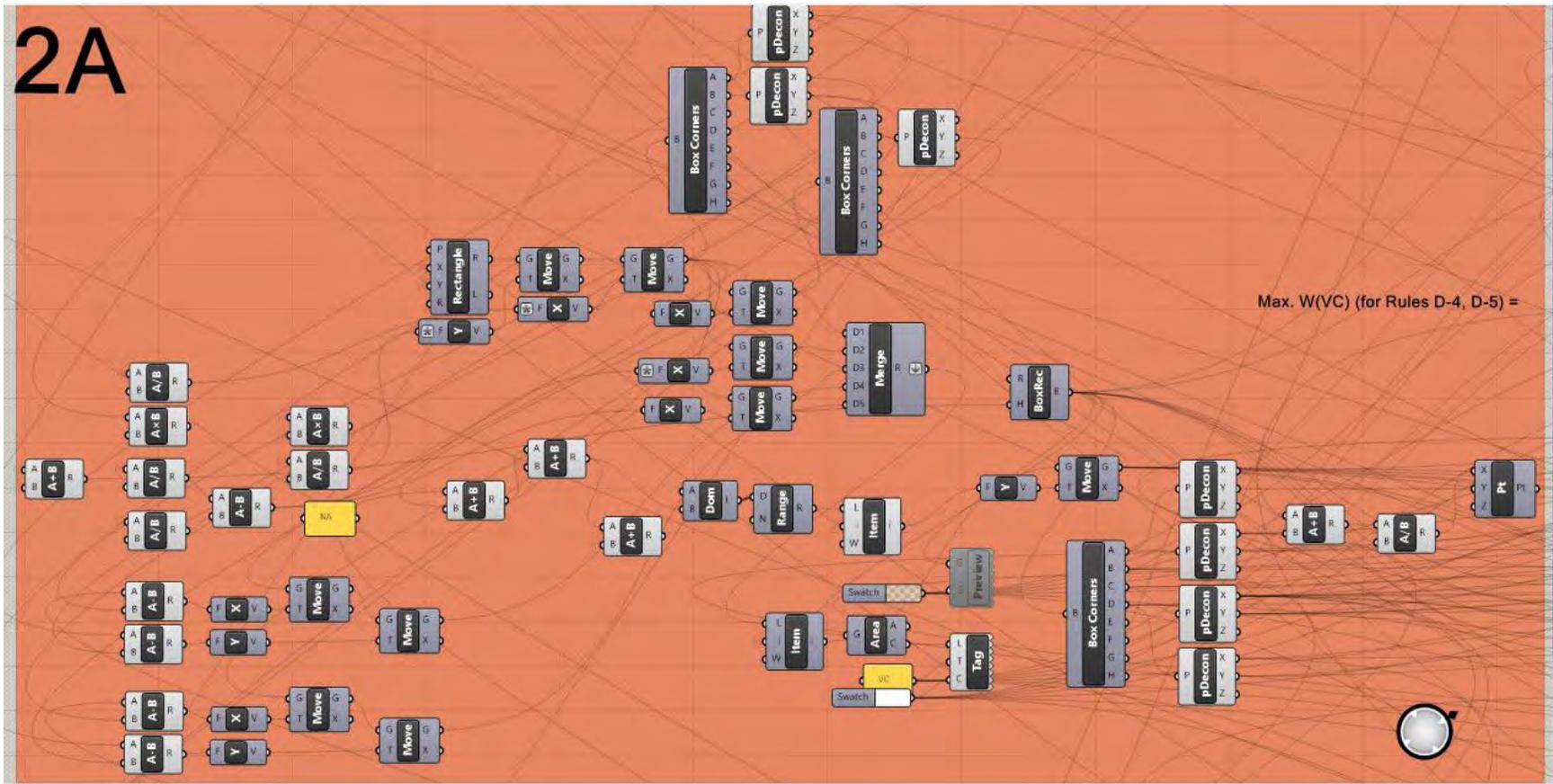


A screenshot showing components for generating a high-rise residential building

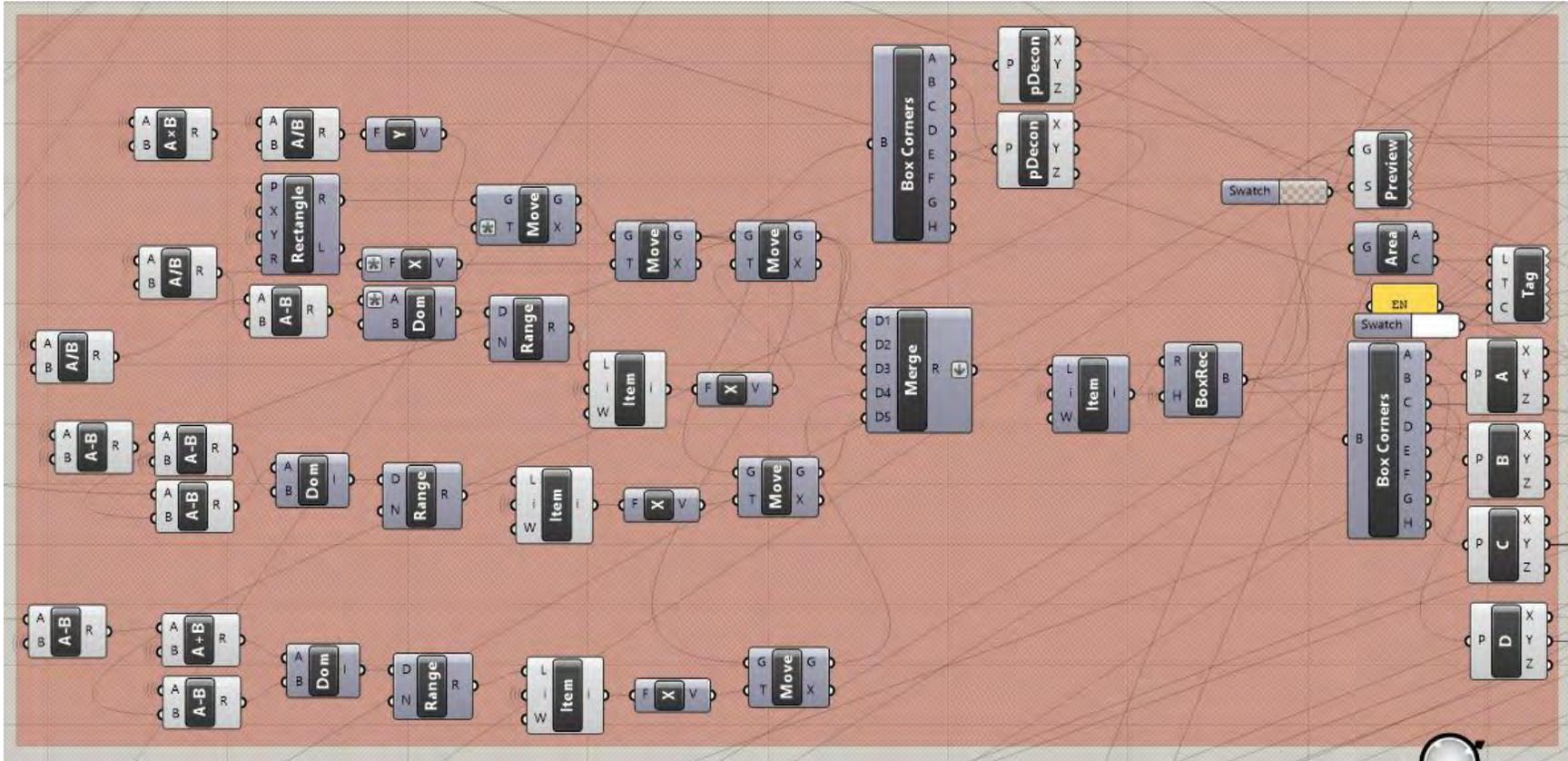


A screenshot showing components for carrying out stage (1) for generating the overall layout of the building

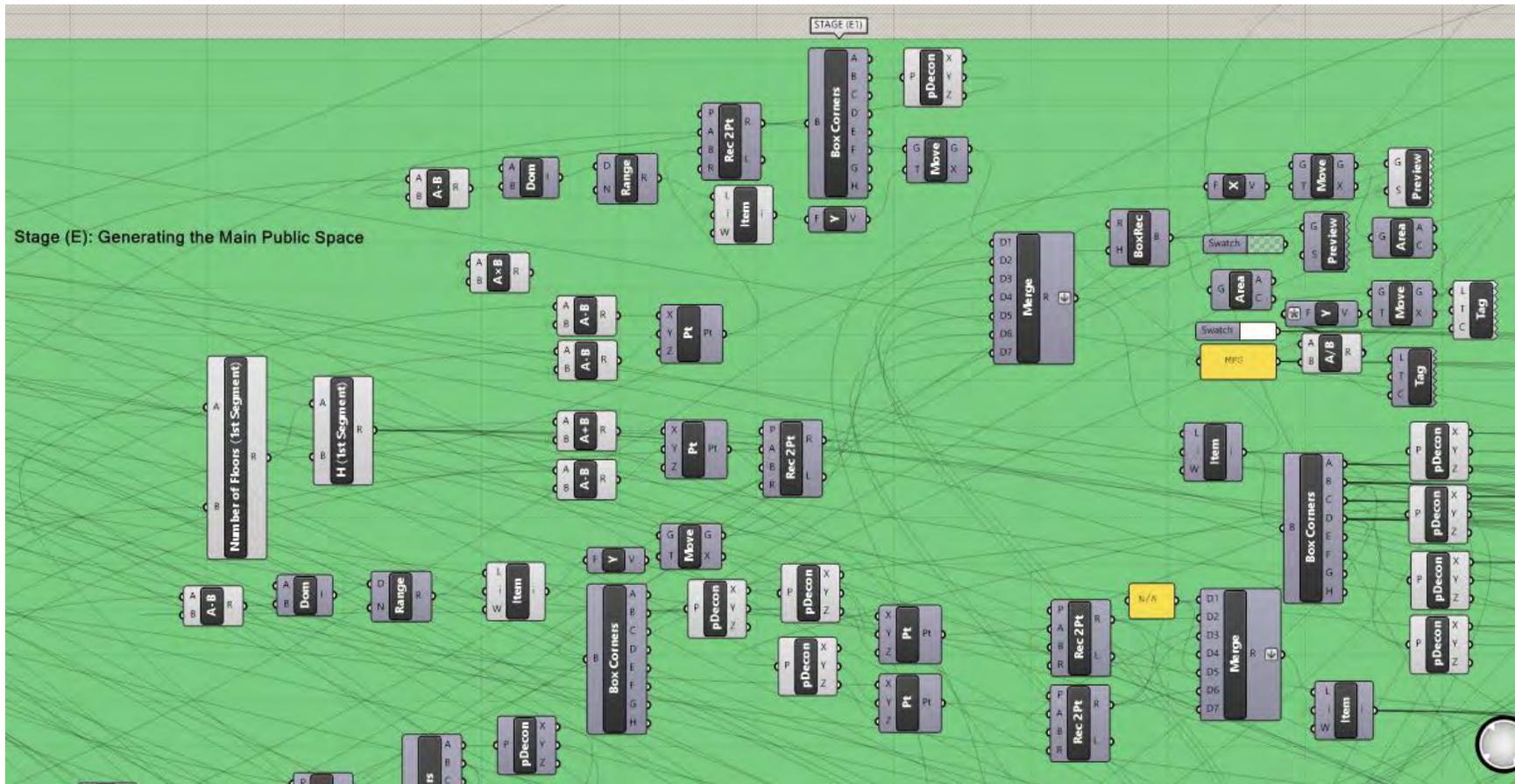
# 2A



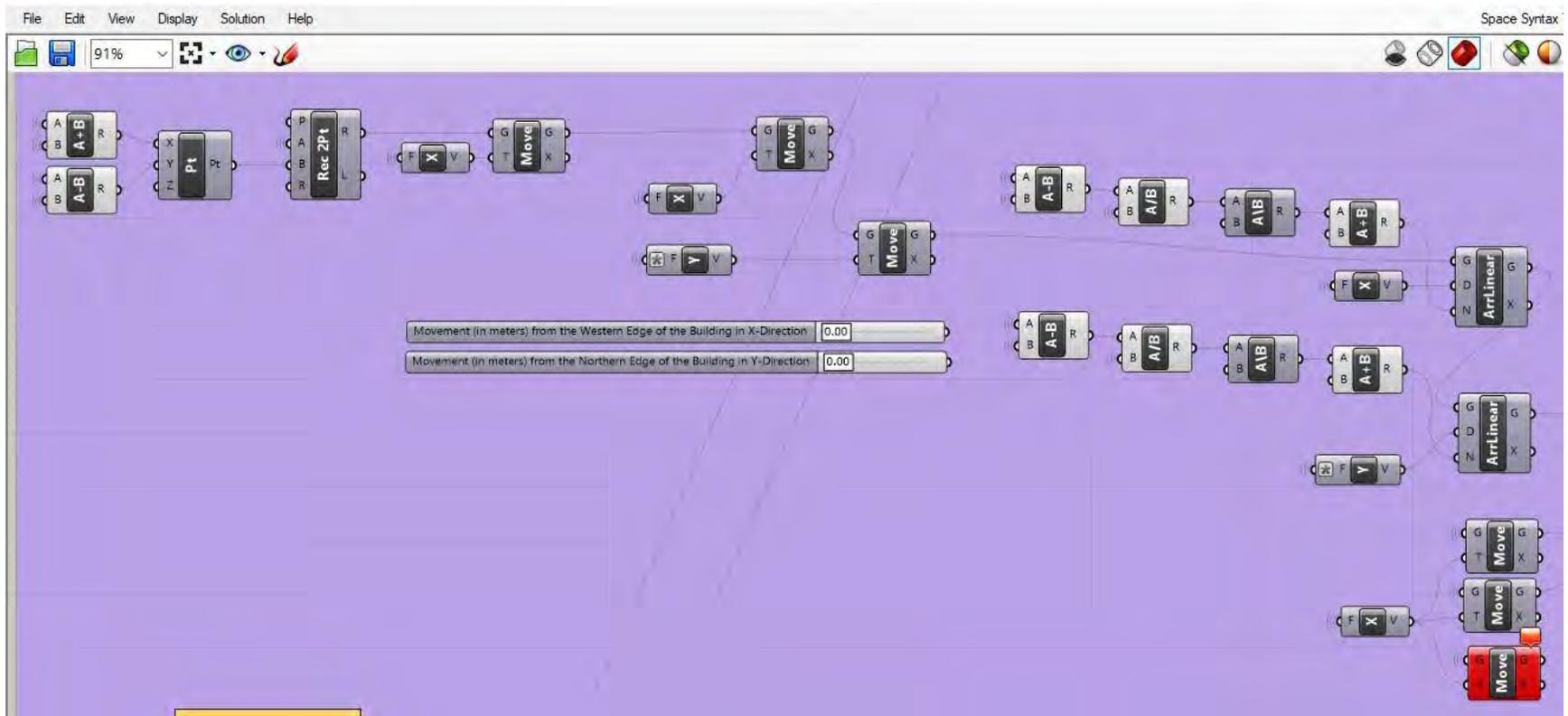
A screenshot showing components for carrying out stage (2) for generating the vertical circulation core (VC)



A screenshot showing components for carrying out stage (3) for generating the main entry hall (EN)

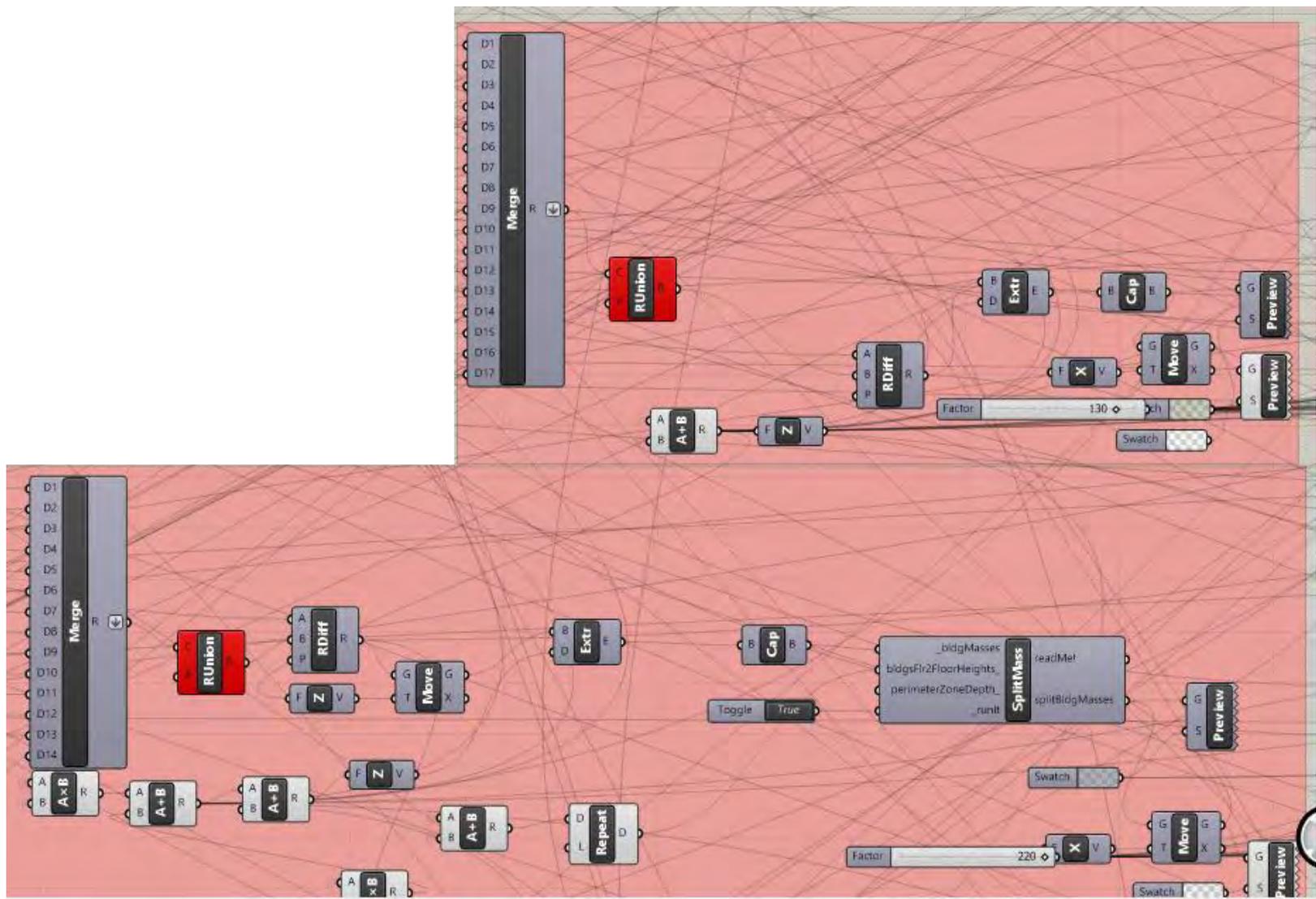


A screenshot showing components for carrying out stage (4) for generating the main public space (MPS)



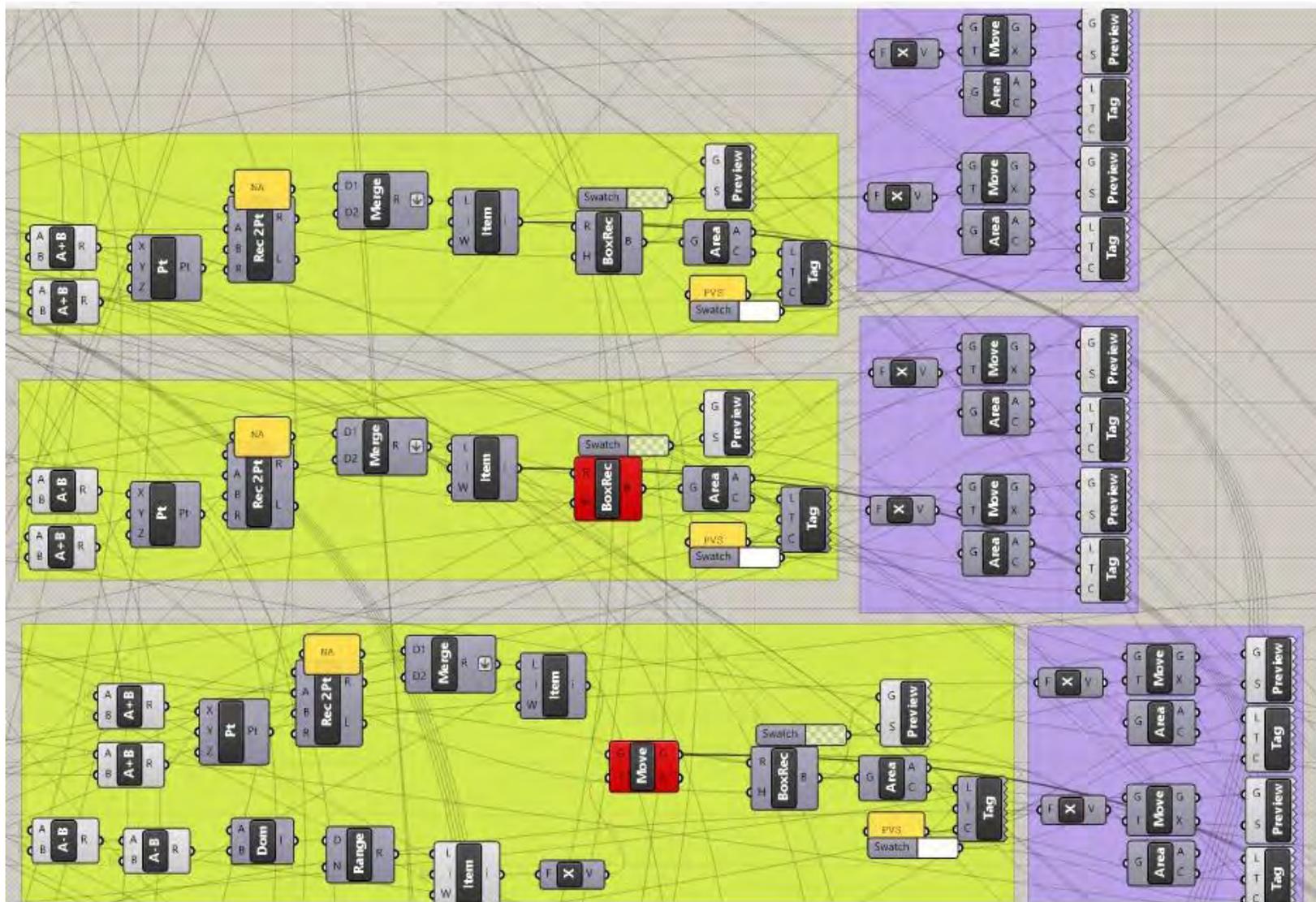
A screenshot showing components for carrying out stage (5) for generating structural columns





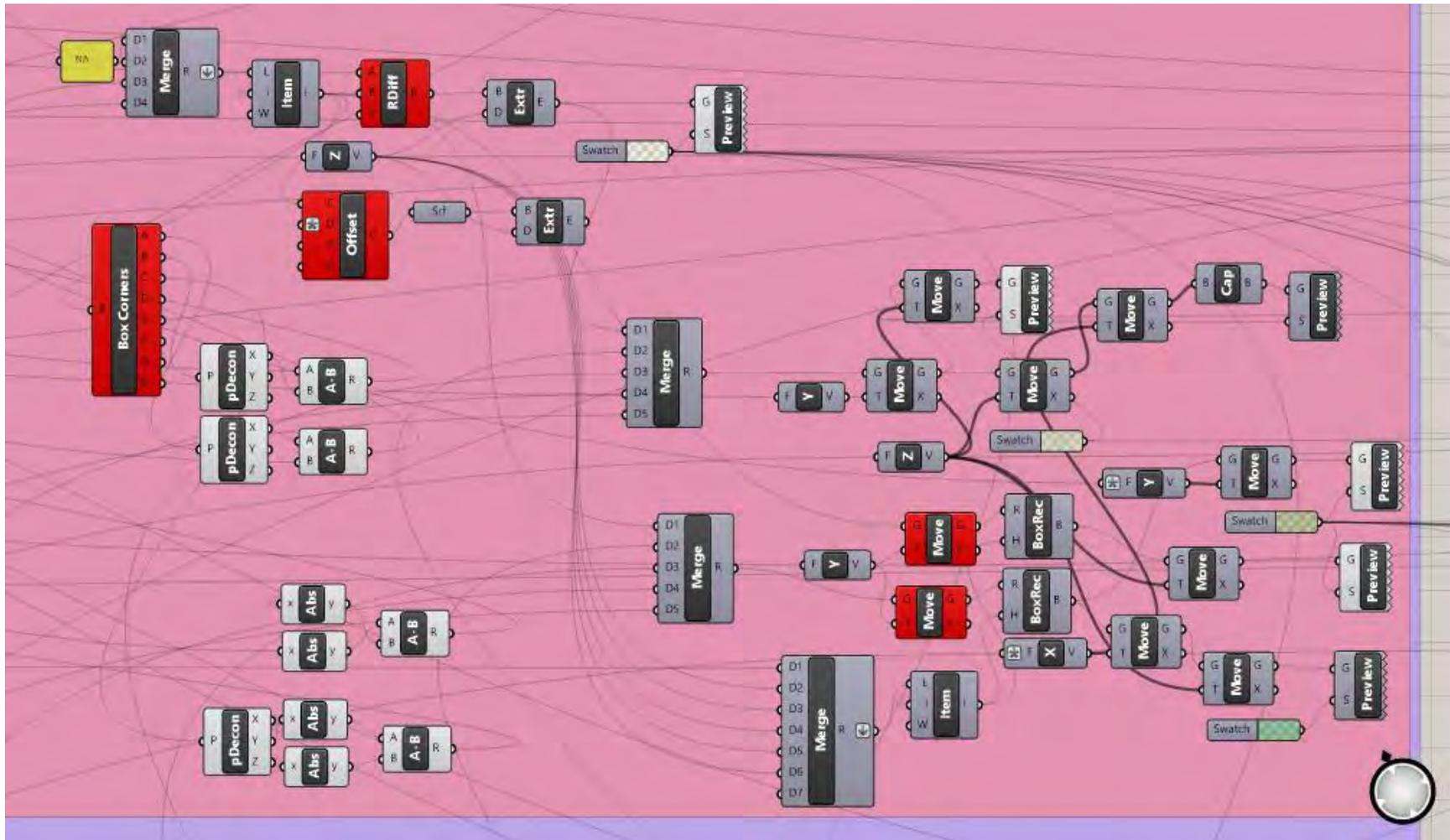
A screenshot showing components for carrying out stage (7) for generating the overall layout of residential units



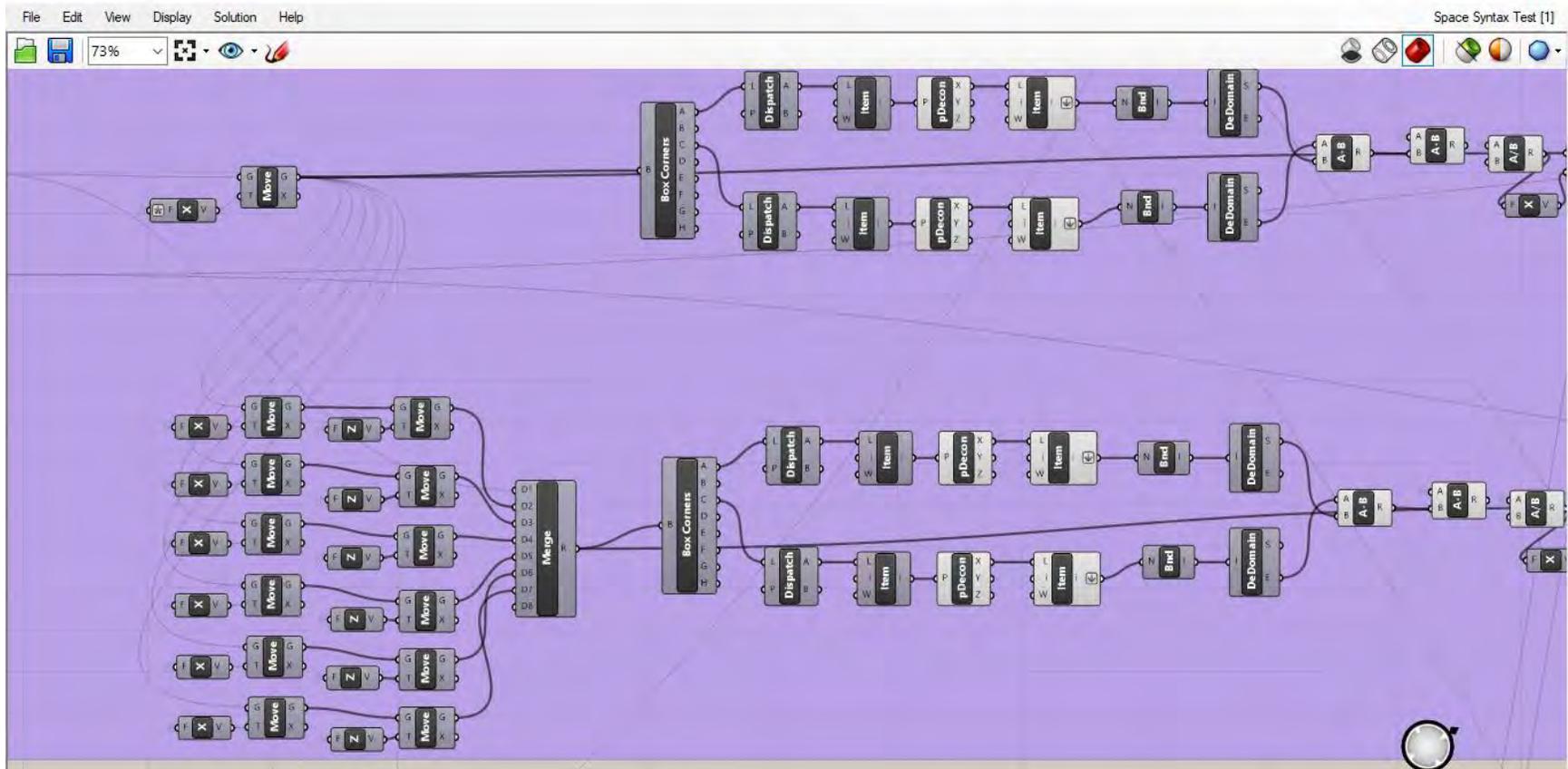


A screenshot showing components for carrying out stage (8) for generating semi-private spaces (PVS)

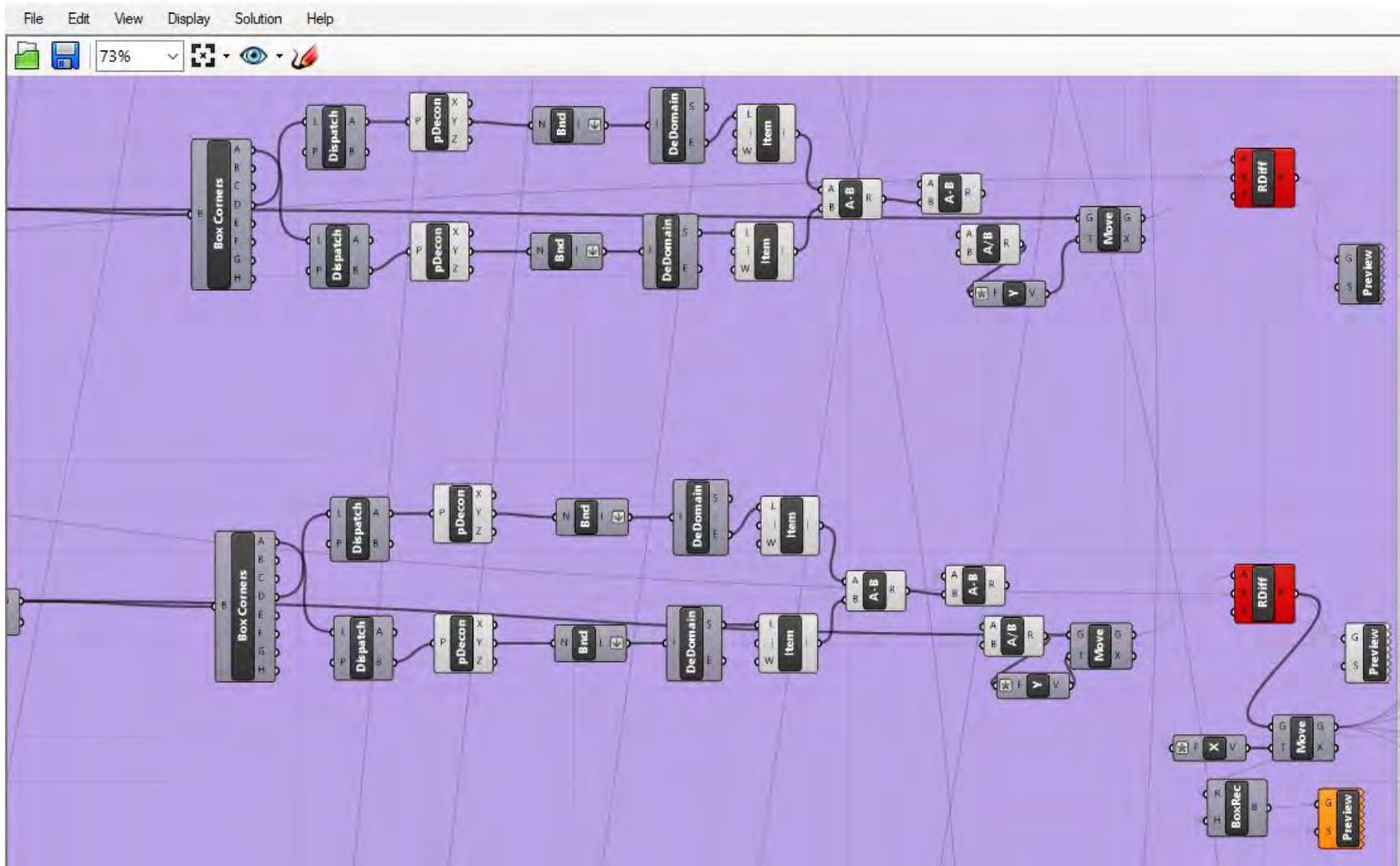




A screenshot showing part of the components for carrying out stages (9 and 10) for generating apartments



A screenshot showing part of the components for carrying out stages (9 and 10) for generating apartments

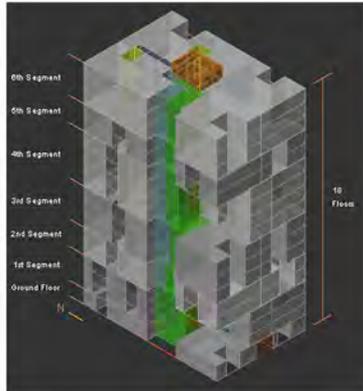


A screenshot showing part of the components for carrying out stages (9 and 10) for generating apartments

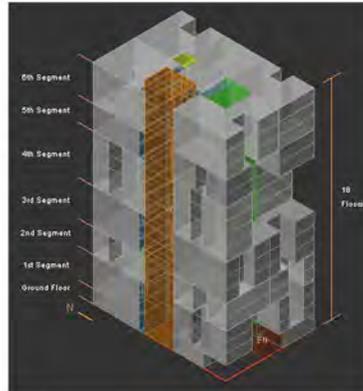
Appendix (5-C-1)

**Three-Dimensional Views for  
All Cases generated by the Researcher**

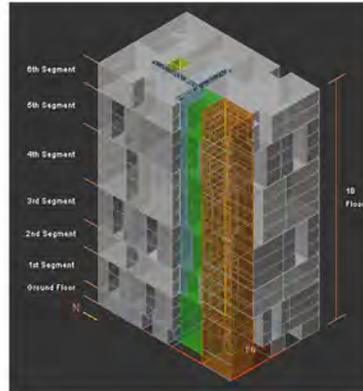
### Case #1



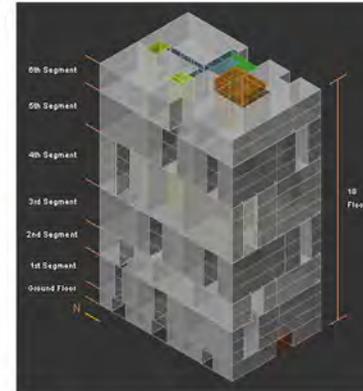
### Case #2



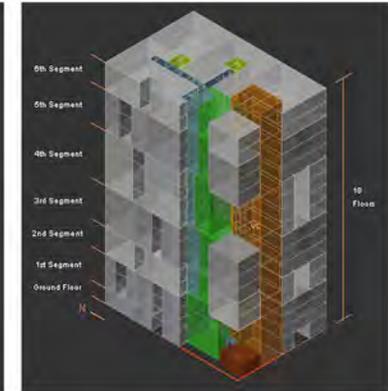
### Case #3



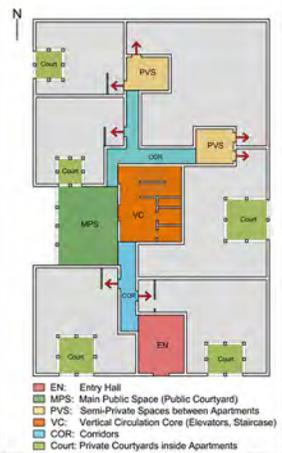
### Case #4



### Case #5



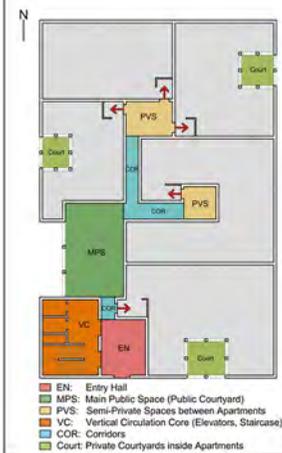
#### Zoning Plan for the Ground Floor



#### Zoning Plan for the Ground Floor



#### Zoning Plan for the Ground Floor



#### Zoning Plan for the Ground Floor



#### Zoning Plan for the Ground Floor



- EN: Entry Hall
- MPS: Main Public Space (Public Courtyard)
- PVS: Semi-Private Spaces between Apartments
- VC: Vertical Circulation Core (Elevators, Staircase)
- COR: Corridors
- Court: Private Courtyards inside Apartments

- EN: Entry Hall
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- PVS: Semi-Private Spaces between Apartments
- VC: Vertical Circulation Core (Elevators, Staircase)
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- COR: Corridors
- Court: Private Courtyards inside Apartments

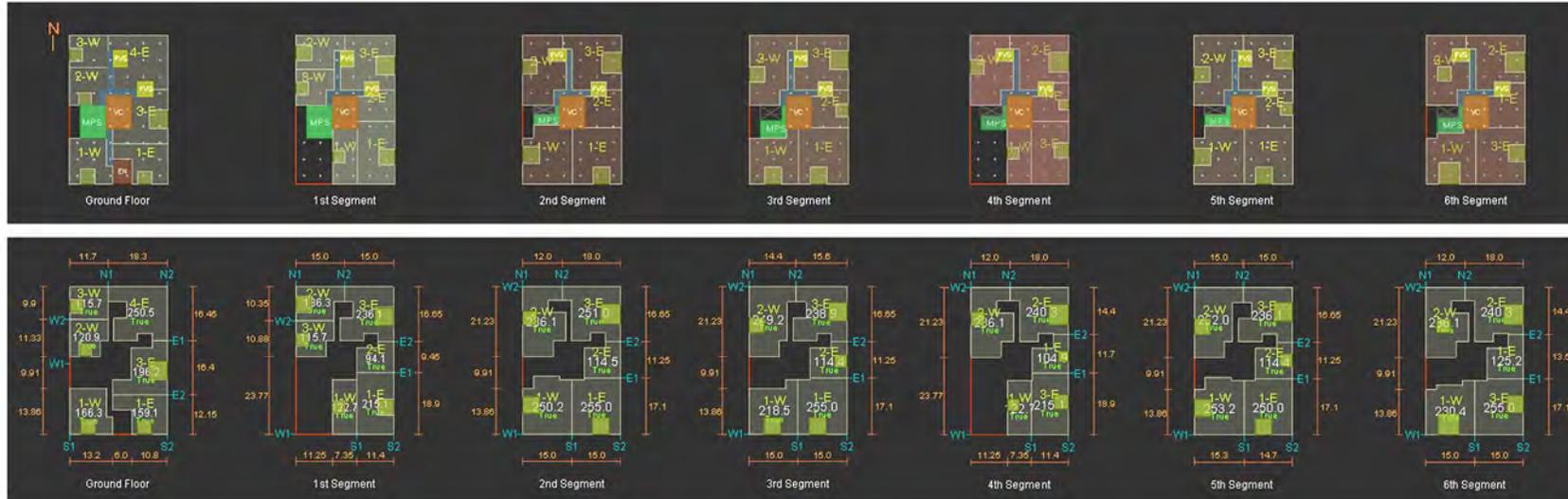
- EN: Entry Hall
- MPS: Main Public Space (Public Courtyard)
- PVS: Semi-Private Spaces between Apartments
- VC: Vertical Circulation Core (Elevators, Staircase)
- COR: Corridors
- Court: Private Courtyards inside Apartments

Appendix (5-C-2)

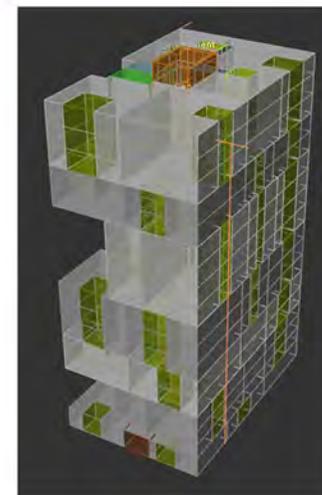
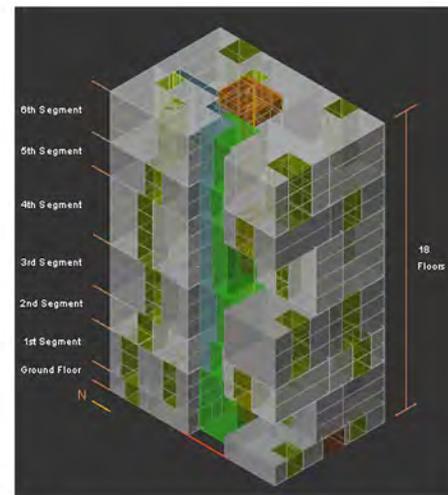
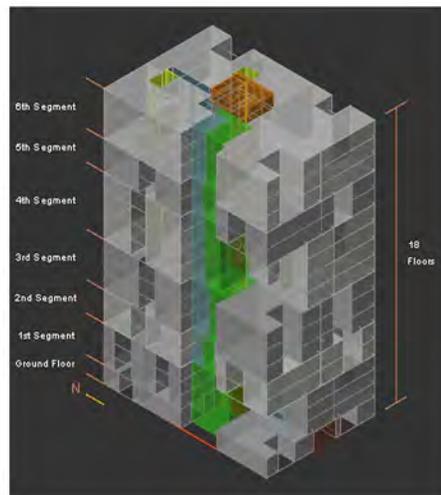
**A Detailed Spatial Analysis for  
All Cases generated by the Researcher**

Case No. 1

Floors Plans and Three-Dimensional Views

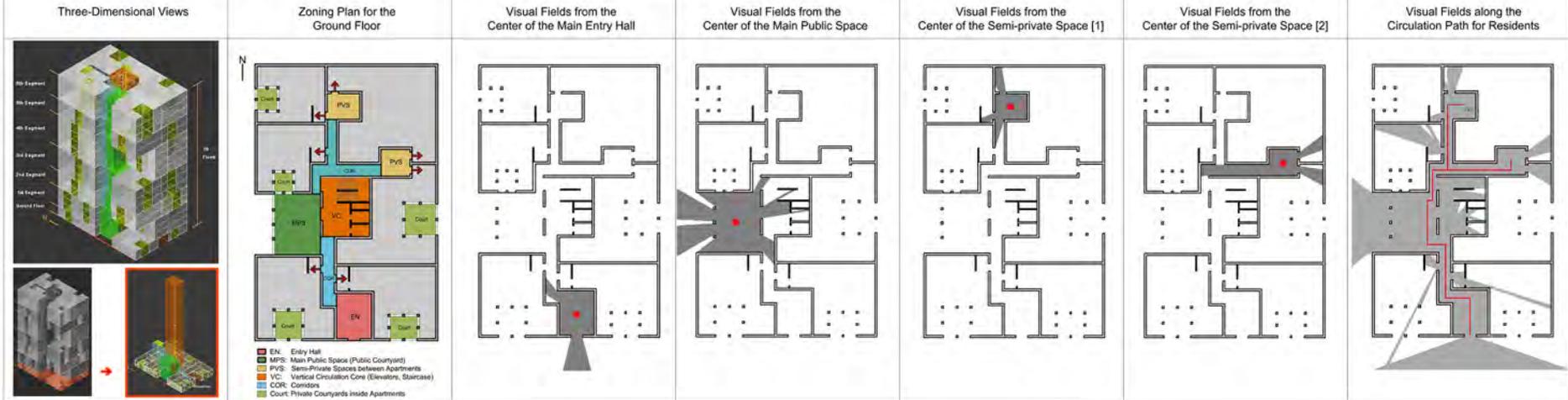


- EN: Entry Hall
- MPS: Main Public Space (Public Courtyard)
- PVS: Semi-Private Spaces between Apartments
- VC: Vertical Circulation Core (Elevators, Staircase)
- COR: Corridors
- Court: Private Courtyards inside Apartments



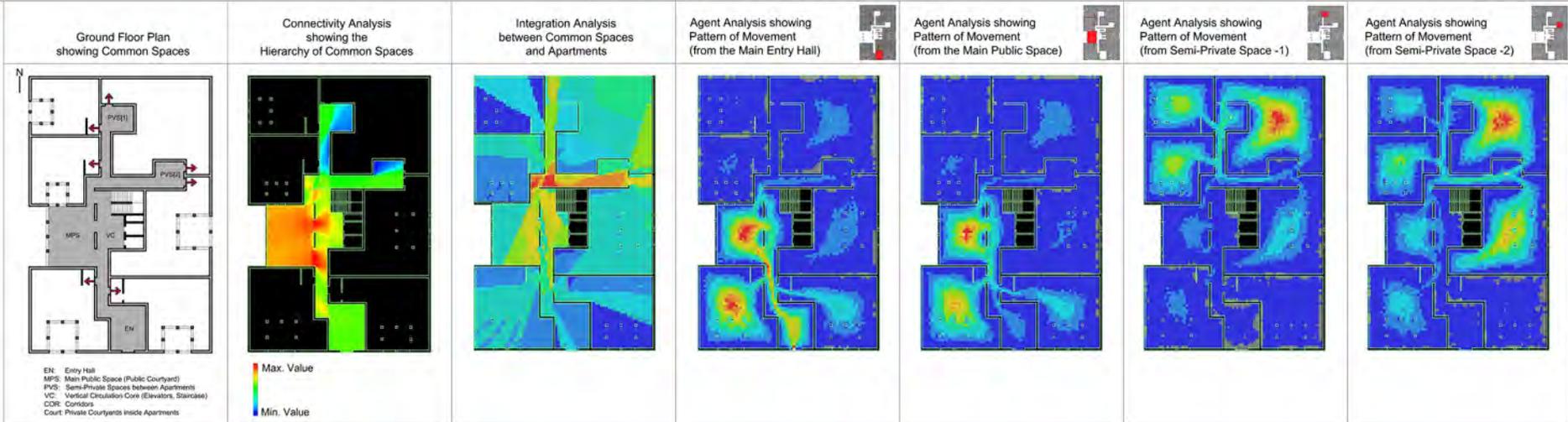
Case No. (1): Ground Floor

Visibility Study for the Ground Floor  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



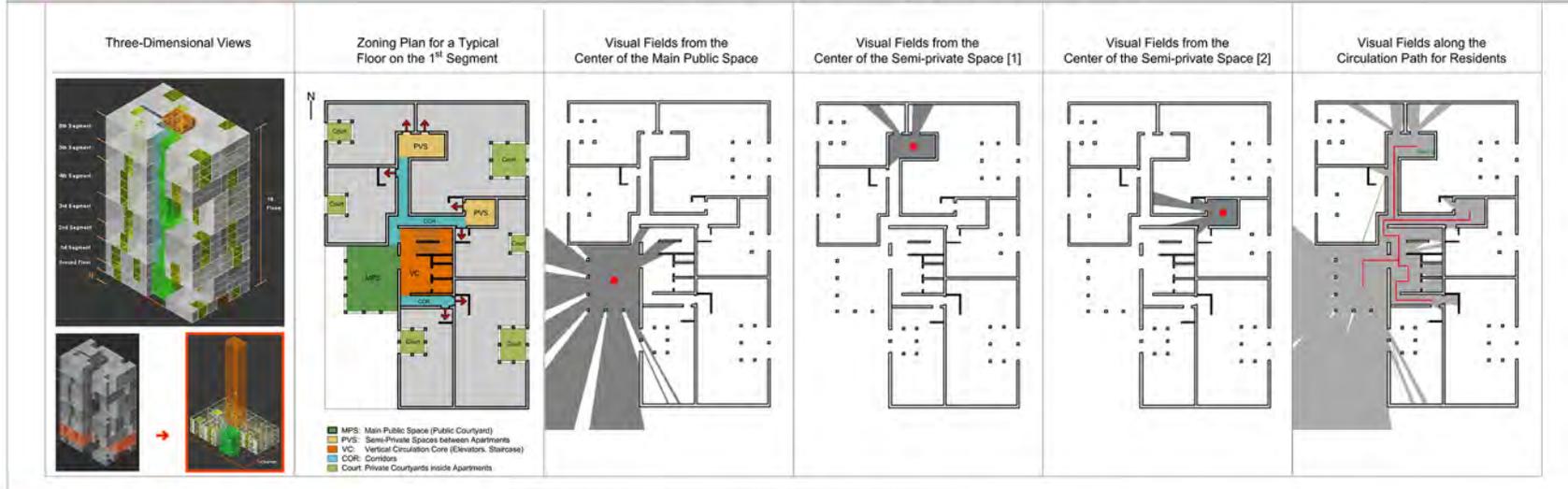
Case No. (1): Ground Floor

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for the Ground Floor  
(Carried out by Author using 'DepthMapX 0.50 Software')



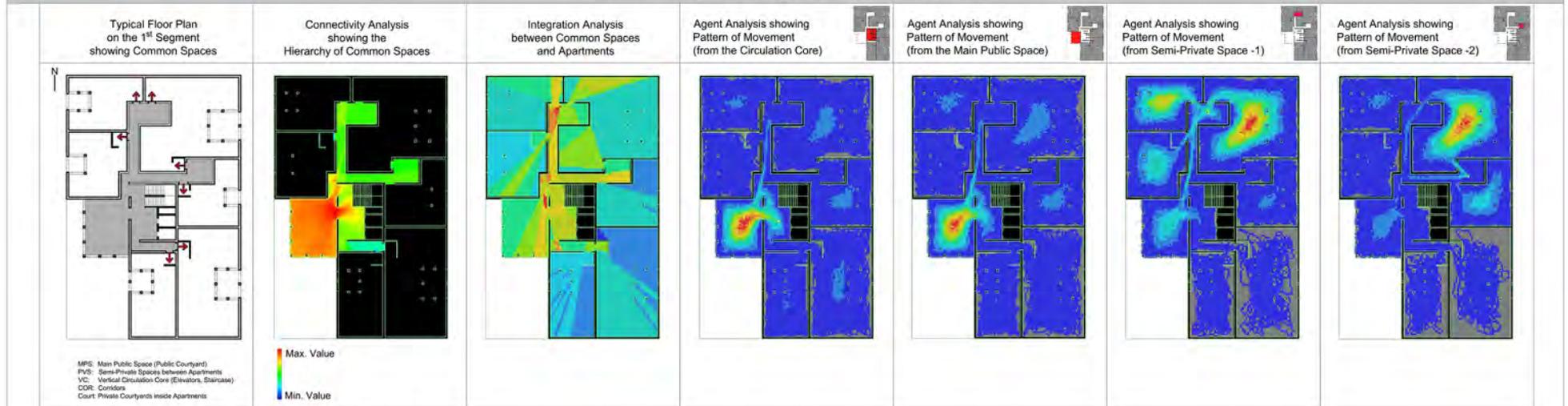
Case No. (1): 1<sup>st</sup> Segment

Visibility Study for a Typical Floor located on the 1<sup>st</sup> Segment  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



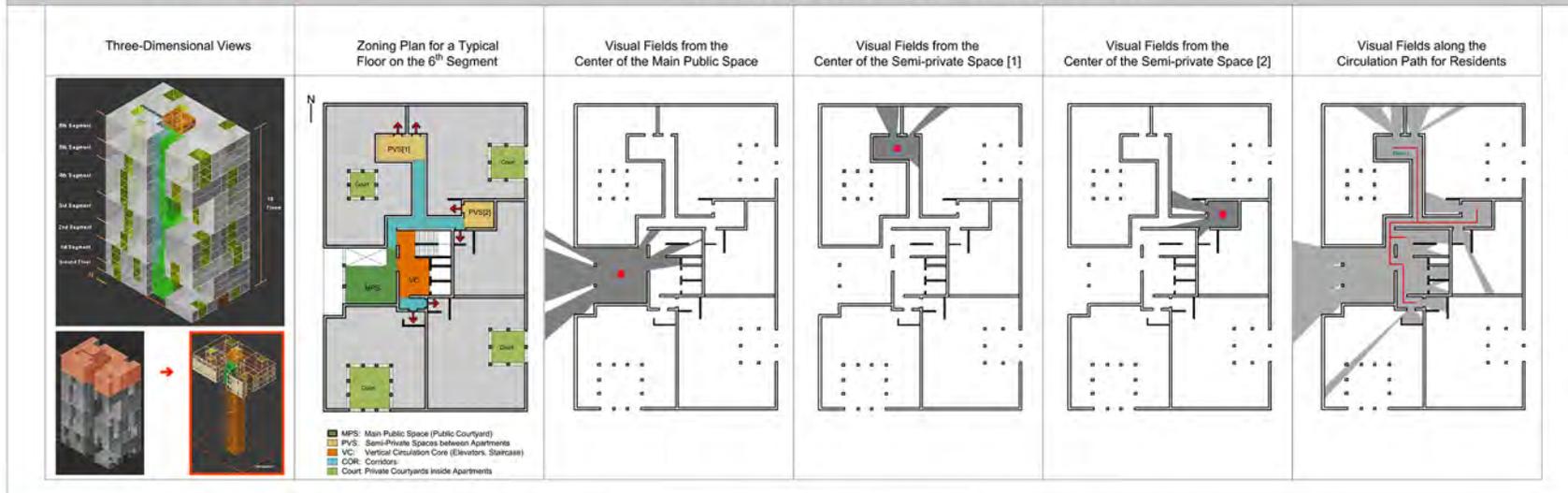
Case No. (1): 1<sup>st</sup> Segment

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for a Typical Floor located on the 1<sup>st</sup> Segment  
(Carried out by Author using 'DepthMapX 0.50 Software')



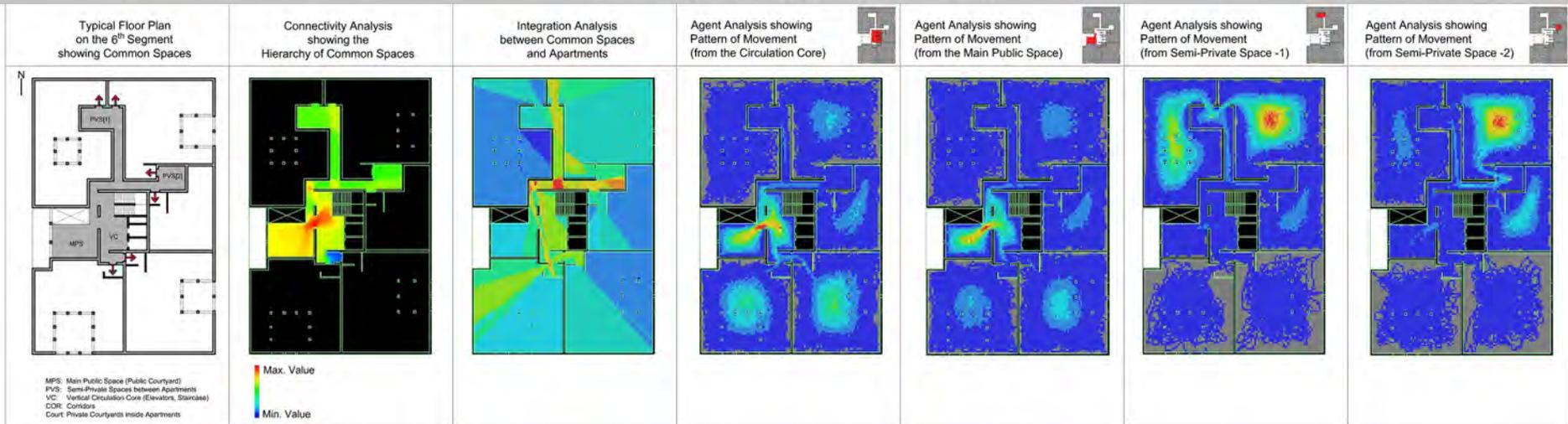
Case No. (1): 6<sup>th</sup> Segment

Visibility Study for a Typical Floor located on the 6<sup>th</sup> Segment  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



Case No. (1): 6<sup>th</sup> Segment

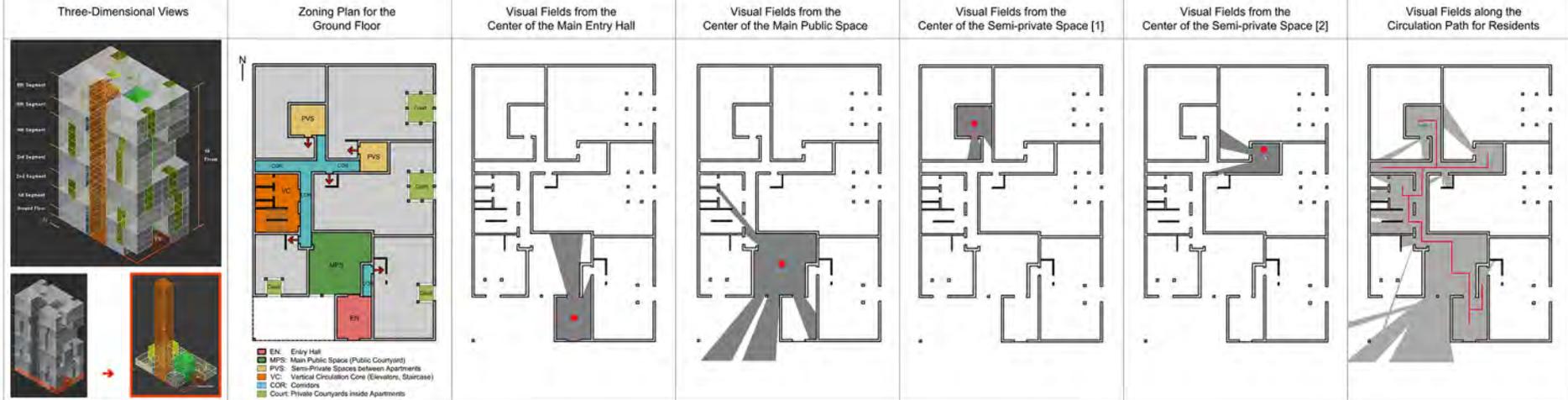
Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for a Typical Floor located on the 6<sup>th</sup> Segment  
(Carried out by Author using 'DepthMapX 0.50 Software')





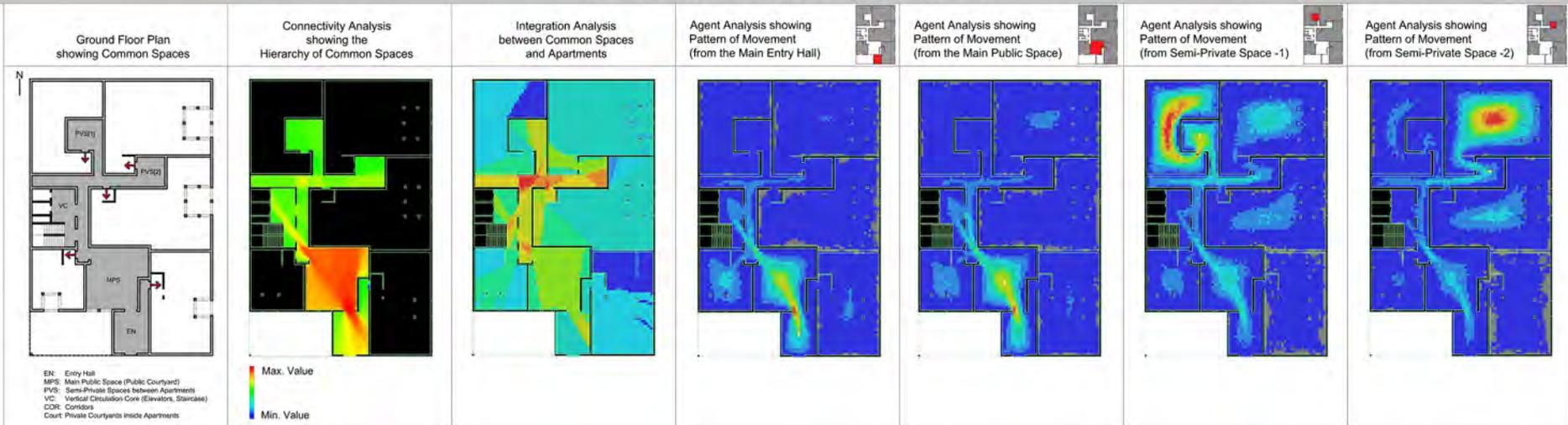
Case No. (2): Ground Floor

Visibility Study for the Ground Floor  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



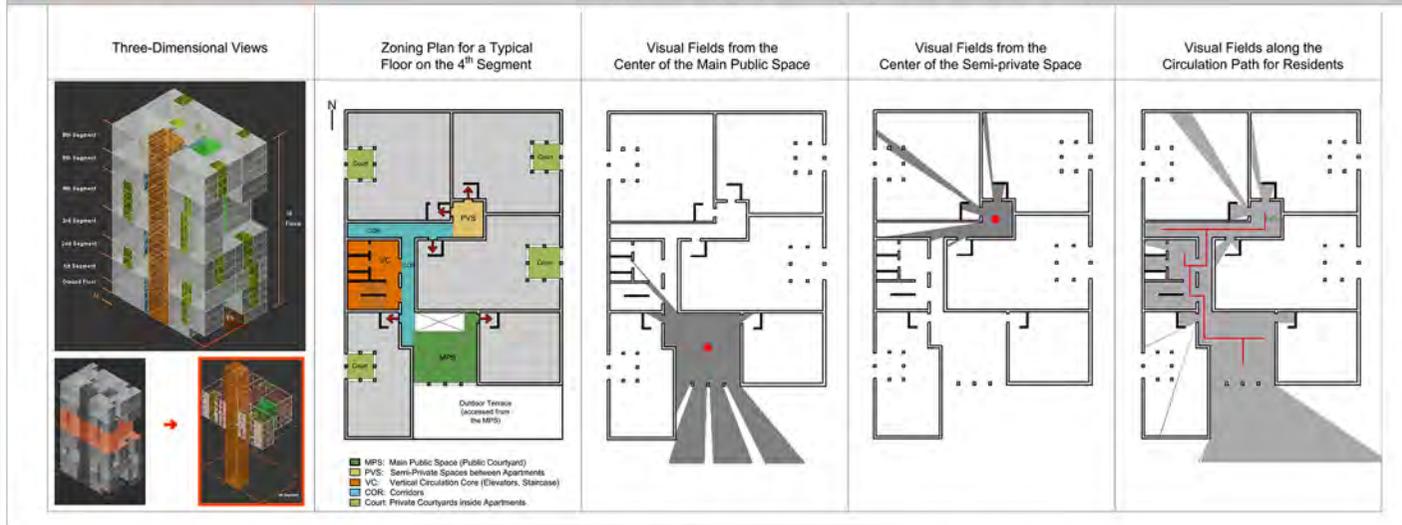
Case No. (2): Ground Floor

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for the Ground Floor  
(Carried out by Author using 'DepthMapX 0.50 Software')



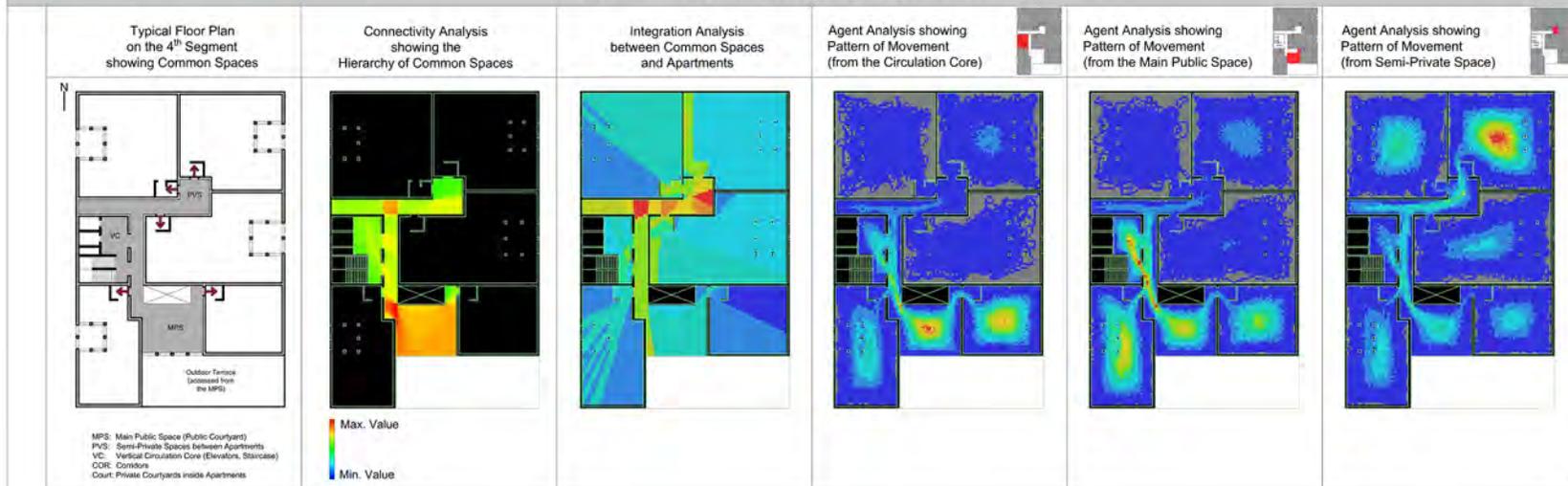
Case No. (2): 4<sup>th</sup> Segment

Visibility Study for a Typical Floor located on the 4<sup>th</sup> Segment  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



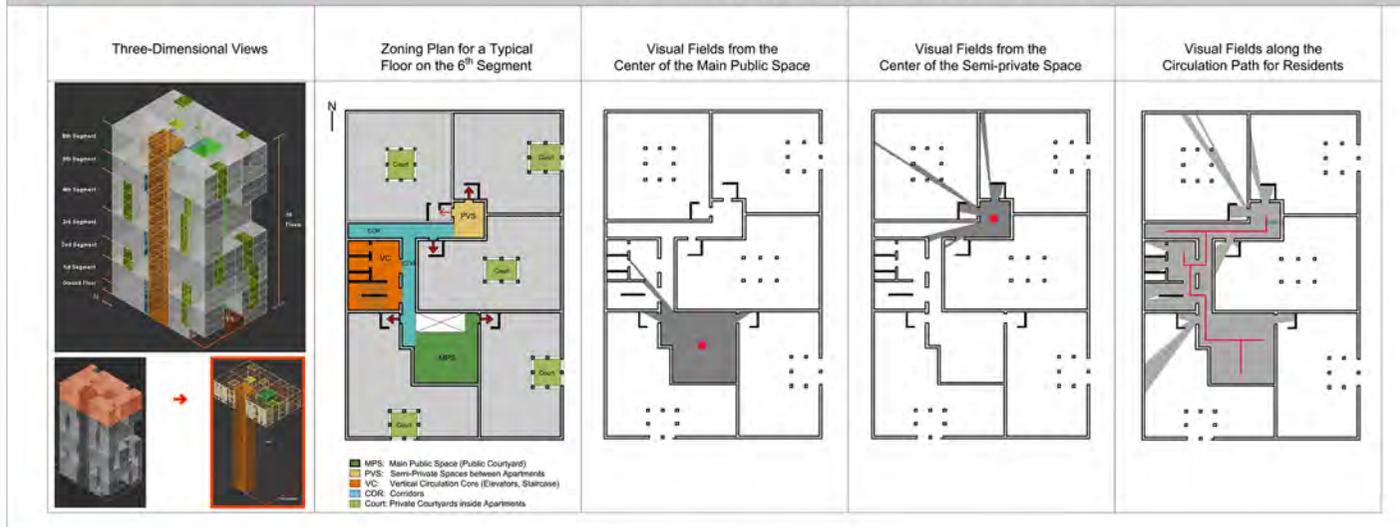
Case No. (2): 4<sup>th</sup> Segment

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for a Typical Floor located on the 4<sup>th</sup> Segment  
(Carried out by Author using 'DepthMapX 0.50 Software')



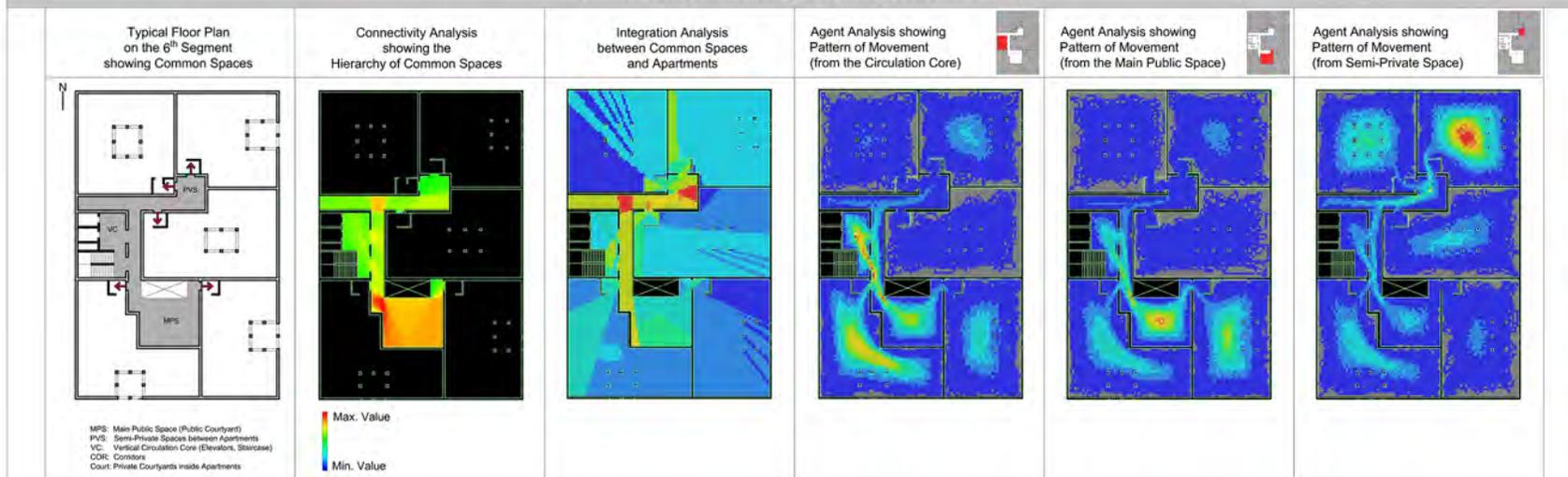
Case No. (2): 6<sup>th</sup> Segment

Visibility Study for a Typical Floor located on the 6<sup>th</sup> Segment  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



Case No. (2): 6<sup>th</sup> Segment

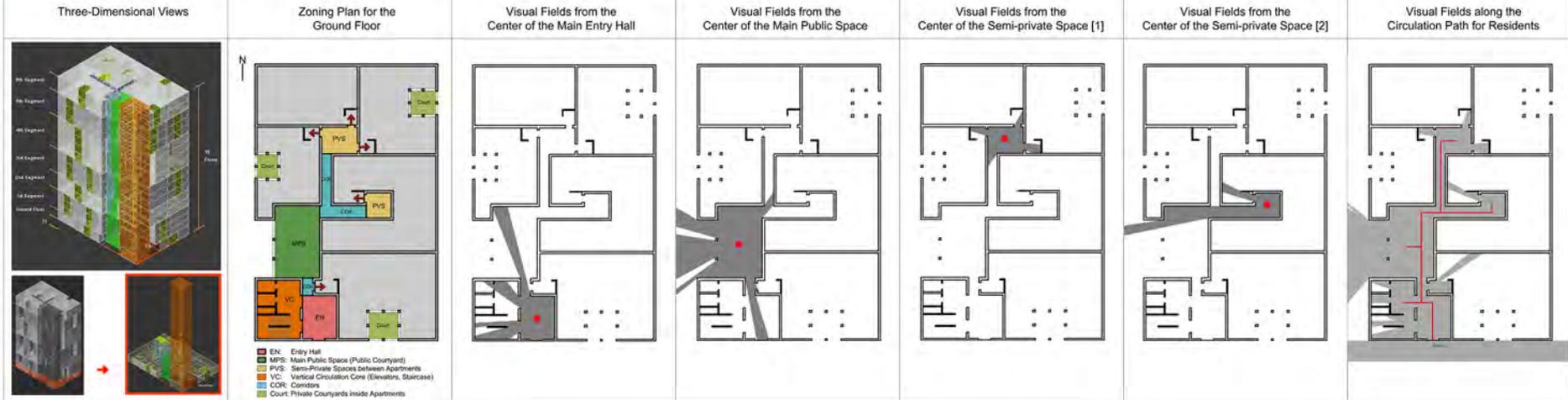
Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for a Typical Floor located on the 6<sup>th</sup> Segment  
(Carried out by Author using 'DepthMapX 0.50 Software')





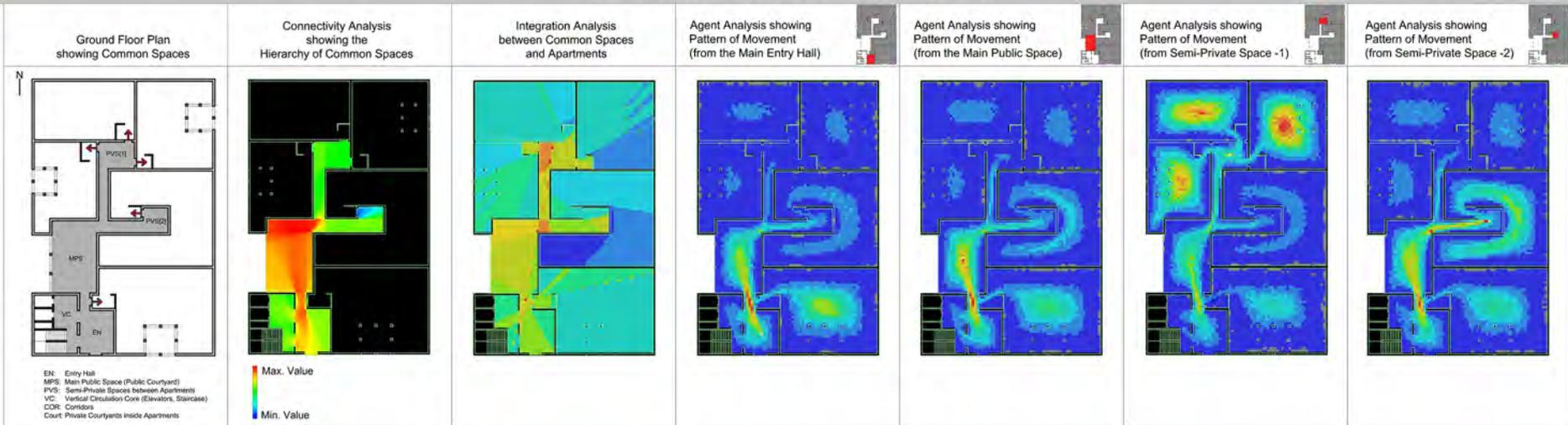
Case No. (3): Ground Floor

Visibility Study for the Ground Floor  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



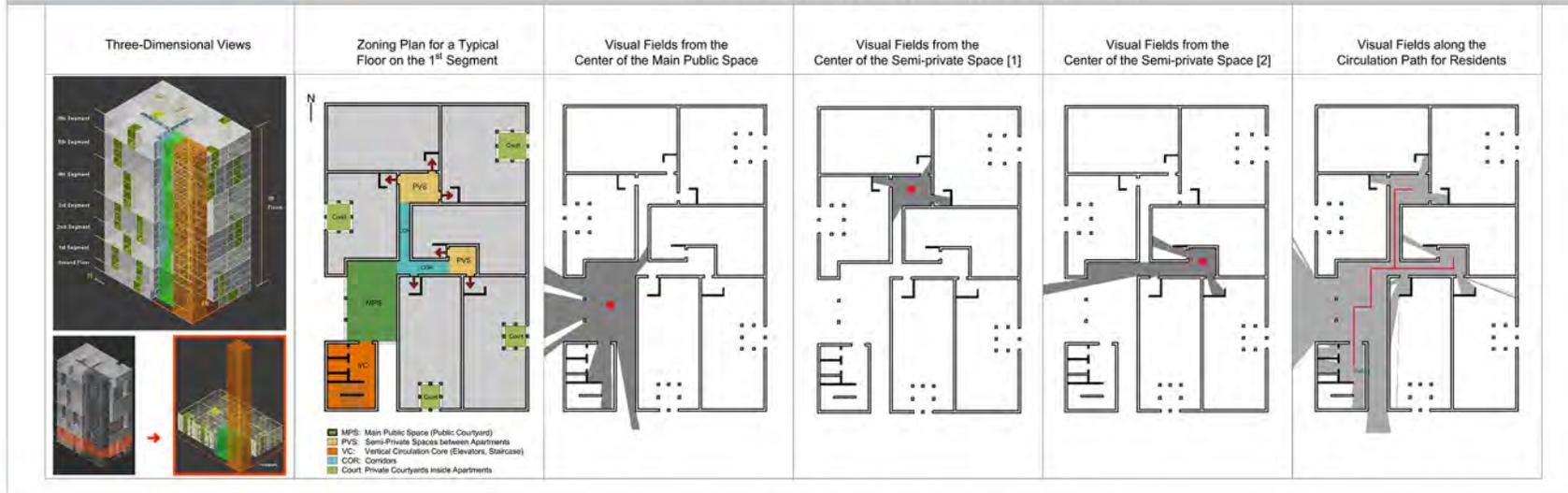
Case No. (3): Ground Floor

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for the Ground Floor  
(Carried out by Author using 'DepthMapX 0.50 Software')



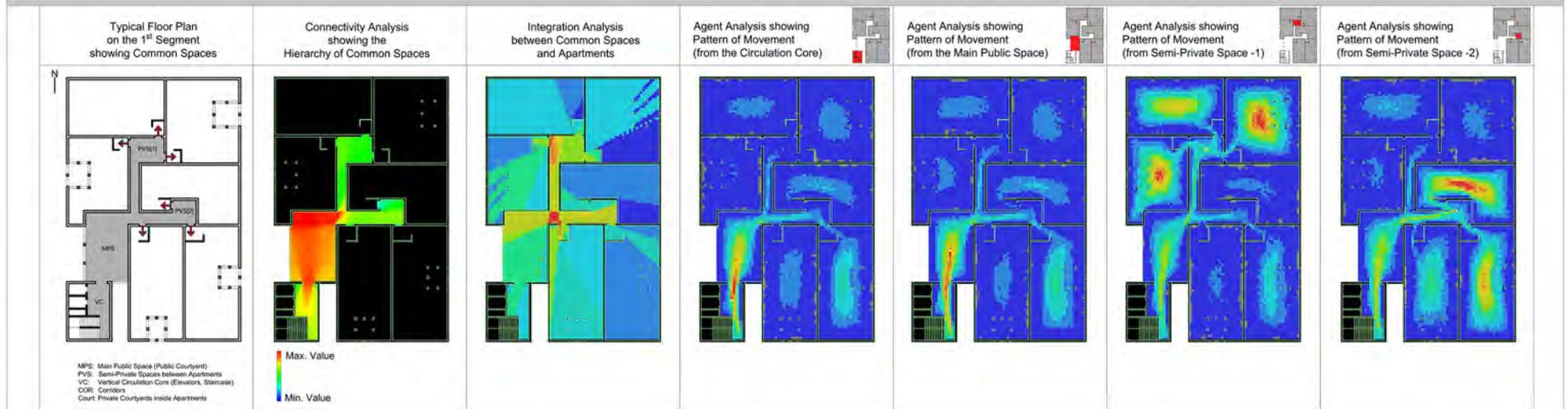
Case No. (3): 1<sup>st</sup> Segment

Visibility Study for a Typical Floor located on the 1<sup>st</sup> Segment  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



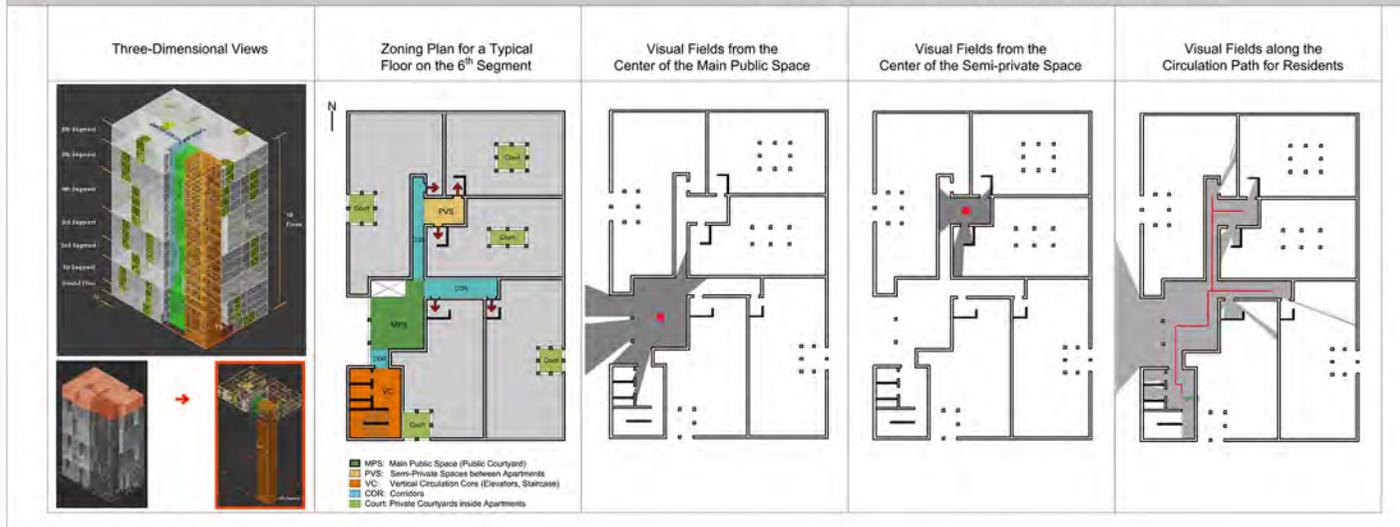
Case No. (3): 1<sup>st</sup> Segment

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for a Typical Floor located on the 1<sup>st</sup> Segment  
(Carried out by Author using 'DepthMapX 0.50 Software')



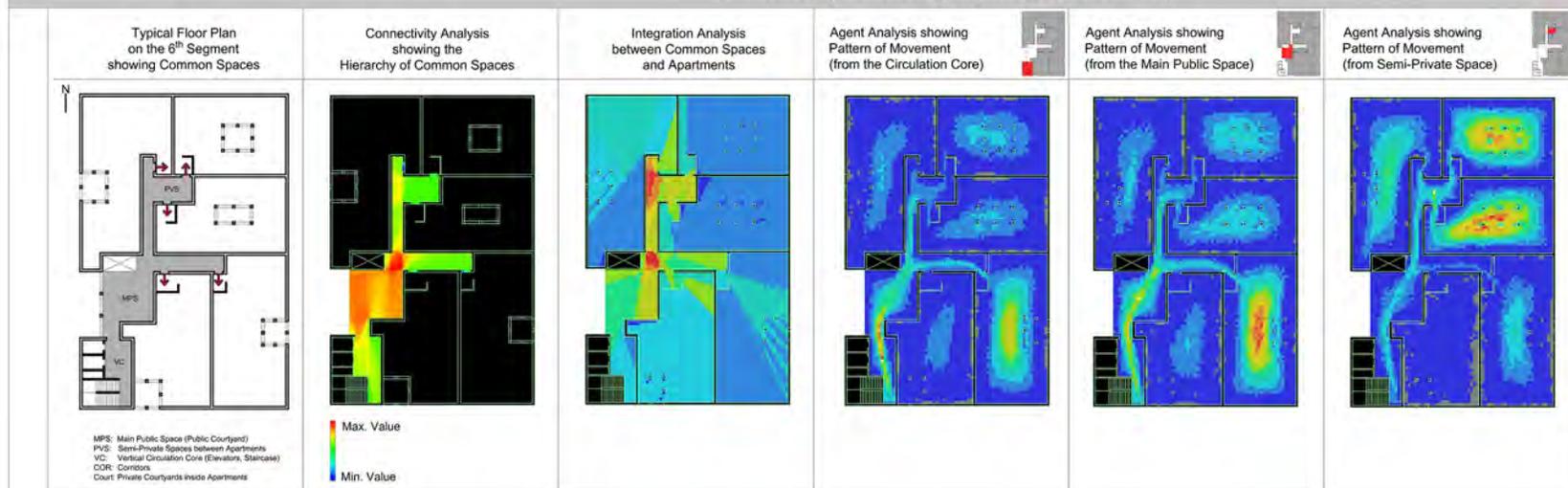
Case No. (3): 6<sup>th</sup> Segment

Visibility Study for a Typical Floor located on the 6<sup>th</sup> Segment  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



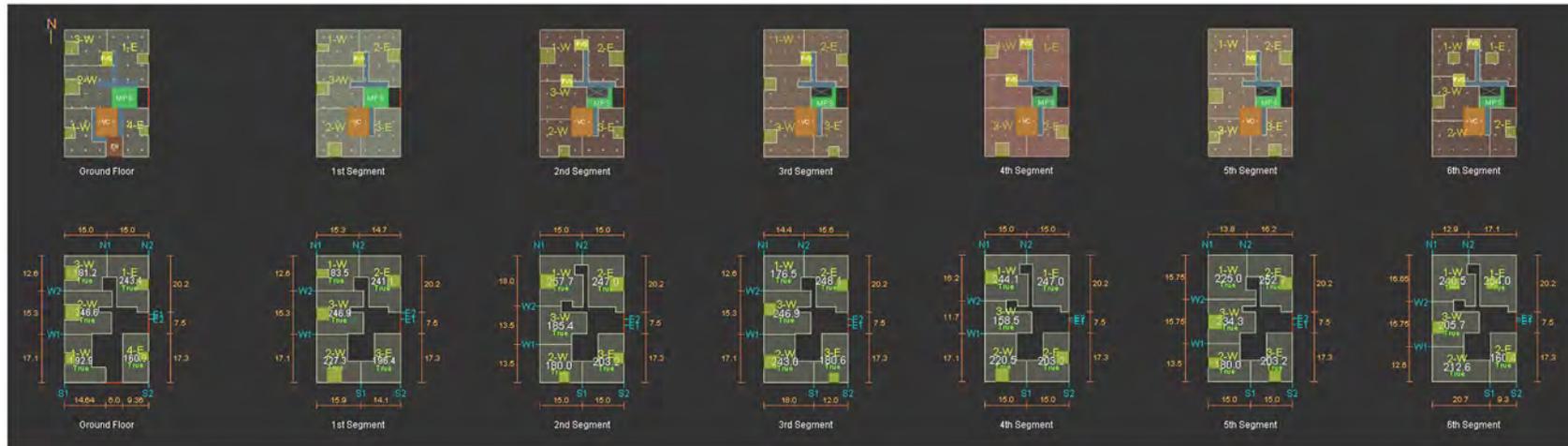
Case No. (3): 6<sup>th</sup> Segment

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for a Typical Floor located on the 6<sup>th</sup> Segment  
(Carried out by Author using 'DepthMapX 0.50 Software')

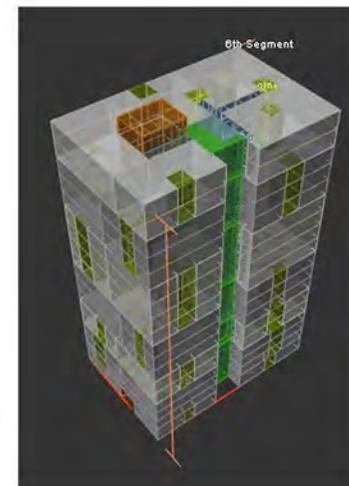
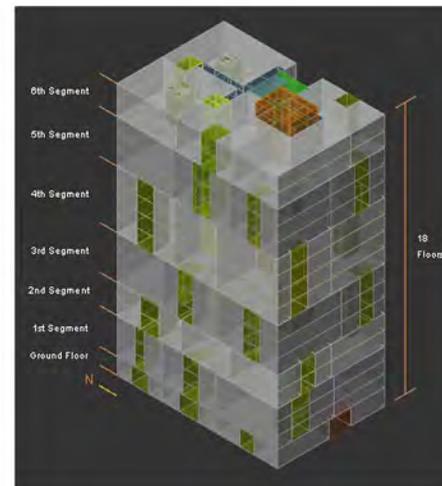
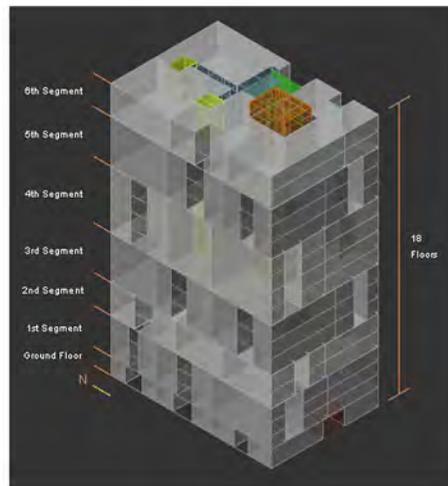


Case No. 4

Floors Plans and Three-Dimensional Views

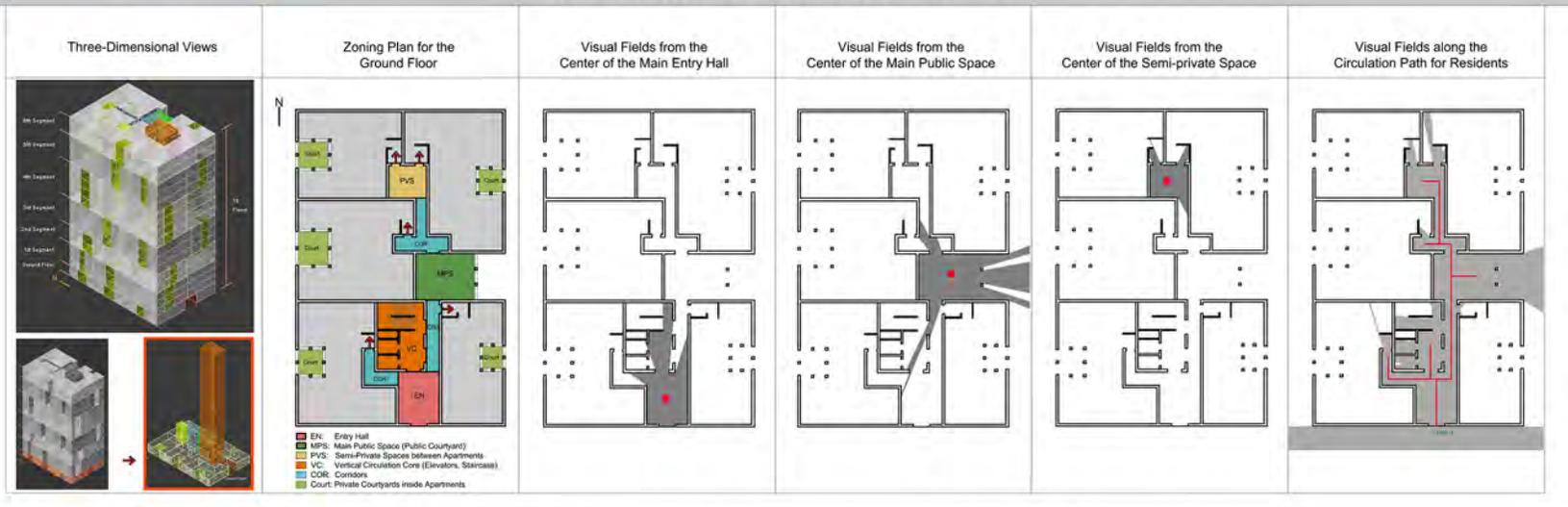


- EN: Entry Hall
- MPS: Main Public Space (Public Courtyard)
- PVS: Semi-Private Spaces between Apartments
- VC: Vertical Circulation Core (Elevators, Staircase)
- COR: Corridors
- Court: Private Courtyards inside Apartments



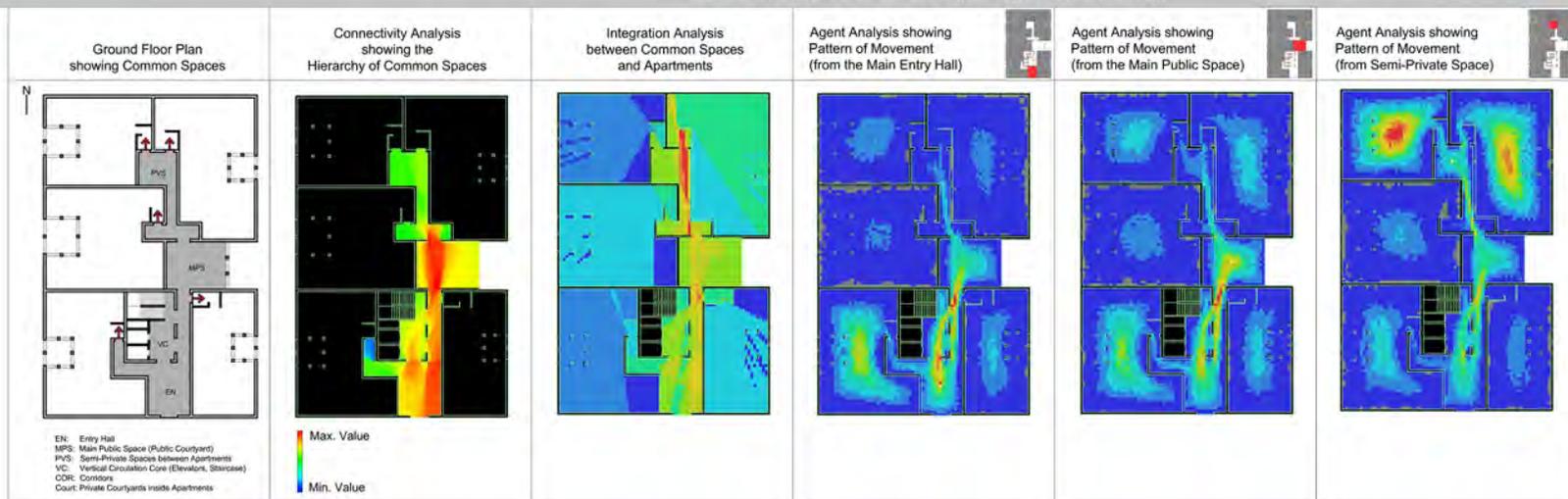
Case No. (4): Ground Floor

Visibility Study for the Ground Floor  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



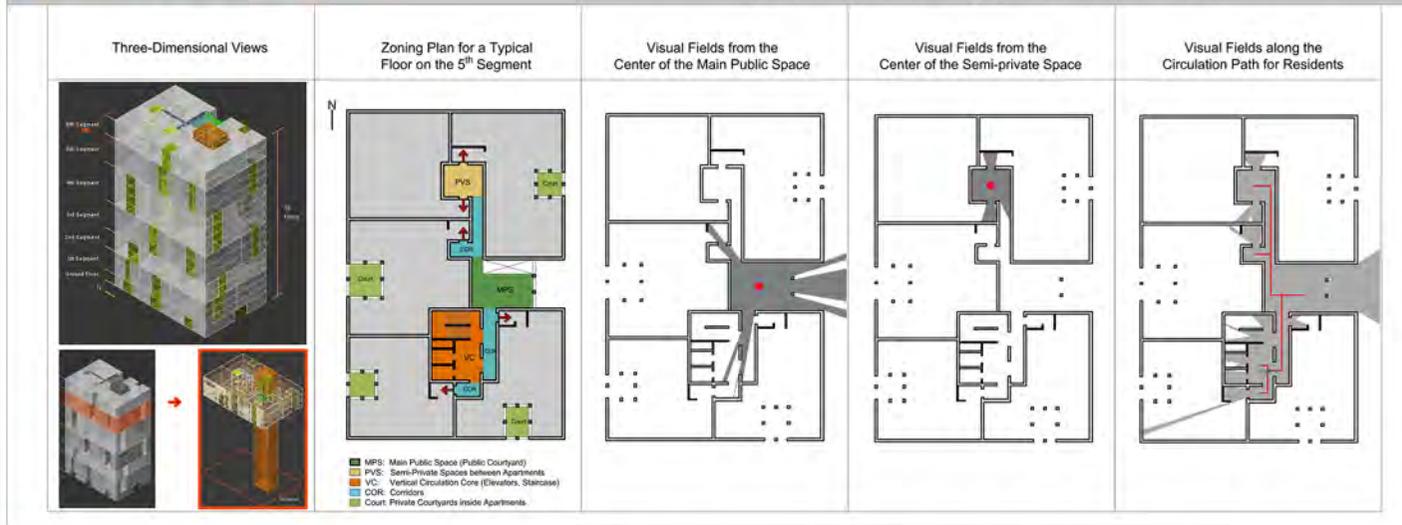
Case No. (4): Ground Floor

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for the Ground Floor  
(Carried out by Author using 'DepthMapX 0.50 Software')



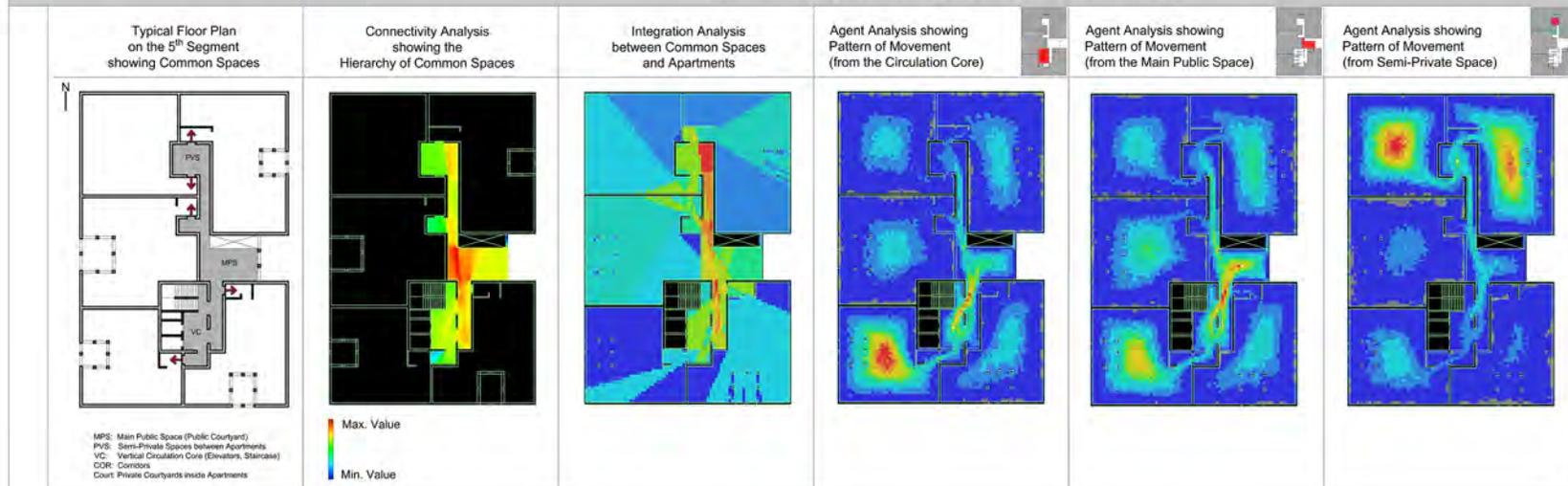
Case No. (4): 5<sup>th</sup> Segment

Visibility Study for a Typical Floor located on the 5<sup>th</sup> Segment  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



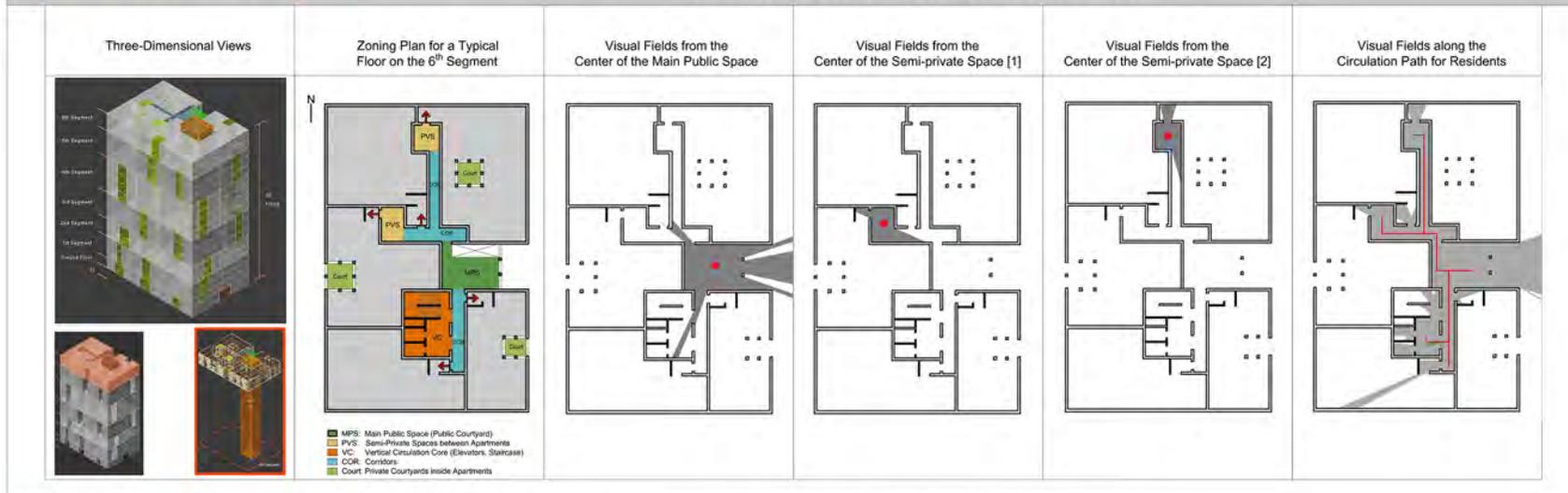
Case No. (4): 5<sup>th</sup> Segment

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for a Typical Floor located on the 5<sup>th</sup> Segment  
(Carried out by Author using 'DepthMapX 0.50 Software')



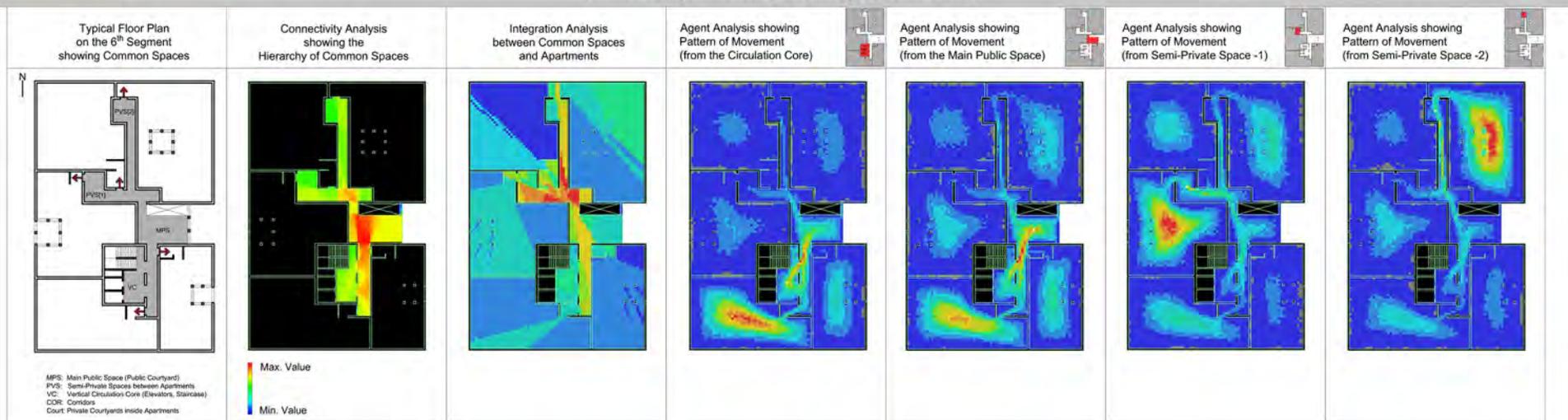
Case No. (4): 6<sup>th</sup> Segment

Visibility Study for a Typical Floor located on the 6<sup>th</sup> Segment  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



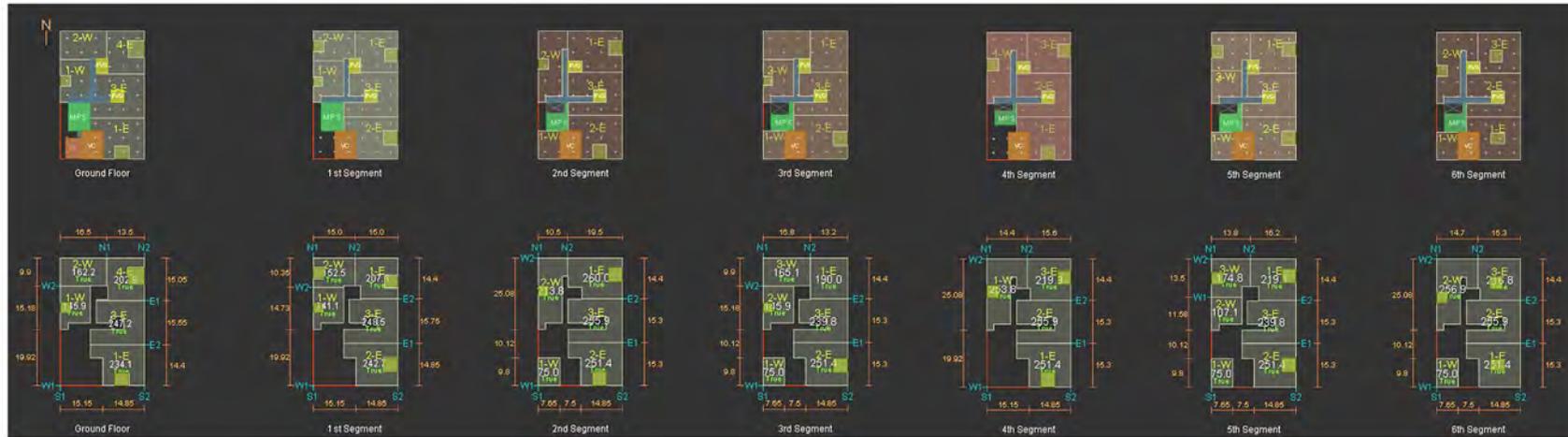
Case No. (4): 6<sup>th</sup> Segment

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for a Typical Floor located on the 6<sup>th</sup> Segment  
(Carried out by Author using 'DepthMapX 0.50 Software')

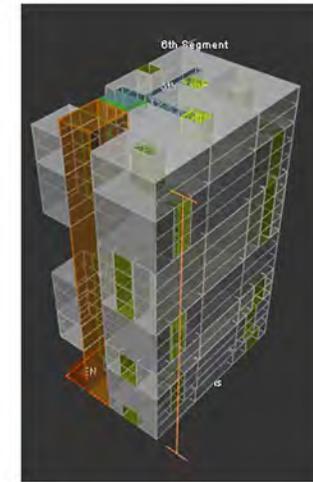
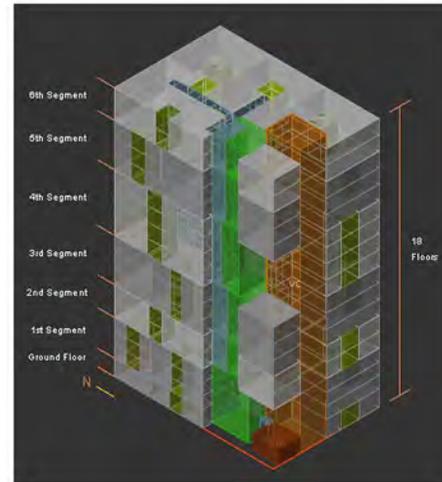
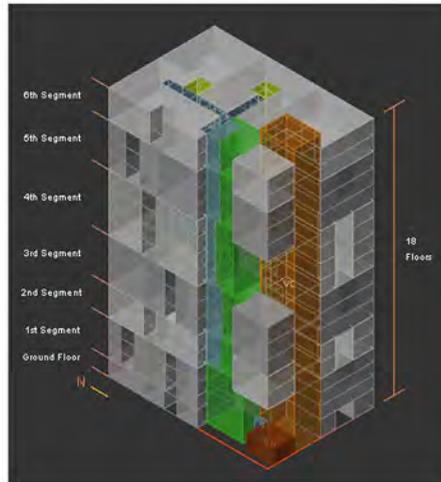


Case No. 5

Floors Plans and Three-Dimensional Views

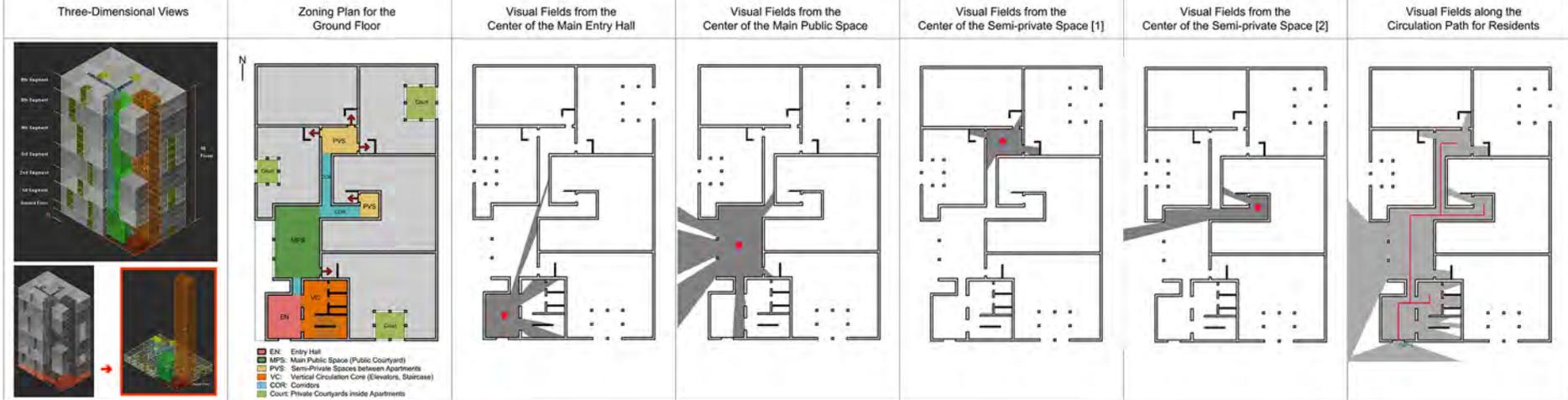


- EN: Entry Hall
- MPS: Main Public Space (Public Courtyard)
- PVS: Semi-Private Spaces between Apartments
- VC: Vertical Circulation Core (Elevators, Staircase)
- COR: Corridors
- Court: Private Courtyards inside Apartments



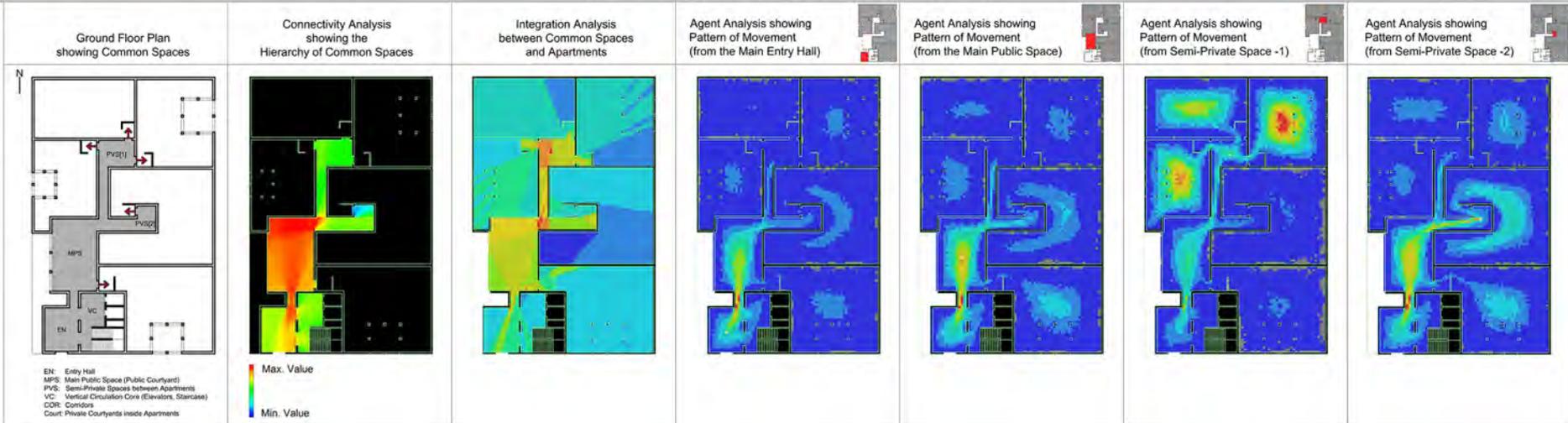
Case No. (5): Ground Floor

Visibility Study for the Ground Floor  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



Case No. (5): Ground Floor

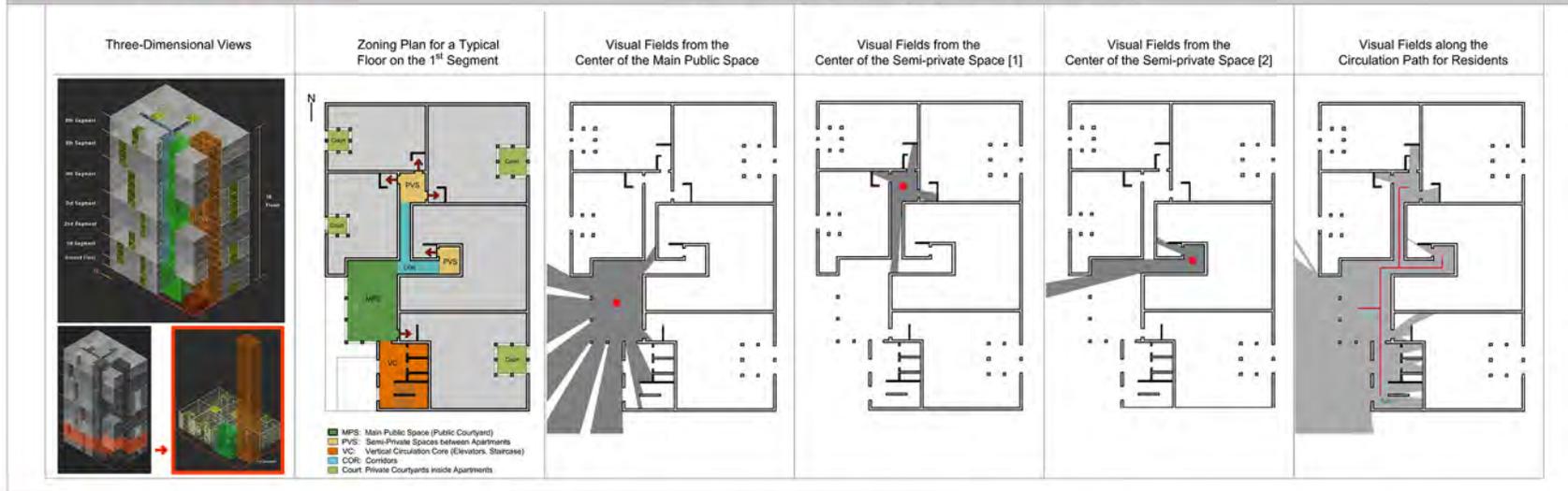
Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for the Ground Floor  
(Carried out by Author using 'DepthMapX 0.50 Software')



Case No. (5): 1<sup>st</sup> Segment

Visibility Study for a Typical Floor located on the 1<sup>st</sup> Segment

(Carried out by Author using 'Syntax2D 1.3.0.7 Software')

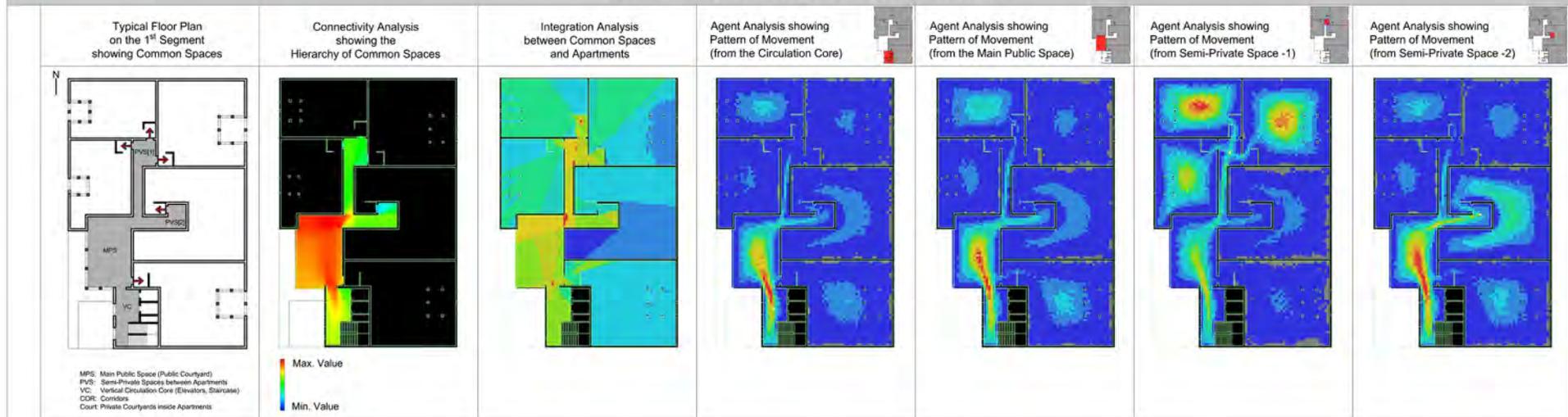


Case No. (5): 1<sup>st</sup> Segment

Syntactic Analysis (using Visibility Graph Analysis - VGA)

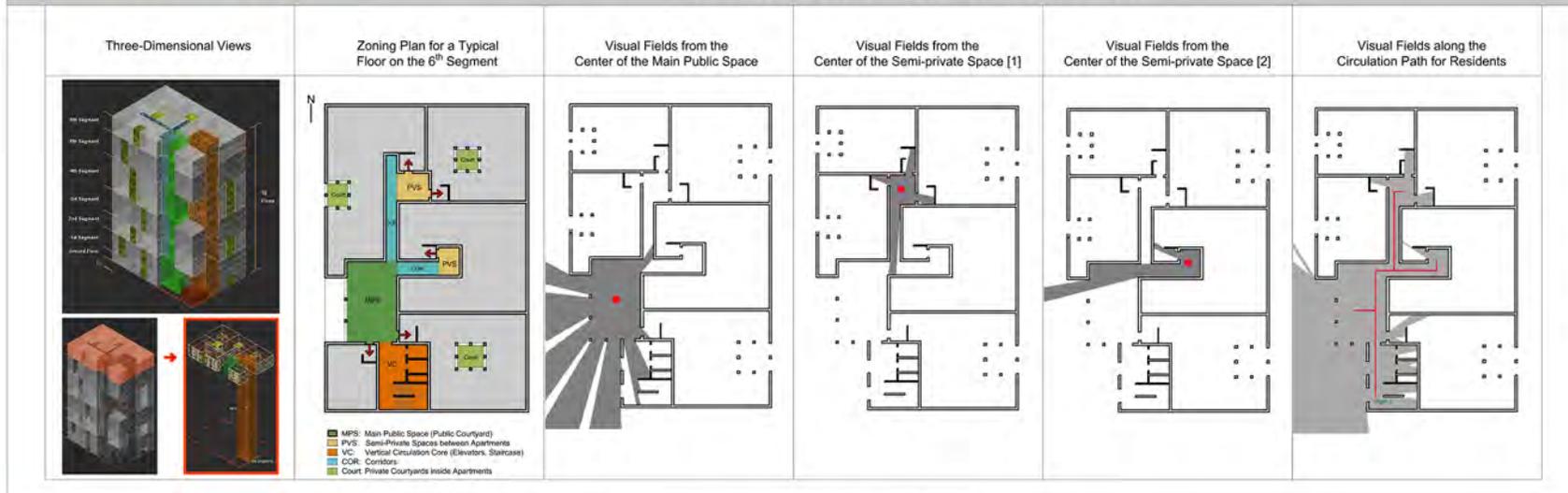
for a Typical Floor located on the 1<sup>st</sup> Segment

(Carried out by Author using 'DepthMapX 0.50 Software')



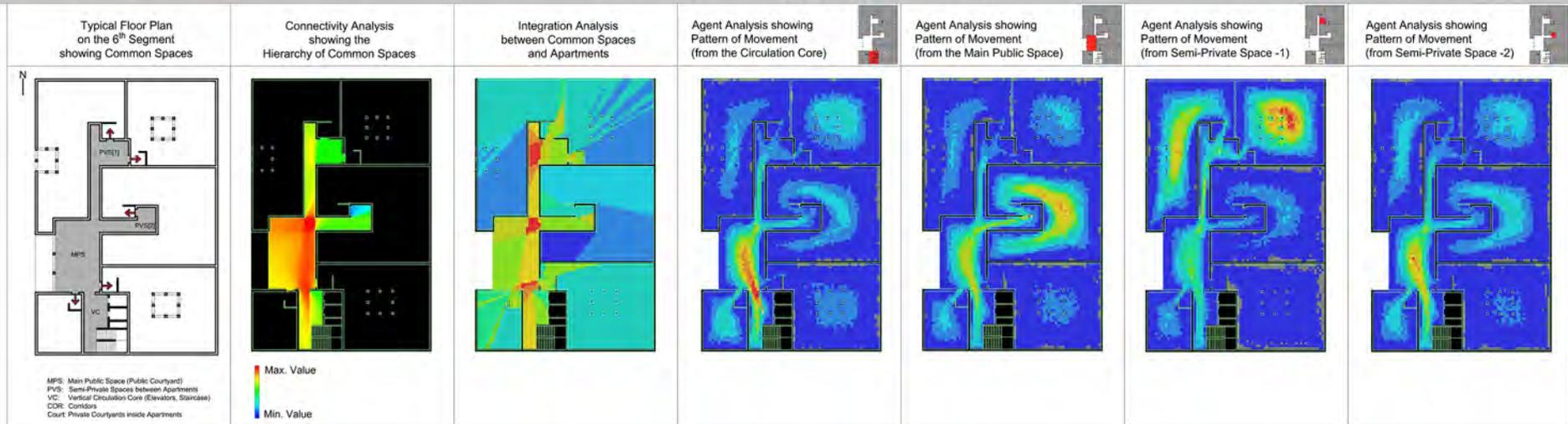
Case No. (5): 6<sup>th</sup> Segment

Visibility Study for a Typical Floor located on the 6<sup>th</sup> Segment  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



Case No. (5): 6<sup>th</sup> Segment

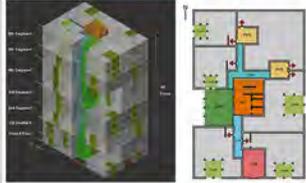
Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for a Typical Floor located on the 6<sup>th</sup> Segment  
(Carried out by Author using 'DepthMapX 0.50 Software')



Appendix (5-C-3)

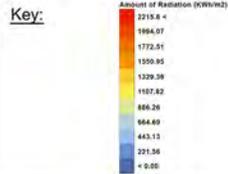
**Results of Radiation Analysis for  
All Cases generated by the Researcher**

Case No. (1)



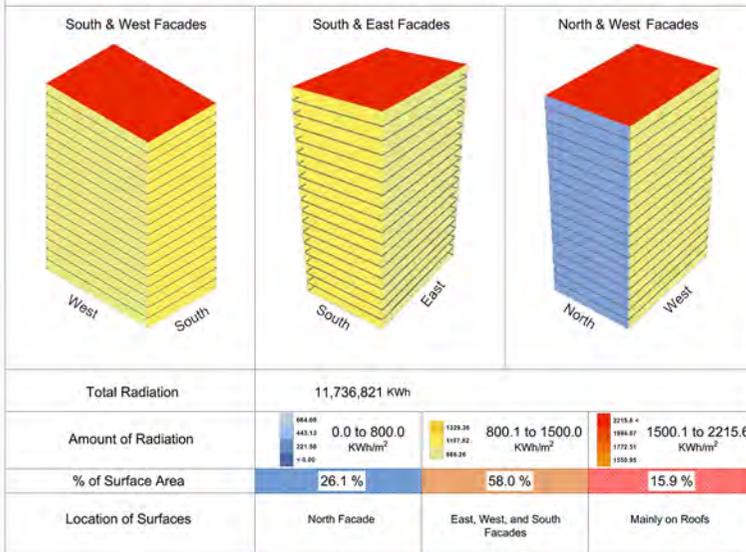
Settings:

- \* All weather data are obtained from (<http://Energyplus.net/weather>), accessed on 24.11.2017
- \* Size of a grid cell for radiation analysis on the test surface = 1 x 1 meter
- \* Total radiation in KWh, falling on the envelope of the building, is computed through a mass addition of results at each of the test points in  $KWh/m^2$  multiplied by the area of the face that the test points is representing.
- \* Time: 1 JAN 1:00 - 31 DEC 24:00

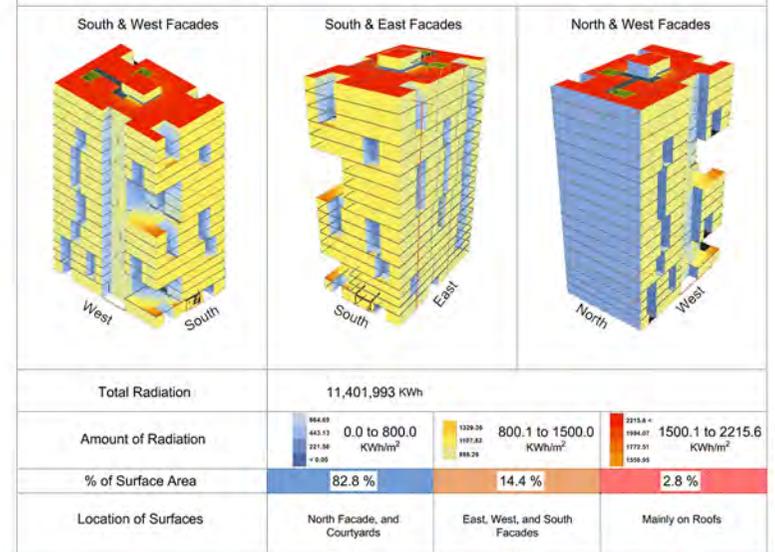


Radiation Analysis (Weather: Riyadh, KSA) Case No. (1)  
(carried out by Author using Ladybug Plug-in, Grasshopper/Rhinoceros 5)

18-Floor Building Mass (30x45x70 meters) with No Courtyards



The Proposed Design (30x45x70 meters) with Courtyards



Reduced: (568%)

Reduced: (403%)

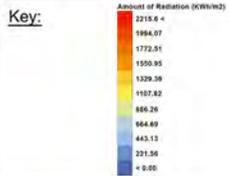
Increased: +315%

Case No. (2)



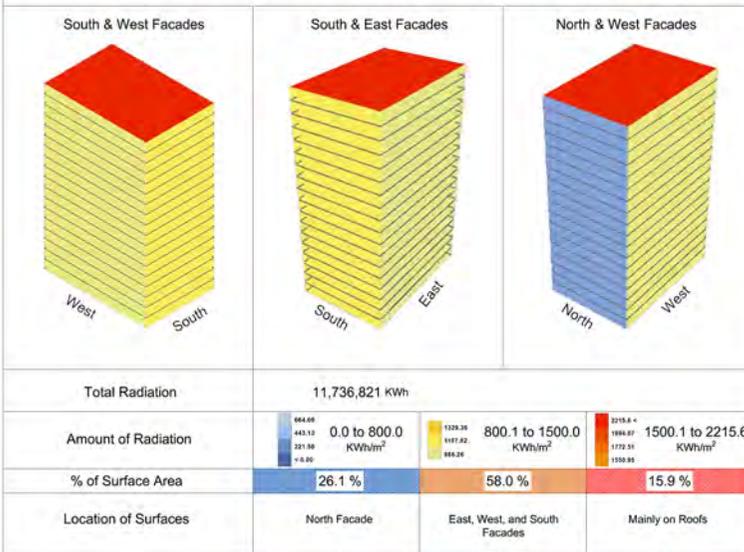
Settings:

- \* All weather data are obtained from (<http://Energyplus.net/weather>), accessed on 24.11.2017
- \* Size of a grid cell for radiation analysis on the test surface = 1 x 1 meter
- \* Total radiation in KWh, falling on the envelope of the building, is computed through a mass addition of results at each of the test points in  $KWh/m^2$  multiplied by the area of the face that the test points is representing.
- \* Time: 1 JAN 1:00 - 31 DEC 24:00

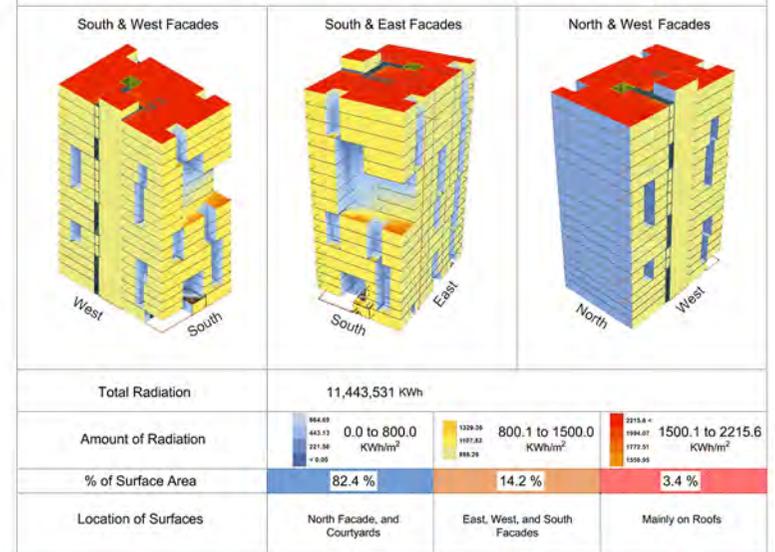


Radiation Analysis (Weather: Riyadh, KSA) Case No. (2)  
(carried out by Author using Ladybug Plug-in, Grasshopper/Rhinoceros 5)

18-Floor Building Mass (30x45x70 meters) with No Courtyards



The Proposed Design (30x45x70 meters) with Courtyards



Reduced: (470%)

Reduced: (410%)

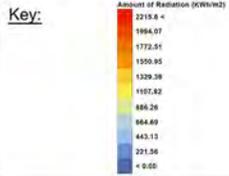
Increased: +315%

Case No. (3)



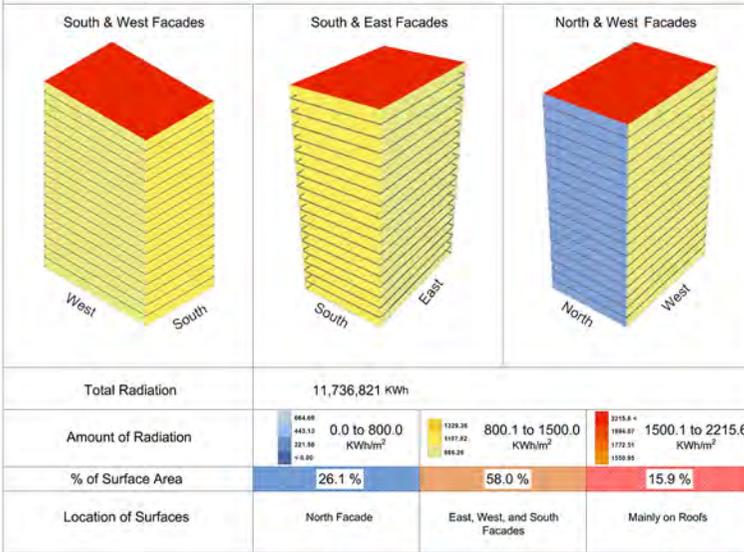
**Settings:**

- \* All weather data are obtained from (<http://Energyplus.net/weather>), accessed on 24.11.2017
- \* Size of a grid cell for radiation analysis on the test surface = 1 x 1 meter
- \* Total radiation in KWh, falling on the envelope of the building, is computed through a mass addition of results at each of the test points in  $KWh/m^2$  multiplied by the area of the face that the test points is representing.
- \* Time: 1 JAN 1:00 - 31 DEC 24:00

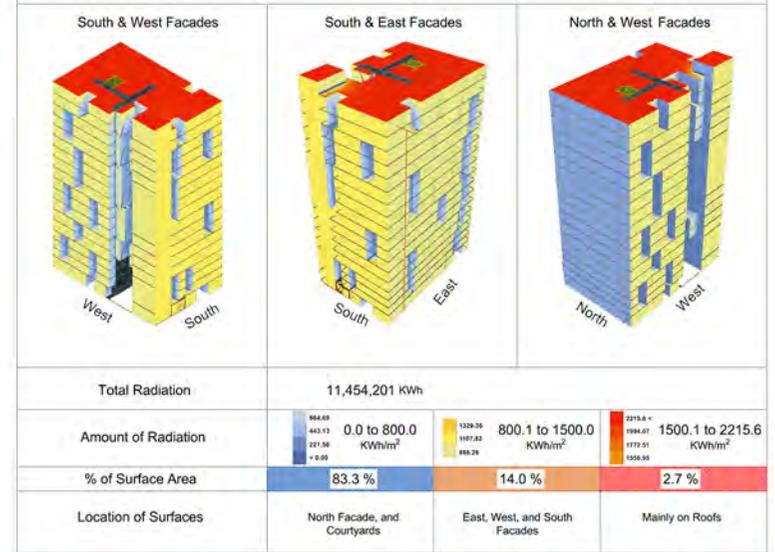


**Radiation Analysis (Weather: Riyadh, KSA) Case No. (3)**  
(carried out by Author using Ladybug Plug-in, Grasshopper/Rhinoceros 5)

**18-Floor Building Mass (30x45x70 meters) with No Courtyards**



**The Proposed Design (30x45x70 meters) with Courtyards**

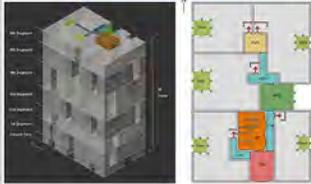


Reduced: (590%)

Reduced: (415%)

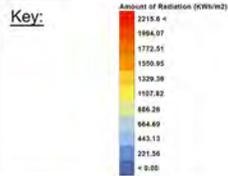
Increased: +320

Case No. (4)



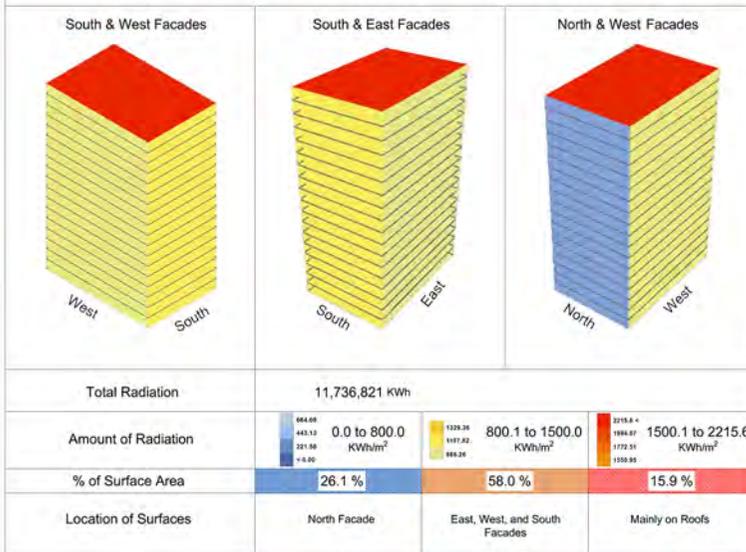
Settings:

- \* All weather data are obtained from (<http://Energyplus.net/weather>), accessed on 24.11.2017
- \* Size of a grid cell for radiation analysis on the test surface = 1 x 1 meter
- \* Total radiation in KWh, falling on the envelope of the building, is computed through a mass addition of results at each of the test points in KWh/m<sup>2</sup> multiplied by the area of the face that the test points is representing.
- \* Time: 1 JAN 1:00 - 31 DEC 24:00

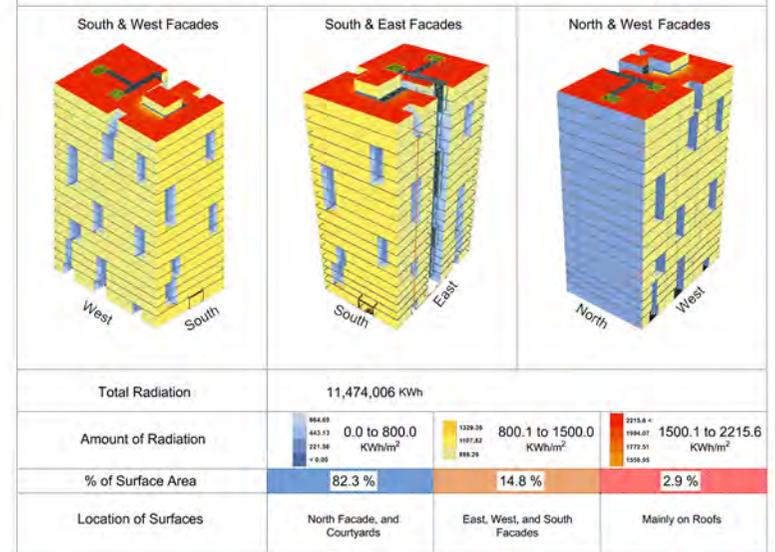


Radiation Analysis (Weather: Riyadh, KSA) Case No. (4)  
(carried out by Author using Ladybug Plug-in, Grasshopper/Rhinoceros 5)

18-Floor Building Mass (30x45x70 meters) with No Courtyards



The Proposed Design (30x45x70 meters) with Courtyards

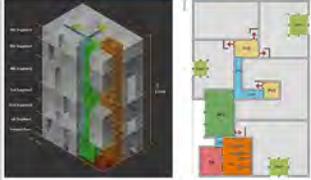


Reduced: (550%)

Reduced: (392%)

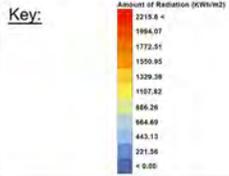
Increased: +315

**Case No. (5)**



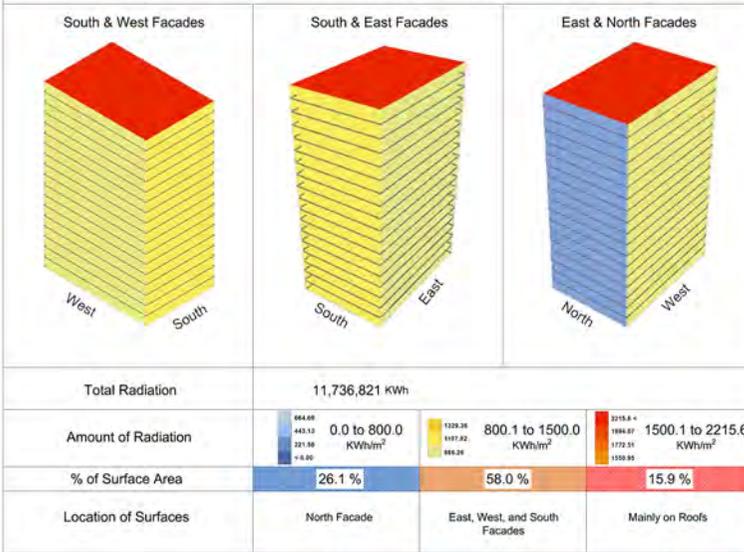
**Settings:**

- \* All weather data are obtained from (<http://Energyplus.net/weather>), accessed on 24.11.2017
- \* Size of a grid cell for radiation analysis on the test surface = 1 x 1 meter
- \* Total radiation in KWh, falling on the envelope of the building, is computed through a mass addition of results at each of the test points in KWh/m<sup>2</sup> multiplied by the area of the face that the test points is representing.
- \* Time: 1 JAN 1:00 - 31 DEC 24:00

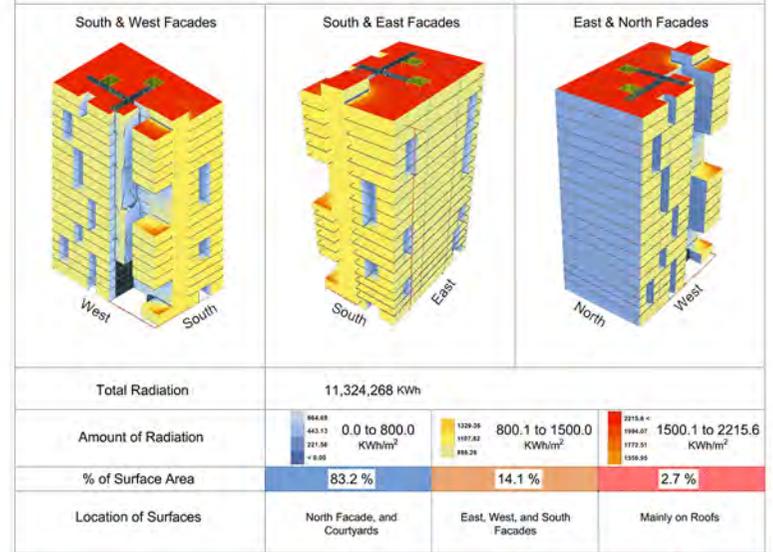


**Radiation Analysis (Weather: Riyadh, KSA) Case No. (5)**  
(carried out by Author using Ladybug Plug-in, Grasshopper/Rhinoceros 5)

**18-Floor Building Mass (30x45x70 meters) with No Courtyards**



**The Proposed Design (30x45x70 meters) with Courtyards**



**Reduced: (590%)**

**Reduced: (411%)**

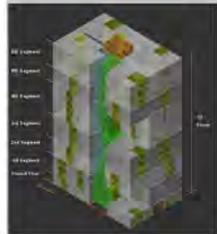
**Increased: +320**

Appendix (5-C-4)

**Detailed Spatial Calculations for  
All Cases generated by the Researcher**

Case No. 1

Spatial Calculations



Ground Floor Plan

Overall Calculations for the Building

|   |      |  |          |
|---|------|--|----------|
| Total Allowable Area for the Building (m <sup>2</sup> ) |      | 24300.0  |          |
| Total Designed Area for the Building (m <sup>2</sup> )  |      | 22517.51   |          |
| Total Number of Floors                                  | 18   | Total Area of Common Spaces on All Floors (m <sup>2</sup> )          | 4158.49  |
|   |      | = 18.47 % of the Total Designed Area                                 |          |
| Total Height of the Building (meter)                    | 70.4 | Total Area of Residential Apartments on All Floors (m <sup>2</sup> ) | 18359.02 |
|   |      | = 81.53 % of the Total Designed Area                                 |          |

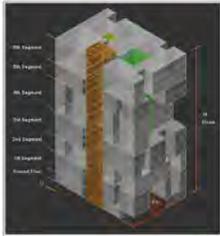
|              | Number of Floors | Total Number of Apartments | Number of Apartments on Each Floor | Designed Area of Each Floor on the Segment (m <sup>2</sup> ) | Total Designed Area for All Floors on Each Segment (m <sup>2</sup> ) | % from the Total Designed Area of the Building |
|--------------|------------------|----------------------------|------------------------------------|--|--|--|
| Ground Floor | 1                | 6                          | 6                                  | 1317.79  | 1317.79  | 5.85 %   |
| 1st Segment  | 3                | 18                         | 6                                  | 1161.9   | 3485.7   | 15.4 %   |
| 2nd Segment  | 2                | 10                         | 5                                  | 1317.79  | 2635.58  | 11.7 %   |
| 3rd Segment  | 3                | 15                         | 5                                  | 1317.79  | 3953.37  | 17.5 %   |
| 4th Segment  | 4                | 20                         | 5                                  | 1134.03  | 4536.12  | 20.1 %   |
| 5th Segment  | 2                | 10                         | 5                                  | 1317.79  | 2635.58  | 11.7 %   |
| 6th Segment  | 3                | 15                         | 5                                  | 1317.79  | 3953.37  | 17.5 %   |
| <b>TOTAL</b> | <b>18</b>        | <b>94</b>                  |                                    |  | <b>22517.51</b>  |  |

Detailed Calculations for Residential Apartments

|              | Private Courtyards inside Apartments |   |                                     |                                   |  | Area of Apartments (including Courtyards) |                               |                                   |  |
|--------------|--------------------------------------|---|-------------------------------------|-----------------------------------|--|---|-------------------------------|-----------------------------------|--|
|              | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Apartments on Each Floor | % from the Total Area of Each Floor | Area on All Floors of the Segment | % from the Total Designed Area of the Building | Area on Each Floor (m <sup>2</sup> )      | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Designed Area of the Building |
| Ground Floor | 100.3                                | 9.94 %                                      | 7.61 %                              | 100.3                             | 0.45 %   | 1008.9                                    | 74.71 %                       | 1008.9                            | 4.48 %   |
| 1st Segment  | 106.0                                | 11.52 %                                     | 9.12 %                              | 318.0                             | 1.41 %   | 920.03                                    | 68.15 %                       | 2760.0                            | 12.26 %  |
| 2nd Segment  | 107.2                                | 9.69 %                                      | 8.13 %                              | 214.4                             | 0.95 %   | 1106.7                                    | 81.98 %                       | 2213.52                           | 9.83 %   |
| 3rd Segment  | 119.5                                | 11.11 %                                     | 9.07 %                              | 358.5                             | 1.59 %   | 1075.9                                    | 79.7 %                        | 3227.75                           | 14.33 %  |
| 4th Segment  | 96.1                                 | 10.46 %                                     | 8.47 %                              | 384.4                             | 1.71 %   | 919.16                                    | 65.09 %                       | 3676.64                           | 16.33 %  |
| 5th Segment  | 121.4                                | 10.98 %                                     | 9.21 %                              | 242.8                             | 1.08 %   | 1105.6                                    | 81.9 %                        | 2211.29                           | 9.82 %   |
| 6th Segment  | 122.8                                | 11.3 %                                      | 9.32 %                              | 368.4                             | 1.64 %   | 1086.9                                    | 80.51 %                       | 3260.82                           | 14.48 %  |
| <b>TOTAL</b> |                                      |   |                                     | <b>1987</b>                       | <b>8.83 %</b>                                  |   |                               | <b>18359.02</b>                   | <b>81.53 %</b>                                 |
|              |                                      |   |                                     |                                   | <b>10.82 %</b>                                 |   |                               |                                   |  |

Detailed Calculations for Common Spaces inside the Building

|              | Main Public Space (MPS)              |                               |                                   |                                       | Semi-Private Spaces (PVS)            |                               |                                   |                                       | Entry Hall (EN)        |                              |                                       | Corridors (COR)                      |                               |                                   | Vertical Core (VC)                    |                                      |                               |                                   |                                       |
|--------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|------------------------|------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|
|              | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area (m <sup>2</sup> ) | % from the Area of the Floor | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building |
| Ground Floor | 79.28                                | 6.02 %                        | 79.28                             | 0.35 %                                | 39.64                                | 3.01 %                        | 39.64                             | 0.18 %                                | 45.0                   | 3.41 %                       | 0.2 %                                 | 71.46                                | 5.42 %                        | 71.46                             | 0.32 %                                | 73.5                                 | 5.58 %                        | 73.5                              | 0.33 %                                |
| 1st Segment  | 79.28                                | 6.82 %                        | 237.84                            | 1.06 %                                | 39.64                                | 3.41 %                        | 118.92                            | 0.53 %                                |                        |                              |                                       | 49.46                                | 4.26 %                        | 148.38                            | 0.66 %                                | 73.5                                 | 6.33 %                        | 220.5                             | 0.98 %                                |
| 2nd Segment  | 30.09                                | 2.28 %                        | 60.18                             | 0.27 %                                | 39.61                                | 3.01 %                        | 79.22                             | 0.35 %                                |                        |                              |                                       | 50.36                                | 3.82 %                        | 100.72                            | 0.45 %                                | 73.5                                 | 5.58 %                        | 147.0                             | 0.65 %                                |
| 3rd Segment  | 49.74                                | 3.77 %                        | 149.22                            | 0.66 %                                | 39.64                                | 3.01 %                        | 118.92                            | 0.53 %                                |                        |                              |                                       | 49.46                                | 3.75 %                        | 148.38                            | 0.66 %                                | 73.5                                 | 5.58 %                        | 220.5                             | 0.98 %                                |
| 4th Segment  | 38.49                                | 3.39 %                        | 153.96                            | 0.68 %                                | 39.61                                | 3.49 %                        | 158.44                            | 0.7 %                                 |                        |                              |                                       | 50.36                                | 4.44 %                        | 201.44                            | 0.89 %                                | 73.5                                 | 6.48 %                        | 294.0                             | 1.31 %                                |
| 5th Segment  | 31.8                                 | 2.41 %                        | 63.0                              | 0.28 %                                | 39.64                                | 3.01 %                        | 79.28                             | 0.35 %                                |                        |                              |                                       | 49.46                                | 3.75 %                        | 98.92                             | 0.44 %                                | 73.5                                 | 5.58 %                        | 147.0                             | 0.65 %                                |
| 6th Segment  | 43.84                                | 3.33 %                        | 131.52                            | 0.58 %                                | 39.61                                | 3.01 %                        | 118.83                            | 0.53 %                                |                        |                              |                                       | 50.36                                | 3.82 %                        | 151.08                            | 0.67 %                                | 73.5                                 | 5.58 %                        | 220.5                             | 0.98 %                                |
| <b>TOTAL</b> |                                      |                               | <b>875.6</b>                      | <b>3.88 %</b>                         |                                      |                               | <b>713.25</b>                     | <b>3.17 %</b>                         | <b>45.0</b>            | <b>3.41 %</b>                | <b>0.2 %</b>                          |                                      | <b>920.38</b>                 | <b>4.09 %</b>                     |                                       |                                      | <b>1323.0</b>                 | <b>5.88 %</b>                     |                                       |



Ground Floor Plan

Overall Calculations for the Building

|   |      |  |   |
|---|------|--|---|
| Total Allowable Area for the Building (m <sup>2</sup> ) |      | 24300.0  |   |
| Total Designed Area for the Building (m <sup>2</sup> )  |      | 22922.68   |   |
| Total Number of Floors                                  | 18   | Total Area of Common Spaces on All Floors (m <sup>2</sup> )          | 4292.96 = 18.73 % of the Total Designed Area  |
| Total Height of the Building (meter)                    | 70.4 | Total Area of Residential Apartments on All Floors (m <sup>2</sup> ) | 18629.72 = 81.27 % of the Total Designed Area |

|              | Number of Floors | Total Number of Apartments | Number of Apartments on Each Floor | Designed Area of Each Floor on the Segment (m <sup>2</sup> ) | Total Designed Area for All Floors on Each Segment (m <sup>2</sup> ) | % from the Total Designed Area of the Building |
|--------------|------------------|----------------------------|------------------------------------|--|--|--|
| Ground Floor | 1                | 6                          | 6                                  | 1214.77  | 1214.77  | 5.81 %   |
| 1st Segment  | 3                | 15                         | 5                                  | 1147.27  | 3441.81  | 16.47 %  |
| 2nd Segment  | 2                | 10                         | 5                                  | 1214.77  | 2429.54  | 11.62 %  |
| 3rd Segment  | 3                | 18                         | 6                                  | 1214.77  | 3644.31  | 17.44 %  |
| 4th Segment  | 4                | 20                         | 5                                  | 1057.5   | 4230.0   | 20.24 %  |
| 5th Segment  | 2                | 10                         | 5                                  | 1147.27  | 2294.54  | 10.98 %  |
| 6th Segment  | 3                | 15                         | 5                                  | 1214.77  | 3644.31  | 17.44 %  |
| <b>TOTAL</b> | <b>18</b>        | <b>94</b>                  |                                    |  | <b>22922.68</b>  |  |

Detailed Calculations for Residential Apartments

|              | Private Courtyards inside Apartments |   |                                     |                                   | Area of Apartments (including Courtyards)      |                                      |  |                                   |  |
|--------------|--------------------------------------|---|-------------------------------------|-----------------------------------|--|--------------------------------------|--|-----------------------------------|--|
|              | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Apartments on Each Floor | % from the Total Area of Each Floor | Area on All Floors of the Segment | % from the Total Designed Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of All Floors of the Segment | Area on All Floors of the Segment | % from the Total Designed Area of the Building |
| Ground Floor | 65.6                                 | 7.21 %                                      | 5.4 %                               | 65.6                              | 0.31 %   | 909.4                                | 67.36 %                                      | 909.4                             | 4.35 %   |
| 1st Segment  | 70.8                                 | 7.07 %                                      | 6.17 %                              | 212.4                             | 1.02 %   | 1000.86                              | 74.14 %                                      | 1302.59                           | 14.37 %  |
| 2nd Segment  | 101.3                                | 8.8 %                                       | 8.34 %                              | 202.6                             | 0.97 %   | 1150.64                              | 85.23 %                                      | 1301.28                           | 11.01 %  |
| 3rd Segment  | 113.7                                | 10.64 %                                     | 9.36 %                              | 341.1                             | 1.63 %   | 1058.36                              | 79.14 %                                      | 1205.09                           | 15.34 %  |
| 4th Segment  | 89.5                                 | 9.36 %                                      | 8.46 %                              | 358.0                             | 1.71 %   | 956.64                               | 70.86 %                                      | 1182.57                           | 18.31 %  |
| 5th Segment  | 52.6                                 | 5.26 %                                      | 4.58 %                              | 105.2                             | 0.5 %  | 1000.86                              | 74.14 %                                      | 2001.73                           | 9.58 %   |
| 6th Segment  | 104.8                                | 9.29 %                                      | 8.63 %                              | 314.4                             | 1.5 %  | 1127.69                              | 83.53 %                                      | 1383.06                           | 16.19 %  |
| <b>TOTAL</b> |                                      |   |                                     | <b>1599</b>                       | <b>7.64 %</b>                                  |                                      |  | <b>18629.72</b>                   | <b>81.27 %</b>                                 |

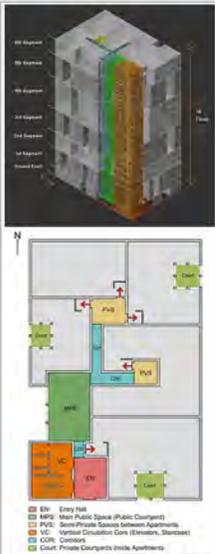
From the Total Area of Apartments

Detailed Calculations for Common Spaces inside the Building

|              | Main Public Space (MPS)              |                               |                                   |                                       | Semi-Private Spaces (PVS)            |                               |                                   |                                       | Entry Hall (EN)        |                              |                                       | Corridors (COR)                      |                               |                                   |                                       | Vertical Core (VC)                   |                               |                                   |                                       |
|--------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|------------------------|------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|
|              | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area (m <sup>2</sup> ) | % from the Area of the Floor | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building |
| Ground Floor | 91.8                                 | 7.56 %                        | 91.8                              | 0.44 %                                | 45.89                                | 3.78 %                        | 45.89                             | 0.22 %                                | 45.0                   | 3.7 %                        | 0.22 %                                | 85.5                                 | 7.04 %                        | 85.5                              | 0.41 %                                | 73.5                                 | 6.05 %                        | 73.5                              | 0.35 %                                |
| 1st Segment  | 91.8                                 | 8.0 %                         | 275.4                             | 1.32 %                                | 45.89                                | 4.0 %                         | 137.67                            | 0.66 %                                |                        |                              |                                       | 70.55                                | 6.15 %                        | 211.65                            | 1.01 %                                | 73.5                                 | 6.41 %                        | 220.5                             | 1.06 %                                |
| 2nd Segment  | 41.96                                | 3.45 %                        | 83.92                             | 0.4 %                                 | 22.95                                | 1.89 %                        | 45.9                              | 0.22 %                                |                        |                              |                                       | 47.88                                | 3.94 %                        | 95.76                             | 0.46 %                                | 73.5                                 | 6.05 %                        | 147.0                             | 0.7 %                                 |
| 3rd Segment  | 61.8                                 | 5.09 %                        | 185.4                             | 0.89 %                                | 45.89                                | 3.78 %                        | 137.67                            | 0.66 %                                |                        |                              |                                       | 70.55                                | 5.81 %                        | 211.65                            | 1.01 %                                | 73.5                                 | 6.05 %                        | 220.5                             | 1.06 %                                |
| 4th Segment  | 68.4                                 | 6.47 %                        | 273.6                             | 1.31 %                                | 22.95                                | 2.17 %                        | 91.8                              | 0.44 %                                |                        |                              |                                       | 47.88                                | 4.53 %                        | 191.52                            | 0.92 %                                | 73.5                                 | 6.95 %                        | 294.0                             | 1.41 %                                |
| 5th Segment  | 68.4                                 | 5.96 %                        | 136.8                             | 0.65 %                                | 45.89                                | 4.0 %                         | 91.78                             | 0.44 %                                |                        |                              |                                       | 70.55                                | 6.15 %                        | 141.1                             | 0.68 %                                | 73.5                                 | 6.41 %                        | 147.0                             | 0.7 %                                 |
| 6th Segment  | 59.22                                | 4.87 %                        | 177.66                            | 0.85 %                                | 22.95                                | 1.89 %                        | 68.85                             | 0.33 %                                |                        |                              |                                       | 47.88                                | 3.94 %                        | 143.64                            | 0.69 %                                | 73.5                                 | 6.05 %                        | 220.5                             | 1.06 %                                |
| <b>TOTAL</b> |                                      |                               | <b>1224.58</b>                    | <b>5.86 %</b>                         |                                      |                               | <b>619.56</b>                     | <b>2.97 %</b>                         | <b>45.0</b>            | <b>3.7 %</b>                 | <b>0.22 %</b>                         |                                      |                               | <b>1080.82</b>                    | <b>5.18 %</b>                         |                                      |                               | <b>1323.0</b>                     | <b>6.34 %</b>                         |

Case No. 3

Spatial Calculations



Ground Floor Plan

Overall Calculations for the Building

|   |      |  |          |
|---|------|--|----------|
| Total Allowable Area for the Building (m <sup>2</sup> ) |      | 24300.0  |          |
| Total Designed Area for the Building (m <sup>2</sup> )  |      | 23248.30   |          |
| Total Number of Floors                                  | 18   | Total Area of Common Spaces on All Floors (m <sup>2</sup> )          | 3906.37  |
| Total Height of the Building (meters)                   | 70.4 | Total Area of Residential Apartments on All Floors (m <sup>2</sup> ) | 19341.93 |
|   |      | = 16.80 % of the Total Designed Area                                 |          |
|   |      | = 83.20 % of the Total Designed Area                                 |          |

|              | Number of Floors | Total Number of Apartments | Number of Apartments on Each Floor | Designed Area of Each Floor on the Segment (m <sup>2</sup> ) | Total Designed Area for All Floors on Each Segment (m <sup>2</sup> ) | % from the Total Designed Area of the Building |
|--------------|------------------|----------------------------|------------------------------------|--|--|--|
| Ground Floor | 1                | 6                          | 6                                  | 1322.17  | 1322.17  | 5.76 %   |
| 1st Segment  | 3                | 18                         | 6                                  | 1216.82  | 3650.46  | 15.9 %   |
| 2nd Segment  | 2                | 10                         | 5                                  | 1322.17  | 2644.34  | 11.5 %   |
| 3rd Segment  | 3                | 18                         | 6                                  | 1322.17  | 3966.51  | 17.2 %   |
| 4th Segment  | 4                | 20                         | 5                                  | 1189.62  | 4758.48  | 20.7 %   |
| 5th Segment  | 3                | 18                         | 6                                  | 1322.17  | 3966.51  | 17.2 %   |
| 6th Segment  | 2                | 10                         | 5                                  | 1322.17  | 2644.34  | 11.5 %   |
| <b>TOTAL</b> | <b>18</b>        | <b>100</b>                 |                                    |  | <b>23248.30</b>  |  |

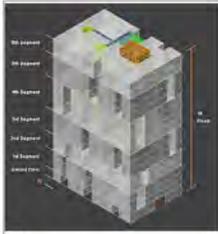
Detailed Calculations for Residential Apartments

|              | Private Courtyards inside Apartments |   |                                     |                                   |  | Area of Apartments (including Courtyards) |                               |                                   |  |
|--------------|--------------------------------------|---|-------------------------------------|-----------------------------------|--|---|-------------------------------|-----------------------------------|--|
|              | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Apartments on Each Floor | % from the Total Area of Each Floor | Area on All Floors of the Segment | % from the Total Designed Area of the Building | Area on Each Floor (m <sup>2</sup> )      | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Designed Area of the Building |
| Ground Floor | 62.3                                 | 6.08 %                                      | 4.71 %                              | 62.3                              | 0.27 %   | 1024.7                                    | 75.9 %                        | 1024.7                            | 4.46 %   |
| 1st Segment  | 69.0                                 | 6.63 %                                      | 5.67 %                              | 207.0                             | 0.9 %  | 1041.24                                   | 77.13 %                       | 3123.72                           | 13.61 %  |
| 2nd Segment  | 56.6                                 | 5.06 %                                      | 4.28 %                              | 113.2                             | 0.49 %   | 1118.14                                   | 82.82 %                       | 2236.28                           | 9.74 %   |
| 3rd Segment  | 88.4                                 | 8.24 %                                      | 6.69 %                              | 265.2                             | 1.16 %   | 1071.09                                   | 79.49 %                       | 3219.28                           | 14.03 %  |
| 4th Segment  | 76.6                                 | 7.27 %                                      | 6.44 %                              | 306.4                             | 1.33 %   | 1053.9                                    | 78.07 %                       | 4215.61                           | 18.37 %  |
| 5th Segment  | 83.1                                 | 7.53 %                                      | 6.29 %                              | 249.3                             | 1.09 %   | 1103.45                                   | 81.74 %                       | 3310.3                            | 14.42 %  |
| 6th Segment  | 81.2                                 | 7.34 %                                      | 6.14 %                              | 162.4                             | 0.71 %   | 1105.99                                   | 81.93 %                       | 2211.98                           | 9.64 %   |
| <b>TOTAL</b> |                                      |   |                                     | <b>1366</b>                       | <b>5.95 %</b>                                  |   |                               | <b>19341.93</b>                   | <b>83.20 %</b>                                 |

From the Total Area of Apartments

Detailed Calculations for Common Spaces inside the Building

|              | Main Public Space (MPS)              |                               |                                   |                                       | Semi-Private Spaces (PVS)            |                               |                                   |                                       | Entry Hall (EN)        |                              |                                       | Corridors (COR)                      |                               |                                   |                                       | Vertical Core (VC)                   |                               |                                   |                                       |
|--------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|------------------------|------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|
|              | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area (m <sup>2</sup> ) | % from the Area of the Floor | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building |
| Ground Floor | 80.96                                | 6.12 %                        | 80.96                             | 0.35 %                                | 40.5                                 | 3.06 %                        | 40.5                              | 0.18 %                                | 45.0                   | 3.4 %                        | 0.2 %                                 | 57.57                                | 4.35 %                        | 57.57                             | 0.25 %                                | 73.5                                 | 5.56 %                        | 73.5                              | 0.32 %                                |
| 1st Segment  | 80.96                                | 6.65 %                        | 242.88                            | 1.06 %                                | 40.5                                 | 3.33 %                        | 121.5                             | 0.53 %                                |                        |                              |                                       | 54.12                                | 4.45 %                        | 162.36                            | 0.71 %                                | 73.5                                 | 6.04 %                        | 220.5                             | 0.96 %                                |
| 2nd Segment  | 34.93                                | 2.64 %                        | 69.86                             | 0.3 %                                 | 20.25                                | 1.53 %                        | 40.5                              | 0.18 %                                |                        |                              |                                       | 61.71                                | 4.67 %                        | 123.42                            | 0.54 %                                | 73.5                                 | 5.56 %                        | 147.0                             | 0.64 %                                |
| 3rd Segment  | 53.59                                | 4.05 %                        | 160.77                            | 0.7 %                                 | 40.5                                 | 3.06 %                        | 121.5                             | 0.53 %                                |                        |                              |                                       | 54.12                                | 4.09 %                        | 162.36                            | 0.71 %                                | 73.5                                 | 5.56 %                        | 220.5                             | 0.96 %                                |
| 4th Segment  | 44.34                                | 3.73 %                        | 177.36                            | 0.77 %                                | 20.25                                | 1.7 %                         | 81.0                              | 0.35 %                                |                        |                              |                                       | 61.71                                | 5.19 %                        | 246.84                            | 1.08 %                                | 73.5                                 | 6.18 %                        | 294.0                             | 1.28 %                                |
| 5th Segment  | 37.51                                | 2.84 %                        | 112.53                            | 0.49 %                                | 40.5                                 | 3.06 %                        | 121.5                             | 0.53 %                                |                        |                              |                                       | 54.12                                | 4.09 %                        | 162.36                            | 0.71 %                                | 73.5                                 | 5.56 %                        | 220.5                             | 0.96 %                                |
| 6th Segment  | 44.34                                | 3.35 %                        | 88.68                             | 0.39 %                                | 20.25                                | 1.53 %                        | 40.5                              | 0.18 %                                |                        |                              |                                       | 61.71                                | 4.67 %                        | 123.42                            | 0.54 %                                | 73.5                                 | 5.56 %                        | 147.0                             | 0.64 %                                |
| <b>TOTAL</b> |                                      |                               | <b>933.04</b>                     | <b>4.06 %</b>                         |                                      |                               | <b>567.0</b>                      | <b>2.48 %</b>                         | <b>45.0</b>            | <b>3.4 %</b>                 | <b>0.2 %</b>                          |                                      |                               | <b>1038.33</b>                    | <b>4.54 %</b>                         |                                      |                               | <b>1323.0</b>                     | <b>5.76 %</b>                         |



Ground Floor Plan

Overall Calculations for the Building

|   |      |  |   |
|---|------|--|---|
| Total Allowable Area for the Building (m <sup>2</sup> ) |      | 24300.0  |   |
| Total Designed Area for the Building (m <sup>2</sup> )  |      | 23733.0  |   |
| Total Number of Floors                                  | 18   | Total Area of Common Spaces on All Floors (m <sup>2</sup> )          | 4266.04 = 17.98 % of the Total Designed Area  |
| Total Height of the Building (meter)                    | 70.4 | Total Area of Residential Apartments on All Floors (m <sup>2</sup> ) | 19466.96 = 82.02 % of the Total Designed Area |

|              | Number of Floors | Total Number of Apartments | Number of Apartments on Each Floor | Designed Area of Each Floor on the Segment (m <sup>2</sup> ) | Total Designed Area for All Floors on Each Segment (m <sup>2</sup> ) | % from the Total Designed Area of the Building |
|--------------|------------------|----------------------------|------------------------------------|--|--|--|
| Ground Floor | 1                | 7                          | 7                                  | 1318.5   | 1318.5   | 5.56 %   |
| 1st Segment  | 3                | 15                         | 5                                  | 1318.5   | 3955.5   | 16.67 %  |
| 2nd Segment  | 2                | 10                         | 5                                  | 1318.5   | 2637.0   | 11.11 %  |
| 3rd Segment  | 3                | 15                         | 5                                  | 1318.5   | 3955.5   | 16.67 %  |
| 4th Segment  | 4                | 20                         | 5                                  | 1318.5   | 5274.0   | 22.22 %  |
| 5th Segment  | 3                | 15                         | 5                                  | 1318.5   | 3955.5   | 16.67 %  |
| 6th Segment  | 2                | 10                         | 5                                  | 1318.5   | 2637.0   | 11.11 %  |
| <b>TOTAL</b> | <b>18</b>        | <b>92</b>                  |                                    |  | <b>23733.0</b>   |  |

Detailed Calculations for Residential Apartments

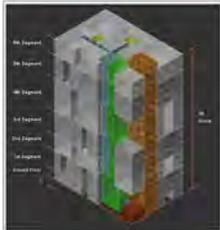
|              | Private Courtyards inside Apartments |   |                                     |                                   | Area of Apartments (including Courtyards)      |                                      |                               |                                   |  |
|--------------|--------------------------------------|---|-------------------------------------|-----------------------------------|--|--------------------------------------|-------------------------------|-----------------------------------|--|
|              | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Apartments on Each Floor | % from the Total Area of Each Floor | Area on All Floors of the Segment | % from the Total Designed Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Designed Area of the Building |
| Ground Floor | 90.1                                 | 8.79 %                                      | 6.83 %                              | 90.1                              | 0.38 %   | 1025.0                               | 75.93 %                       | 1025.0                            | 4.32 %   |
| 1st Segment  | 76.0                                 | 6.94 %                                      | 5.76 %                              | 228.0                             | 0.96 %   | 1095.1                               | 81.12 %                       | 3285.48                           | 13.84 %  |
| 2nd Segment  | 83.8                                 | 7.81 %                                      | 6.36 %                              | 167.6                             | 0.71 %   | 1073.1                               | 79.5 %                        | 2146.38                           | 9.04 %   |
| 3rd Segment  | 70.6                                 | 6.45 %                                      | 5.35 %                              | 211.8                             | 0.89 %   | 1095.1                               | 81.12 %                       | 3285.49                           | 13.84 %  |
| 4th Segment  | 64.5                                 | 6.01 %                                      | 4.89 %                              | 258.0                             | 1.09 %   | 1073.1                               | 79.5 %                        | 4292.75                           | 18.09 %  |
| 5th Segment  | 79.0                                 | 7.21 %                                      | 5.99 %                              | 237.0                             | 1.0 %  | 1095.1                               | 81.12 %                       | 3285.49                           | 13.84 %  |
| 6th Segment  | 65.7                                 | 6.12 %                                      | 4.98 %                              | 131.4                             | 0.55 %   | 1073.1                               | 79.5 %                        | 2146.37                           | 9.04 %   |
| <b>TOTAL</b> |                                      |   |                                     | <b>1324</b>                       | <b>5.58 %</b>                                  |                                      |                               | <b>19466.96</b>                   | <b>82.02 %</b>                                 |

Detailed Calculations for Common Spaces inside the Building

|              | Main Public Space (MPS)              |                               |                                   |                                       | Semi-Private Spaces (PVS)            |                               |                                   |                                       | Entry Hall (EN)        |                              |                                       | Corridors (COR)                      |                               |                                   |                                       | Vertical Core (VC)                   |                               |                                   |                                       |
|--------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|------------------------|------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|
|              | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area (m <sup>2</sup> ) | % from the Area of the Floor | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building |
| Ground Floor | 67.5                                 | 5.12 %                        | 67.5                              | 0.28 %                                | 16.87                                | 1.28 %                        | 16.87                             | 0.07 %                                | 45.0                   | 3.41 %                       | 0.19 %                                | 90.63                                | 6.87 %                        | 90.63                             | 0.38 %                                | 73.5                                 | 5.57 %                        | 73.5                              | 0.31 %                                |
| 1st Segment  | 67.5                                 | 5.12 %                        | 202.5                             | 0.85 %                                | 16.87                                | 1.28 %                        | 50.61                             | 0.21 %                                |                        |                              |                                       | 65.47                                | 4.97 %                        | 196.41                            | 0.83 %                                | 73.5                                 | 5.57 %                        | 220.5                             | 0.93 %                                |
| 2nd Segment  | 39.38                                | 2.99 %                        | 78.76                             | 0.33 %                                | 33.78                                | 2.56 %                        | 67.56                             | 0.28 %                                |                        |                              |                                       | 70.54                                | 5.35 %                        | 141.08                            | 0.59 %                                | 73.5                                 | 5.57 %                        | 147.0                             | 0.62 %                                |
| 3rd Segment  | 40.58                                | 3.08 %                        | 121.74                            | 0.51 %                                | 16.87                                | 1.28 %                        | 50.61                             | 0.21 %                                |                        |                              |                                       | 65.47                                | 4.97 %                        | 196.41                            | 0.83 %                                | 73.5                                 | 5.57 %                        | 220.5                             | 0.93 %                                |
| 4th Segment  | 41.55                                | 3.15 %                        | 166.2                             | 0.7 %                                 | 33.78                                | 2.56 %                        | 135.12                            | 0.57 %                                |                        |                              |                                       | 70.54                                | 5.35 %                        | 282.16                            | 1.19 %                                | 73.5                                 | 5.57 %                        | 294.0                             | 1.24 %                                |
| 5th Segment  | 41.55                                | 3.15 %                        | 124.65                            | 0.53 %                                | 16.87                                | 1.28 %                        | 50.61                             | 0.21 %                                |                        |                              |                                       | 65.47                                | 4.97 %                        | 196.41                            | 0.83 %                                | 73.5                                 | 5.57 %                        | 220.5                             | 0.93 %                                |
| 6th Segment  | 41.55                                | 3.15 %                        | 83.1                              | 0.35 %                                | 33.78                                | 2.56 %                        | 67.56                             | 0.28 %                                |                        |                              |                                       | 70.54                                | 5.35 %                        | 141.08                            | 0.59 %                                | 73.5                                 | 5.57 %                        | 147.0                             | 0.62 %                                |
| <b>TOTAL</b> |                                      |                               | <b>844.45</b>                     | <b>3.55 %</b>                         |                                      |                               | <b>438.94</b>                     | <b>1.83 %</b>                         | <b>45.0</b>            | <b>3.41 %</b>                | <b>0.19 %</b>                         |                                      |                               | <b>1244.18</b>                    | <b>5.24 %</b>                         |                                      |                               | <b>1323.0</b>                     | <b>5.58 %</b>                         |

Case No. 5

Spatial Calculations



Ground Floor Plan

Overall Calculations for the Building

|   |      |  |   |
|---|------|--|---|
| Total Allowable Area for the Building (m <sup>2</sup> ) |      | 24300.0  |   |
| Total Designed Area for the Building (m <sup>2</sup> )  |      | 22855.21   |   |
| Total Number of Floors                                  | 18   | Total Area of Common Spaces on All Floors (m <sup>2</sup> )          | 4334.22 = 18.96 % of the Total Designed Area  |
| Total Height of the Building (meters)                   | 70.4 | Total Area of Residential Apartments on All Floors (m <sup>2</sup> ) | 18520.99 = 81.04 % of the Total Designed Area |

|              | Number of Floors | Total Number of Apartments | Number of Apartments on Each Floor | Designed Area of Each Floor on the Segment (m <sup>2</sup> ) | Total Designed Area for All Floors on Each Segment (m <sup>2</sup> ) | % from the Total Designed Area of the Building |
|--------------|------------------|----------------------------|------------------------------------|--|--|--|
| Ground Floor | 1                | 6                          | 6                                  | 1216.8   | 1216.8   | 5.78 %   |
| 1st Segment  | 3                | 15                         | 5                                  | 1111.4   | 3334.4   | 15.8 %   |
| 2nd Segment  | 2                | 10                         | 5                                  | 1216.8   | 2433.6   | 11.5 %   |
| 3rd Segment  | 3                | 18                         | 6                                  | 1216.8   | 3650.4   | 17.3 %   |
| 4th Segment  | 4                | 16                         | 4                                  | 1084.2   | 4337.0   | 20.6 %   |
| 5th Segment  | 3                | 18                         | 6                                  | 1216.8   | 3650.4   | 17.3 %   |
| 6th Segment  | 2                | 10                         | 5                                  | 1216.8   | 2433.6   | 11.5 %   |
| <b>TOTAL</b> | <b>18</b>        | <b>93</b>                  |                                    |  | <b>22855.21</b>  |  |

Detailed Calculations for Residential Apartments

|              | Private Courtyards inside Apartments |   |                                     |                                   | Area of Apartments (including Courtyards)      |                                      |                               |                                   |  |
|--------------|--------------------------------------|---|-------------------------------------|-----------------------------------|--|--------------------------------------|-------------------------------|-----------------------------------|--|
|              | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Apartments on Each Floor | % from the Total Area of Each Floor | Area on All Floors of the Segment | % from the Total Designed Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Designed Area of the Building |
| Ground Floor | 70.9                                 | 7.15 %                                      | 5.83 %                              | 70.9                              | 0.34 %   | 992.26                               | 73.5 %                        | 992.26                            | 4.71 %   |
| 1st Segment  | 70.9                                 | 7.15 %                                      | 6.38 %                              | 212.7                             | 1.01 %   | 992.26                               | 73.5 %                        | 2976.78                           | 14.14 %  |
| 2nd Segment  | 64.3                                 | 6.09 %                                      | 5.28 %                              | 128.6                             | 0.61 %   | 1056.0                               | 78.23 %                       | 2112.11                           | 10.03 %  |
| 3rd Segment  | 35.5                                 | 3.33 %                                      | 2.92 %                              | 106.5                             | 0.51 %   | 1067.2                               | 79.05 %                       | 3201.69                           | 15.21 %  |
| 4th Segment  | 65.7                                 | 6.7 %                                       | 6.06 %                              | 262.8                             | 1.25 %   | 981.09                               | 72.67 %                       | 3924.35                           | 18.64 %  |
| 5th Segment  | 65.8                                 | 6.17 %                                      | 5.41 %                              | 197.4                             | 0.94 %   | 1067.2                               | 79.05 %                       | 3201.69                           | 15.21 %  |
| 6th Segment  | 51.8                                 | 4.91 %                                      | 4.26 %                              | 103.6                             | 0.49 %   | 1056.0                               | 78.23 %                       | 2112.11                           | 10.03 %  |
| <b>TOTAL</b> |                                      |   |                                     | <b>1082</b>                       | <b>5.15 %</b>                                  |                                      |                               | <b>18520.99</b>                   | <b>81.04 %</b>                                 |

Detailed Calculations for Common Spaces inside the Building

|              | Main Public Space (MPS)              |                               |                                   |                                       | Semi-Private Spaces (PVS)            |                               |                                   |                                       | Entry Hall (EN)        |                              |                                       | Corridors (COR)                      |                               |                                   |                                       | Vertical Core (VC)                   |                               |                                   |                                       |
|--------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|------------------------|------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|
|              | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area (m <sup>2</sup> ) | % from the Area of the Floor | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building |
| Ground Floor | 80.96                                | 6.65 %                        | 80.96                             | 0.38 %                                | 40.5                                 | 3.33 %                        | 40.5                              | 0.19 %                                | 45.0                   | 3.7 %                        | 0.21 %                                | 63.44                                | 5.21 %                        | 63.44                             | 0.3 %                                 | 73.5                                 | 6.04 %                        | 73.5                              | 0.35 %                                |
| 1st Segment  | 80.96                                | 7.28 %                        | 242.88                            | 1.15 %                                | 40.5                                 | 3.64 %                        | 121.5                             | 0.58 %                                |                        |                              |                                       | 59.99                                | 5.4 %                         | 179.97                            | 0.85 %                                | 73.5                                 | 6.61 %                        | 220.5                             | 1.05 %                                |
| 2nd Segment  | 56.35                                | 4.63 %                        | 112.7                             | 0.54 %                                | 41.15                                | 3.38 %                        | 82.3                              | 0.39 %                                |                        |                              |                                       | 70.5                                 | 5.79 %                        | 141.0                             | 0.67 %                                | 73.5                                 | 6.04 %                        | 147.0                             | 0.7 %                                 |
| 3rd Segment  | 53.59                                | 4.4 %                         | 160.77                            | 0.76 %                                | 40.5                                 | 3.33 %                        | 121.5                             | 0.58 %                                |                        |                              |                                       | 59.99                                | 4.93 %                        | 179.97                            | 0.85 %                                | 73.5                                 | 6.04 %                        | 220.5                             | 1.05 %                                |
| 4th Segment  | 44.34                                | 4.09 %                        | 177.36                            | 0.84 %                                | 41.15                                | 3.8 %                         | 164.6                             | 0.78 %                                |                        |                              |                                       | 70.5                                 | 6.5 %                         | 282.0                             | 1.34 %                                | 73.5                                 | 6.78 %                        | 294.0                             | 1.4 %                                 |
| 5th Segment  | 58.0                                 | 4.77 %                        | 174.0                             | 0.83 %                                | 40.5                                 | 3.33 %                        | 121.5                             | 0.58 %                                |                        |                              |                                       | 59.99                                | 4.93 %                        | 179.97                            | 0.85 %                                | 73.5                                 | 6.04 %                        | 220.5                             | 1.05 %                                |
| 6th Segment  | 58.0                                 | 4.77 %                        | 116.0                             | 0.55 %                                | 41.15                                | 3.38 %                        | 82.3                              | 0.39 %                                |                        |                              |                                       | 70.5                                 | 5.79 %                        | 141.0                             | 0.67 %                                | 73.5                                 | 6.04 %                        | 147.0                             | 0.7 %                                 |
| <b>TOTAL</b> |                                      |                               | <b>1064.67</b>                    | <b>5.05 %</b>                         |                                      |                               | <b>734.2</b>                      | <b>3.49 %</b>                         | <b>45.0</b>            | <b>3.7 %</b>                 | <b>0.21 %</b>                         |                                      |                               | <b>1167.35</b>                    | <b>5.53 %</b>                         |                                      |                               | <b>1323.0</b>                     | <b>6.3 %</b>                          |

Appendix (5-C-5)

**Questionnaire Form for the Evaluation  
of the Computational Tool, and  
Ethical Approval Form**

# Guide for Designing High-rise Residential Buildings using a Computational Tool

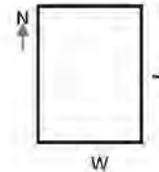


Welsh School of Architecture  
Cardiff University  
Cardiff, CF10 3NB  
Wales, UK

This experiment is part of study undertaken for obtaining a PhD degree about generating socially sustainable high-rise residential buildings. The study includes the development of a computational tool that offers architects the possibility to improve their designs. The tool uses 2D/3D CAD modeling software "RhinoCeros 3D", with its plugin "Grasshopper". You do not need any previous experience in Grasshopper.

The researcher would like to ask you to use the tool for the design of a high-rise residential building with the following requirements:

- Building dimensions: Max. Width = 50 meters, Max. Length = 50 meters.
- Maximum height of the building is 30 floors.
- The main entrance is located on the southern edge of the building.
- Maximum number of apartments on each floor = 6
- Area of each apartment could be ranged between 90 and 260 m<sup>2</sup>.



The tool offers designers the ability to include the following spaces:

- An entry hall (EN),
- A main public space (MPS),
- Small private gathering spaces between residential units (PVS),
- Corridors that connect common spaces (COR),
- Private courtyards inside apartments.

For input data, you need to select numbers on each slider.

The design strategy adopted in this tool is to split the building into vertical segments.

The maximum number of segments is six, and each segment could be reached up to five floors.

A short tutorial will be presented before you start. After you finish the design, the researcher would like to ask you some questions about the tool. Your answers are appreciated, as the information you provide will be very helpful for evaluating the tool.

The experiment and the questionnaire will take about 30 minutes to complete. Please do not feel obliged to do the exercise or to answer a question if you do not wish to. Your response will be strictly confidential and used only for this academic research. Please do not hesitate to ask any question and feel free to add your comments. Thank you for your time and feedback.

Researcher: **Amer Al-Jokhadar**  
Al-JokhadarA@cardiff.ac.uk

Supervisor: **Dr. Wassim Jabi**  
JabiW@cardiff.ac.uk

Starting time of implementation: ..... Finishing time of implementation: .....

1.1. Are you:

- Architecture Student:     2<sup>nd</sup> Year     3<sup>rd</sup> Year  
 Architect:    Years of experience: .....

1.2. Do you have previous experience in Grasshopper?     Yes     No

**Questions to be answered after the implementation:**

2.1. Using a scale of 1 to 5, where (1) indicates 'strongly disagree' and (5) indicates 'strongly agree', how would you describe your level of satisfaction with the tool:

| Criteria  | Strongly Disagree | Slightly Disagree | Neutral | Fairly Agree | Strongly Agree |
|---|-------------------|-------------------|---------|--------------|----------------|
| 1. The tool can be used effectively in professional practice                          | 1                 | 2                 | 3       | 4            | 5              |
| 2. Suitable in early stages of design   | 1                 | 2                 | 3       | 4            | 5              |
| 3. Final result matched your initial expectations                                     | 1                 | 2                 | 3       | 4            | 5              |
| 4. Appropriate number of input data   | 1                 | 2                 | 3       | 4            | 5              |
| 5. Performing tasks was easy to learn   | 1                 | 2                 | 3       | 4            | 5              |
| 6. Needs the support of a person to use this tool                                     | 1                 | 2                 | 3       | 4            | 5              |
| 7. You were able to complete the task in a reasonable amount of time                  | 1                 | 2                 | 3       | 4            | 5              |
| 8. You can become productive using the tool   | 1                 | 2                 | 3       | 4            | 5              |
| 9. You could recover from mistakes easily   | 1                 | 2                 | 3       | 4            | 5              |
| 10. Information provided with each stage was clear and effective to complete the task | 1                 | 2                 | 3       | 4            | 5              |
| 11. The organisation of the interface was clear                                       | 1                 | 2                 | 3       | 4            | 5              |
| 12. The interface and colours were pleasant   | 1                 | 2                 | 3       | 4            | 5              |
| 13. The tool has all functions and capabilities you expect it to have                 | 1                 | 2                 | 3       | 4            | 5              |

**2.2. List the most positive aspects of the tool:**

1. ....
2. ....
3. ....

**2.3. List the most negative aspects of the tool:**

1. ....
2. ....
3. ....

End of the Questionnaire  
Thank you for your time and kind effort

**For the use of researcher:**

1. **Number of questions asked by the user during the implementation:**
  - a. About commands .....
  - b. About the design process .....
2. **Number of errors facing the user:** .....
3. **Number of times the user expressed clear frustration during the experiment:** .....

**WELSH SCHOOL OF ARCHITECTURE  
ETHICS APPROVAL FORM FOR STAFF AND PHD/MPHIL PROJECTS**

WSA

|                                 |  |   |
|---------------------------------|--|---|
| Tick one box:                   | <input type="checkbox"/> STAFF   | <input checked="" type="checkbox"/> PHD/MPHIL |
| Title of project:               | Towards a Socio-Spatial Grammar for Sustainable Tall Residential Buildings in Hot-Arid Regions (Learning from the Vernacular Model in the Middle-East and North-Africa). |   |
| Name of researcher(s):          | Amer Al-Jokhadar   |   |
| Name of principal investigator: | Dr Wassim Jabi   |   |
| Contact e-mail address:         | <a href="mailto:Al-JokhadarA@cardiff.ac.uk">Al-JokhadarA@cardiff.ac.uk</a>   |   |
| Date:                           | 13 <sup>th</sup> November 2017   |   |

| Participants  |  | YES | NO | N/A |
|---|--|-----|----|-----|
| Does the research involve participants from any of the following groups?  | • Children (under 16 years of age)           |     | X  |     |
|   | • People with learning difficulties          |     | X  |     |
|   | • Patients (NHS approval is required)        |     | X  |     |
|   | • People in custody                          |     | X  |     |
|   | • People engaged in illegal activities       |     | X  |     |
|   | • Vulnerable elderly people                  |     | X  |     |
|   | • Any other vulnerable group not listed here |     | X  |     |
| • When working with children: I have read the Interim Guidance for Researchers Working with Children and Young People ( <a href="http://www.cardiff.ac.uk/archi/ethics_committee.php">http://www.cardiff.ac.uk/archi/ethics_committee.php</a> ) |  |     |    | X   |

| Consent Procedure   |  | YES | NO | N/A |
|---|--|-----|----|-----|
| • Will you describe the research process to participants in advance, so that they are informed about what to expect?  |  | X   |    |     |
| • Will you tell participants that their participation is voluntary?   |  | X   |    |     |
| • Will you tell participants that they may withdraw from the research at any time and for any reason?   |  | X   |    |     |
| • Will you obtain valid consent from participants? (specify how consent will be obtained in Box A) <sup>1</sup>   |  | X   |    |     |
| • Will you give participants the option of omitting questions they do not want to answer?   |  | X   |    |     |
| • If the research is observational, will you ask participants for their consent to being observed?  |  | X   |    |     |
| • If the research involves photography or other audio-visual recording, will you ask participants for their consent to being photographed / recorded and for its use/publication? |  | X   |    |     |

| Possible Harm to Participants   |  | YES | NO | N/A |
|---|--|-----|----|-----|
| • Is there any realistic risk of any participants experiencing either physical or psychological distress or discomfort?   |  |     | X  |     |
| • Is there any realistic risk of any participants experience a detriment to their interests as a result of participation? |  |     | X  |     |

| Data Protection  |  | YES | NO | N/A |
|--|--|-----|----|-----|
| • Will any non-anonymous and/or personalised data be generated or stored?    |  |     | X  |     |
| • If the research involves non-anonymous and/or personalised data, will you: | • gain written consent from the participants   |     | X  |     |
|  | • allow the participants the option of anonymity for all or part of the information they provide | X   |    |     |

| Health and Safety   |  | YES | NO | N/A |
|---|--|-----|----|-----|
| Does the research meet the requirements of the University's Health & Safety policies? ( <a href="http://www.cf.ac.uk/osheu/index.html">http://www.cf.ac.uk/osheu/index.html</a> ) |  | X   |    |     |

| Research Governance   |  | YES | NO | N/A |
|---|--|-----|----|-----|
| Does your study include the use of a drug?<br>You need to contact Research Governance before submission ( <a href="mailto:resgov@cf.ac.uk">resgov@cf.ac.uk</a> )                    |  |     | X  |     |
| Does the study involve the collection or use of human tissue?<br>You need to contact the Human Tissue Act team before submission ( <a href="mailto:hta@cf.ac.uk">hta@cf.ac.uk</a> ) |  |     | X  |     |

<sup>1</sup> If any non-anonymous and/or personalised data be generated or stored, *written consent* is required.

If any of the shaded boxes have been ticked, you must explain clearly how the ethical issues are addressed. The list of ethical issues on this form is not exhaustive; if you are aware of any other ethical issues you need to make the SREC aware of them.

**Box A The Project** (provide all the information listed below in a separate attachment)

1. Title of Project
2. Purpose of the project and its academic rationale
3. Brief description of methods and measurements
4. Participants: recruitment methods, number, age, gender, exclusion/inclusion criteria
5. Consent and participation information arrangements - please attached consent forms if they are to be used
6. A clear and concise statement of the ethical considerations raised by the project and how is dealt with them
7. Estimated start date and duration of project

All information must be submitted along with this form to the School Research Ethics Committee for consideration

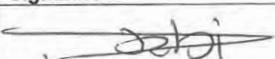
**Researcher's declaration** (tick as appropriate)

- I consider this project to have **negligible ethical implications** (can only be used if none of the grey areas of the checklist have been ticked).
- I consider this project research to have **some ethical implications**.
- I consider this project to have **significant ethical implications**

**PhD student:**

| Signature   | Name             | Date       |
|---|------------------|------------|
|  | Amer Al-Jokhadar | 13.11.2017 |

**Supervisor:**

| Signature   | Name            | Date       |
|---|-----------------|------------|
|  | Dr. Wassim Jabi | 14.11.2017 |

**Advice from the School Research Ethics Committee**

**STATEMENT OF ETHICAL APPROVAL**

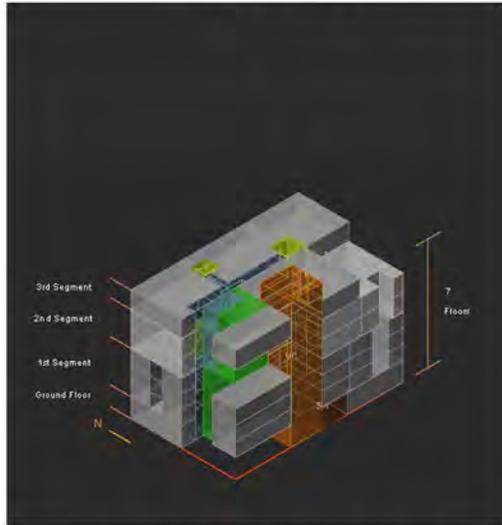
This project had been considered using agreed Departmental procedures and is now approved

|   |                                  |               |
|---|----------------------------------|---------------|
| Signature  | Name Gabriela Zapata - LAU UJPER | Date 16/11/17 |
| Chair, School Research Ethics Committee   |                                  |               |

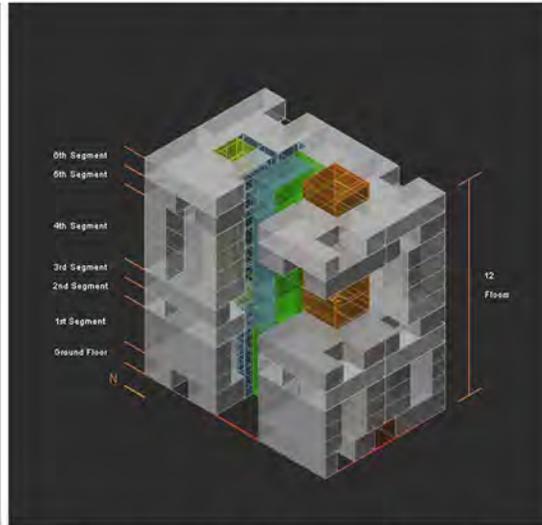
Appendix (5-C-6)

**Three-Dimensional Views for  
All Experiments generated by Participants**

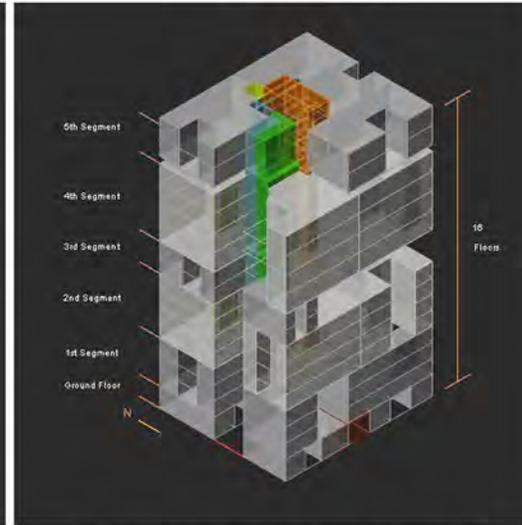
Exp. # A



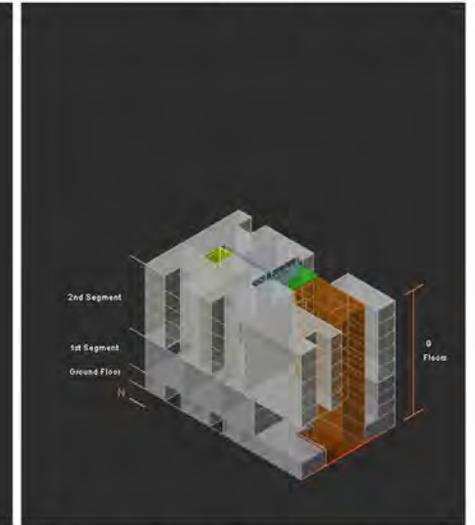
Exp. # B



Exp. # C



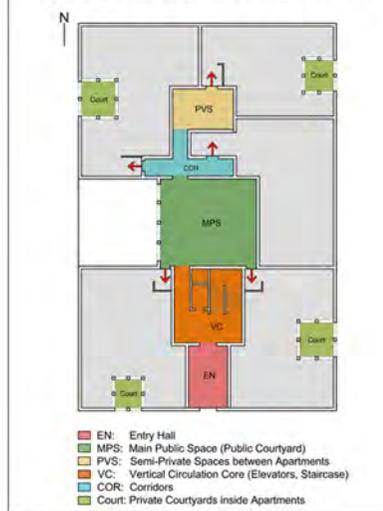
Exp. # D



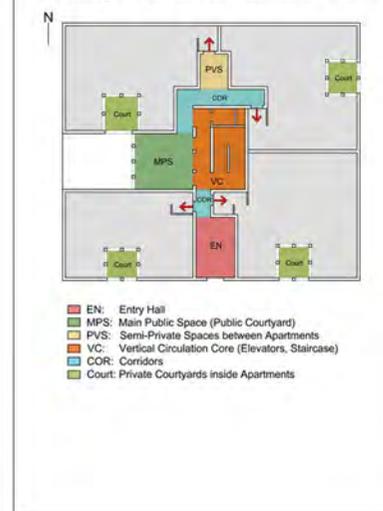
Zoning Plan for the Ground Floor



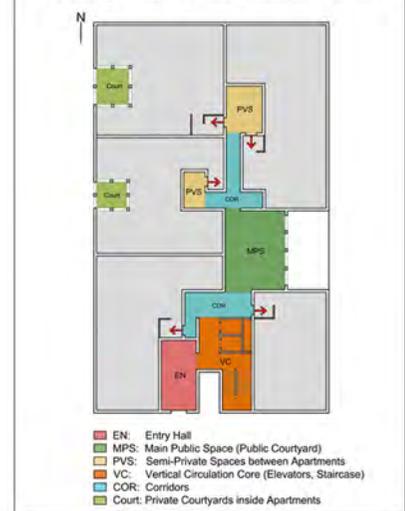
Zoning Plan for the Ground Floor



Zoning Plan for the Ground Floor



Zoning Plan for the Ground Floor



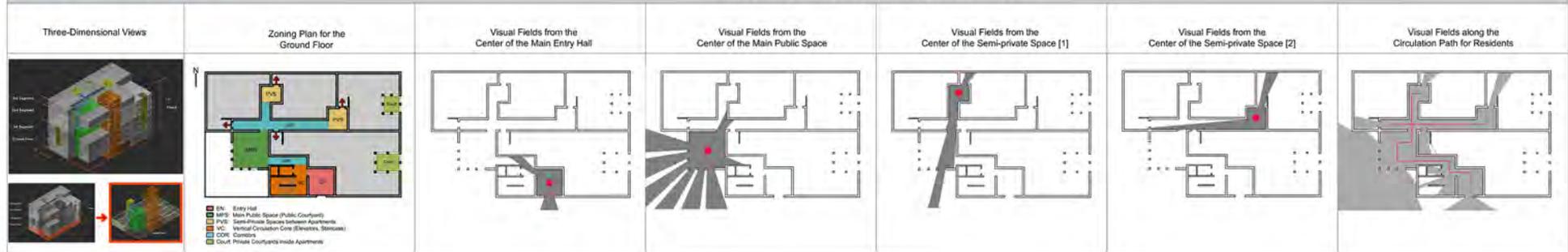
Appendix (5-C-7)

**A Detailed Spatial Analysis for  
All Experiments generated by the Participants**



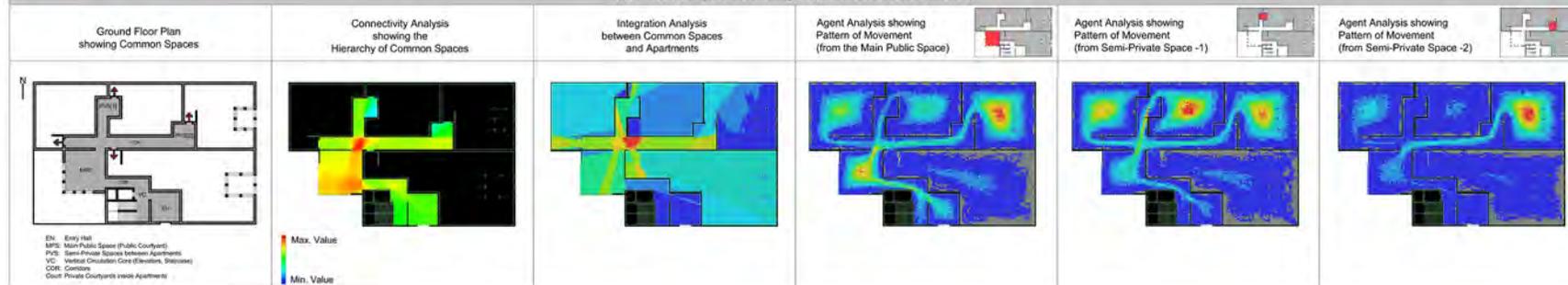
Exp. No. (A): Ground Floor

Visibility Study for the Ground Floor  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



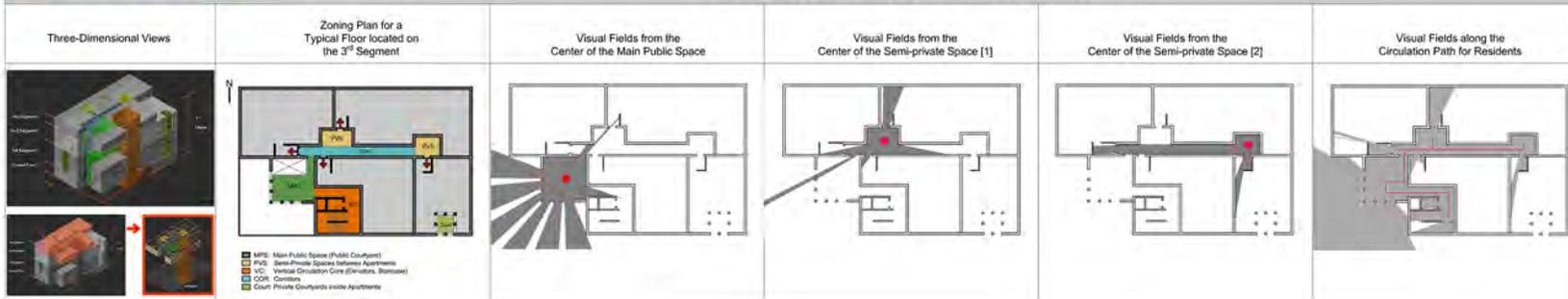
Exp. No. (A): Ground Floor

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for the Ground Floor  
(Carried out by Author using 'DepthMapX 0.50 Software')



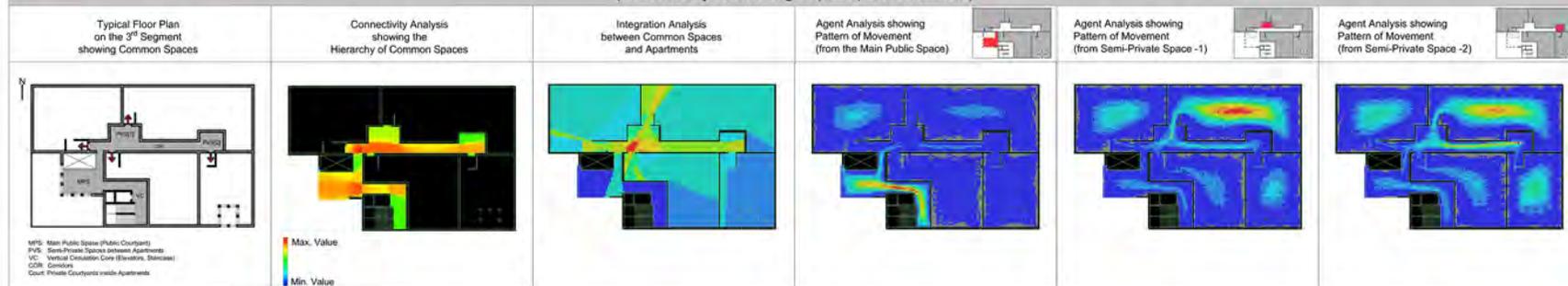
Exp. No. (A): 3<sup>rd</sup> Segment

Visibility Study for a Typical Floor located on the 3<sup>rd</sup> Segment  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



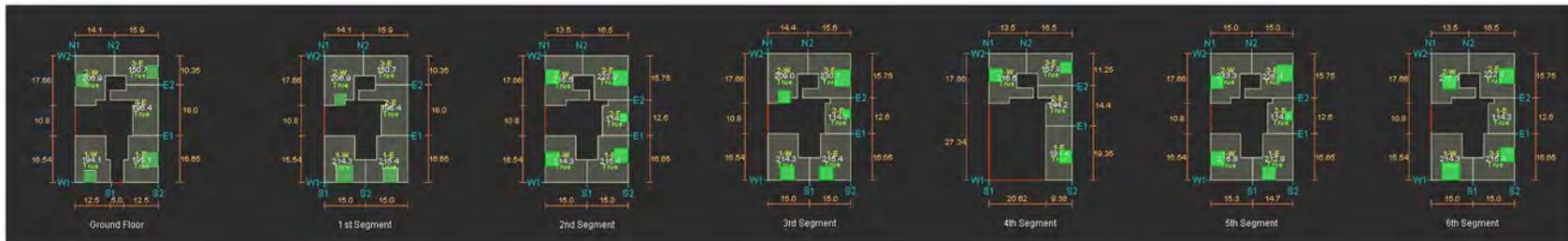
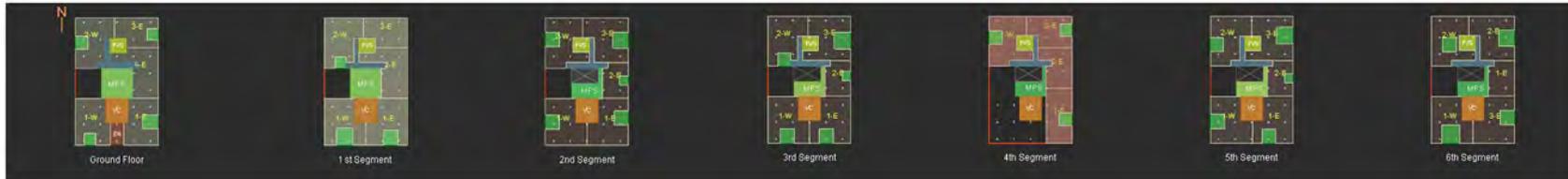
Exp. No. (A): 3<sup>rd</sup> Segment

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for a Typical Floor located on the 3<sup>rd</sup> Segment  
(Carried out by Author using 'DepthMapX 0.5.0 Software')

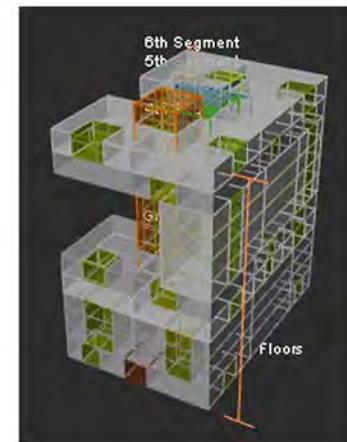
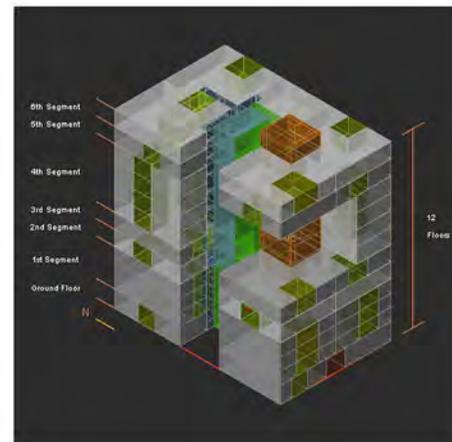
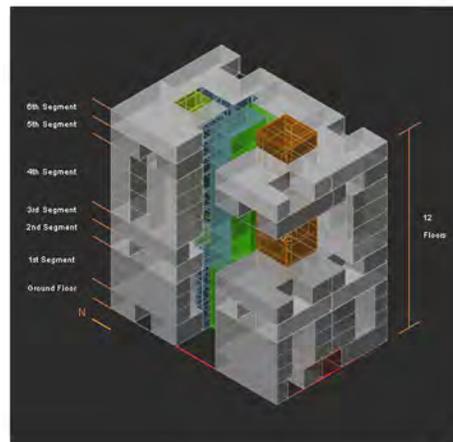


Exp. No. (B)

## Floors Plans and Three-Dimensional Views

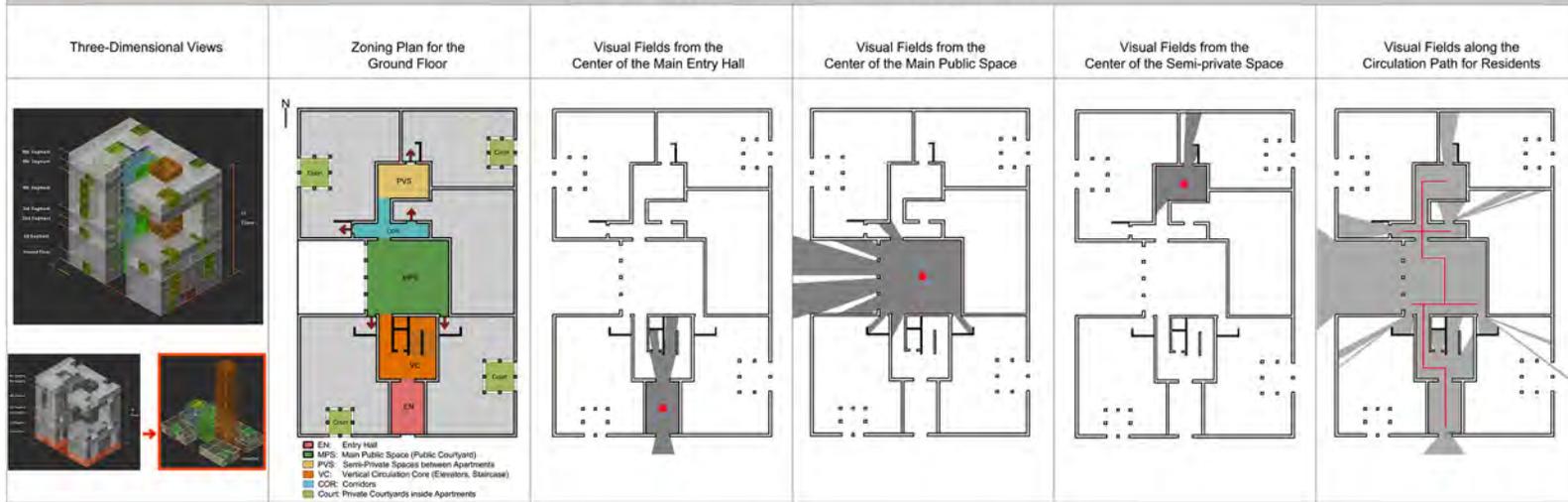


- EN: Entry Hall
- MPS: Main Public Space (Public Courtyard)
- PVS: Semi-Private Spaces between Apartments
- VC: Vertical Circulation Core (Elevators, Staircase)
- COR: Corridors
- COURT: Private Courtyards inside Apartments



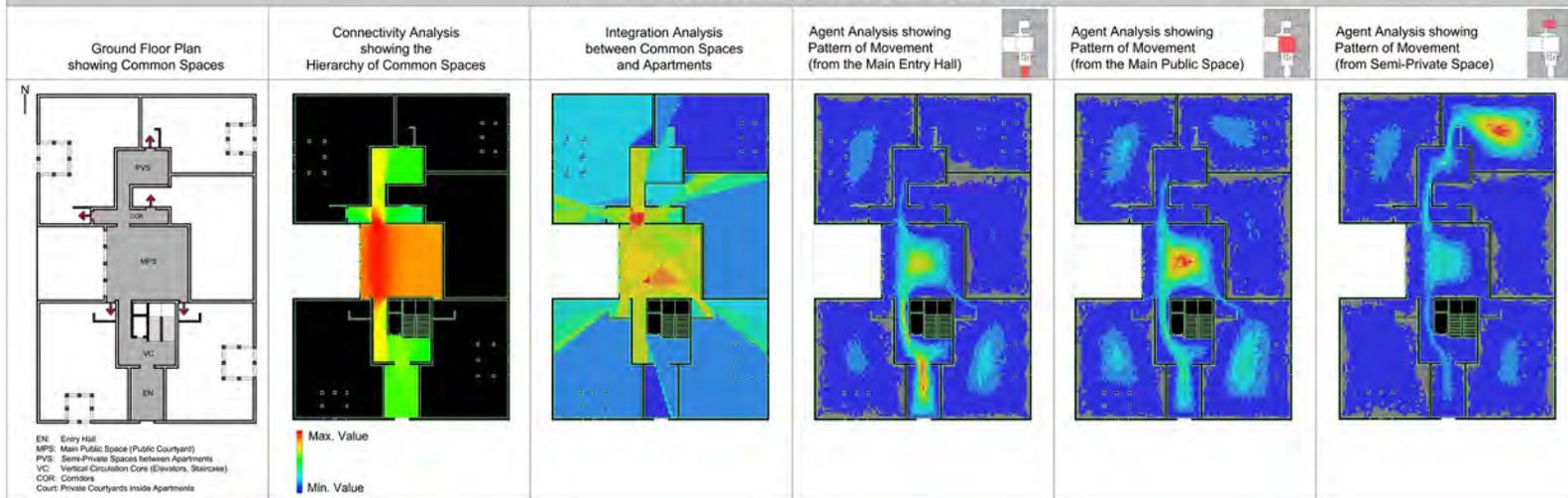
Exp. No. (B): Ground Floor

Visibility Study for the Ground Floor  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



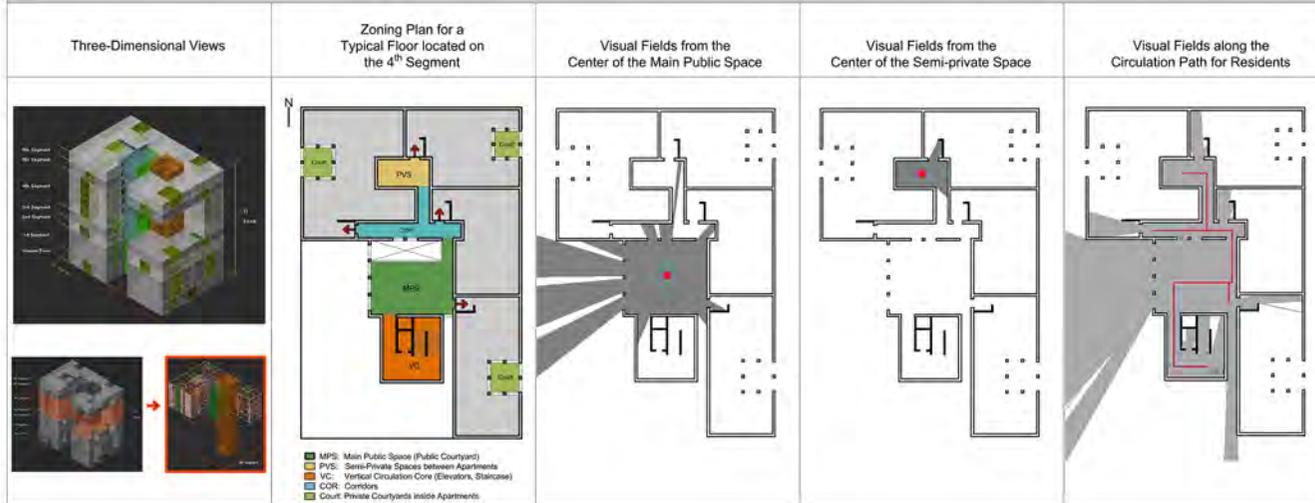
Exp. No. (B): Ground Floor

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for the Ground Floor  
(Carried out by Author using 'DepthMapX 0.50 Software')



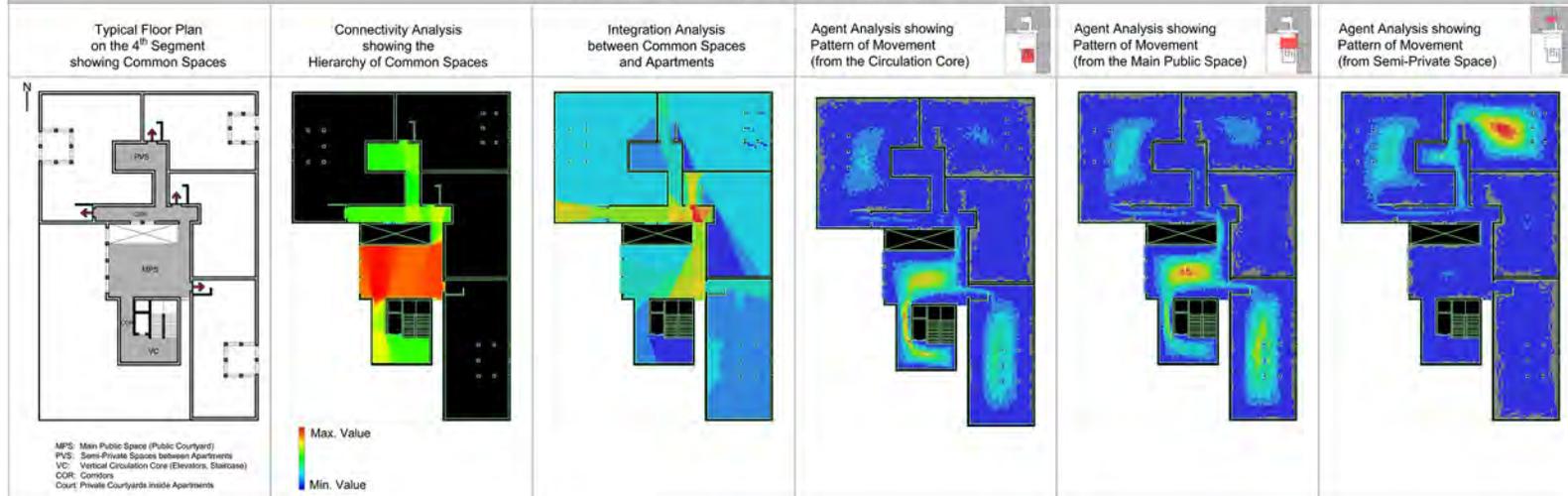
Exp. No. (B): 4<sup>th</sup> Segment

Visibility Study for a Typical Floor located on the 4<sup>th</sup> Segment  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



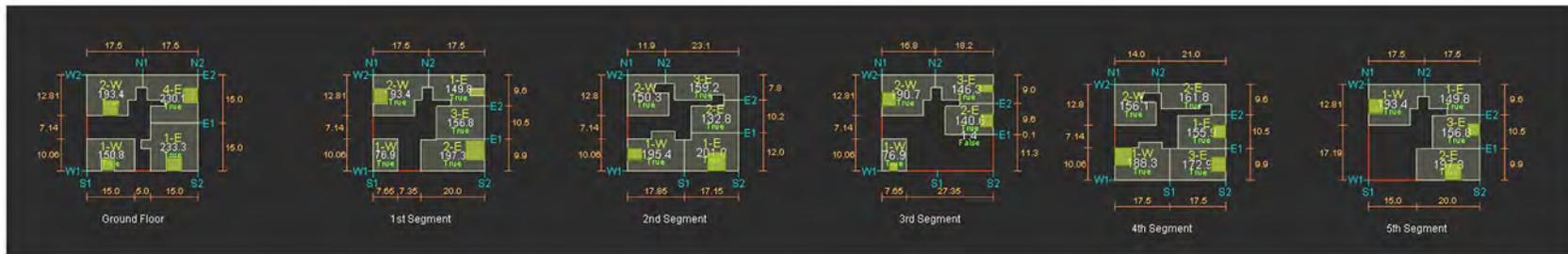
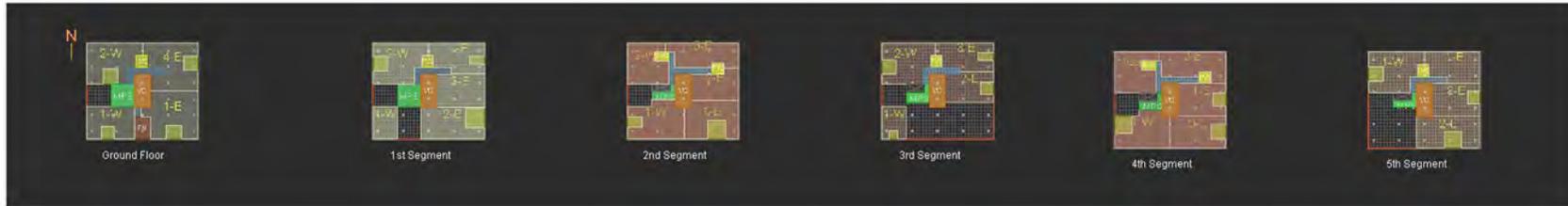
Exp. No. (B): 4<sup>th</sup> Segment

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for a Typical Floor located on the 4<sup>th</sup> Segment  
(Carried out by Author using 'DepthMapX 0.50 Software')

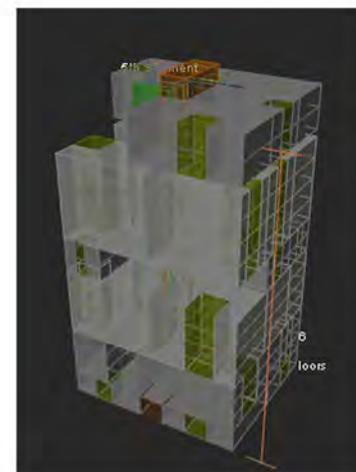
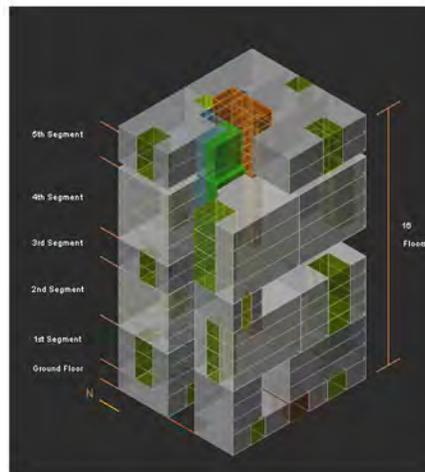
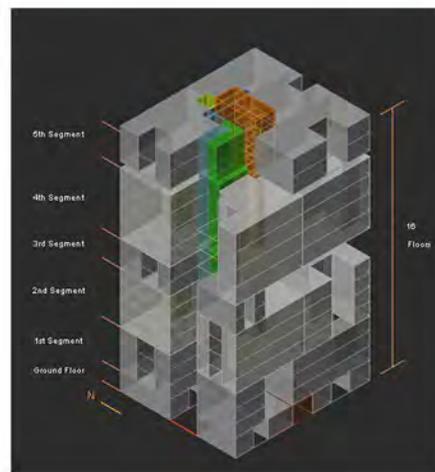


Exp. No. (C)

## Floors Plans and Three-Dimensional Views

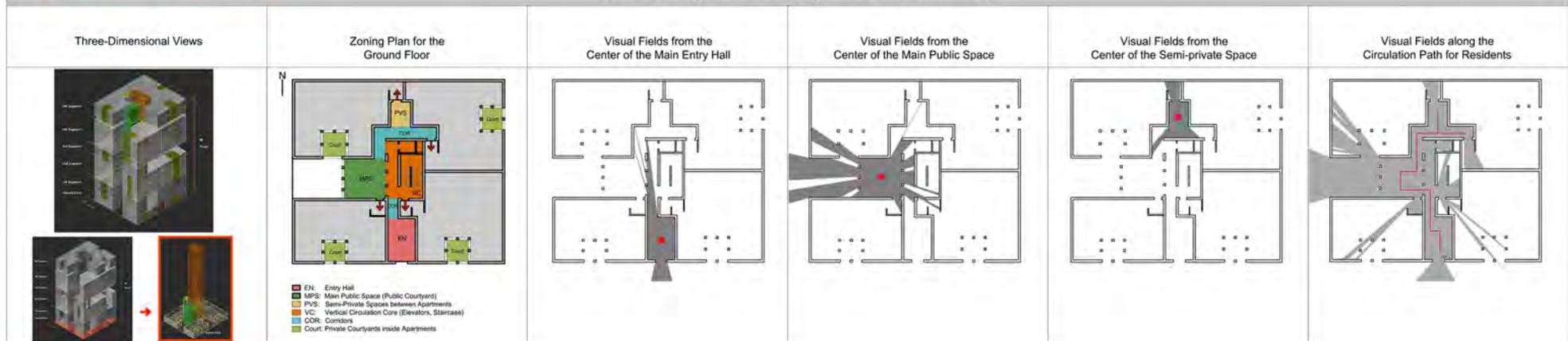


- EN: Entry Hall
- MPS: Main Public Space (Public Courtyard)
- PVS: Semi-Private Spaces between Apartments
- VC: Vertical Circulation Core (Elevators, Staircase)
- COR: Corridors
- Court: Private Courtyards inside Apartments



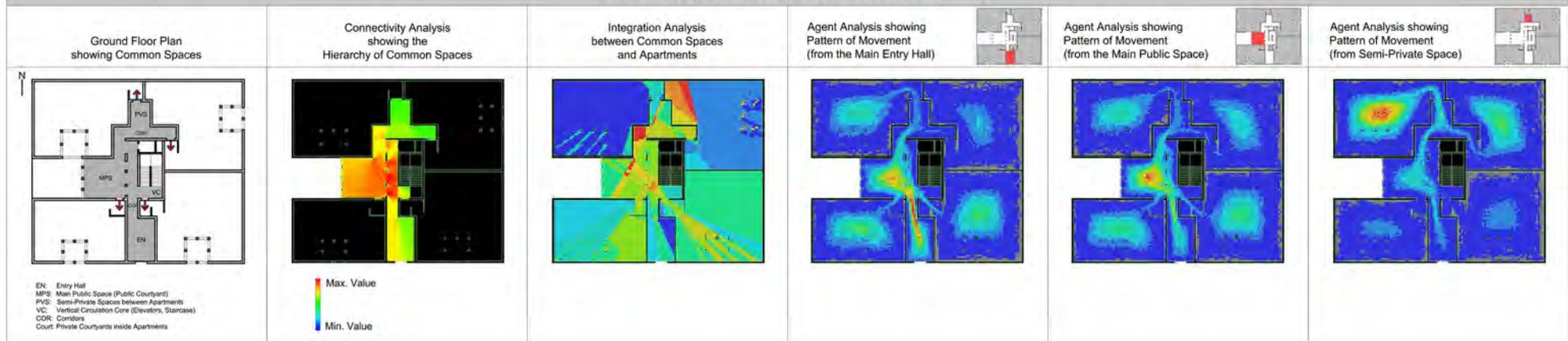
Exp. No. (C): Ground Floor

Visibility Study for the Ground Floor  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



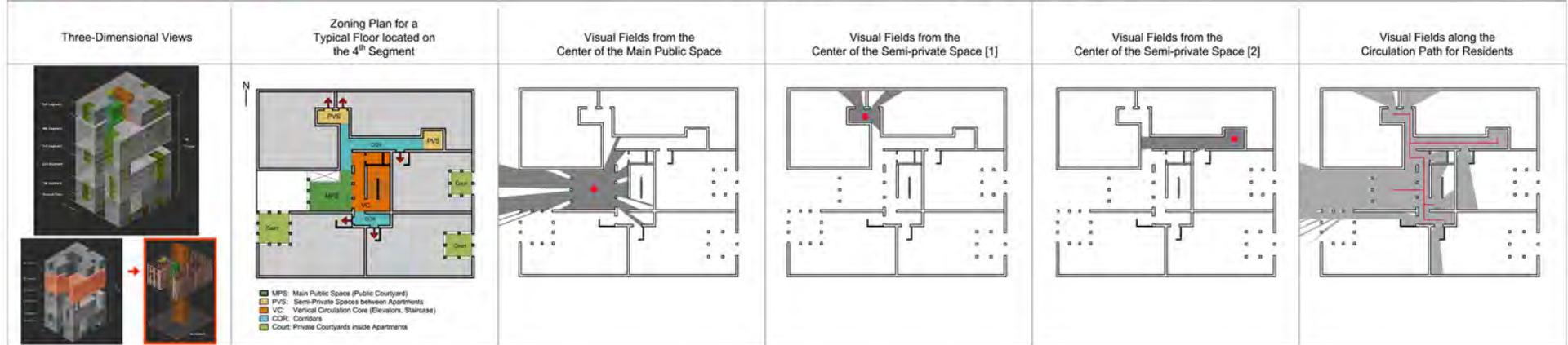
Exp. No. (C): Ground Floor

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for the Ground Floor  
(Carried out by Author using 'DepthMapX 0.50 Software')



Exp. No. (C): 4<sup>th</sup> Segment

Visibility Study for a Typical Floor located on the 4<sup>th</sup> Segment  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



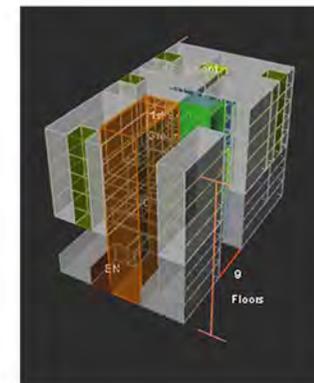
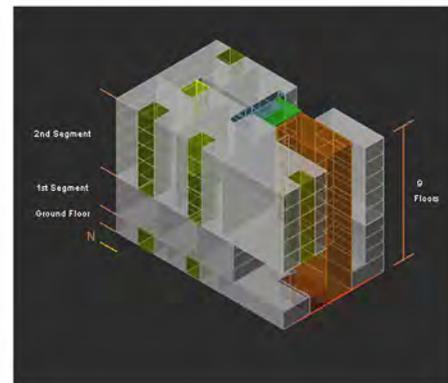
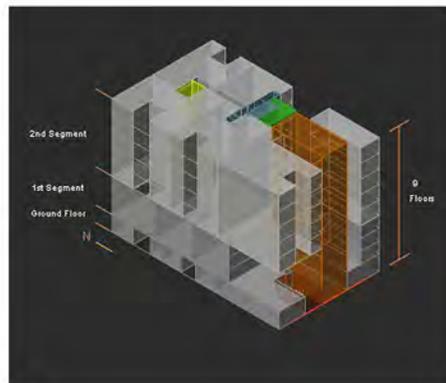
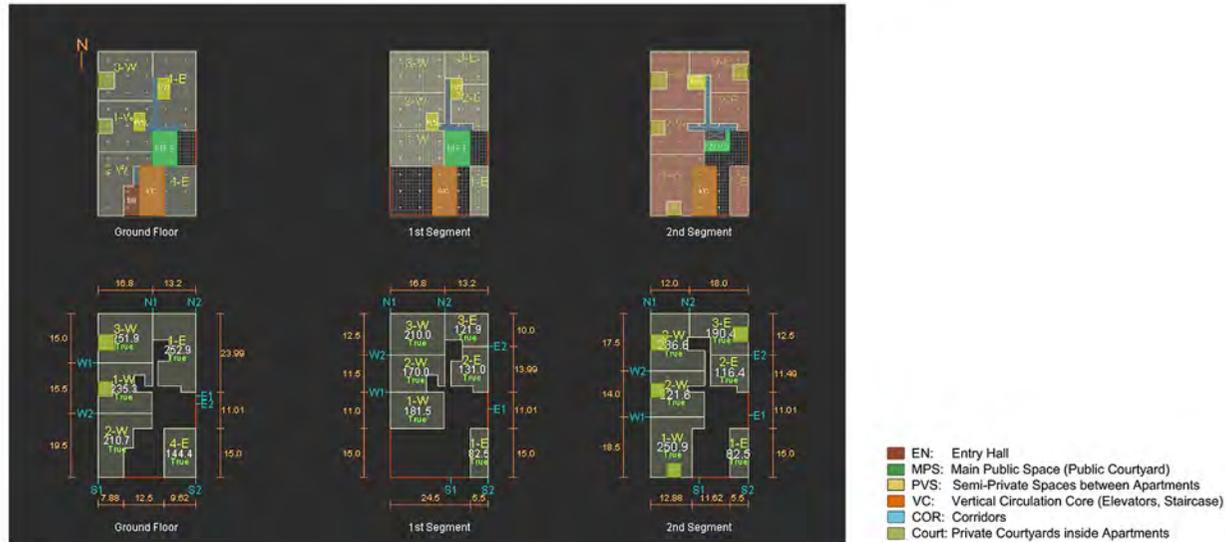
Exp. No. (C): 4<sup>th</sup> Segment

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for a Typical Floor located on the 4<sup>th</sup> Segment  
(Carried out by Author using 'DepthMapX 0.50 Software')



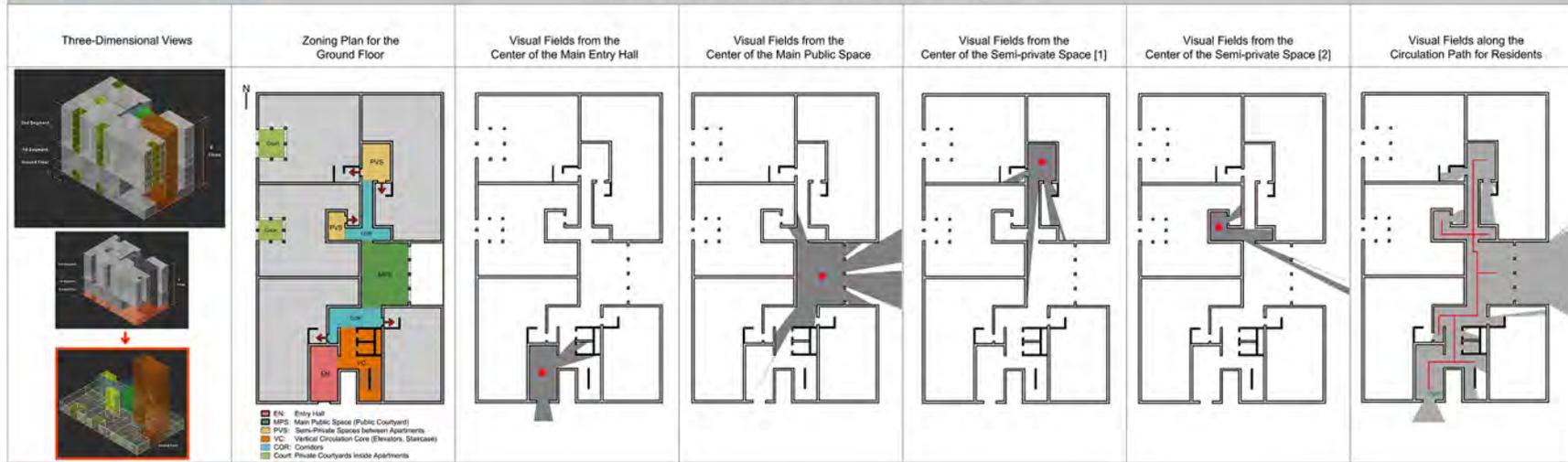
Exp. No. (D)

## Floors Plans and Three-Dimensional Views



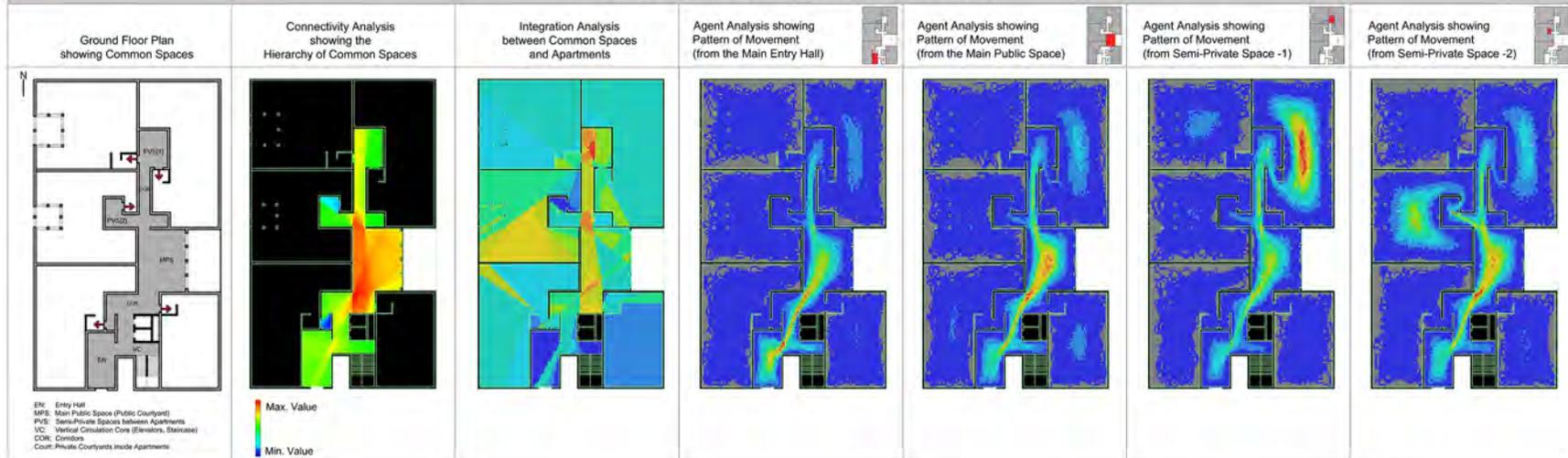
Exp. No. (D): Ground Floor

Visibility Study for the Ground Floor  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



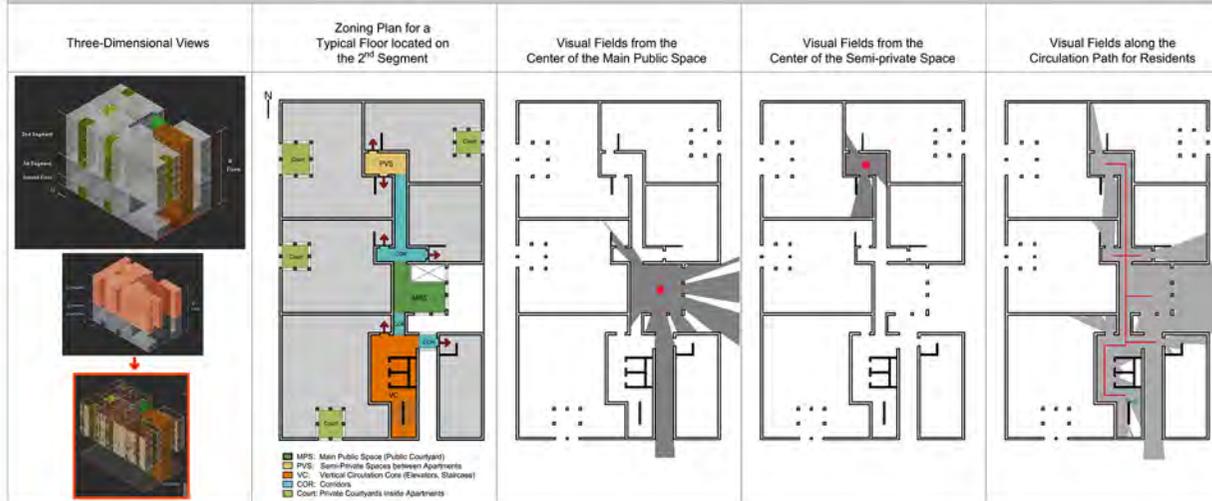
Exp. No. (D): Ground Floor

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for the Ground Floor  
(Carried out by Author using 'DepthMapX 0.50 Software')



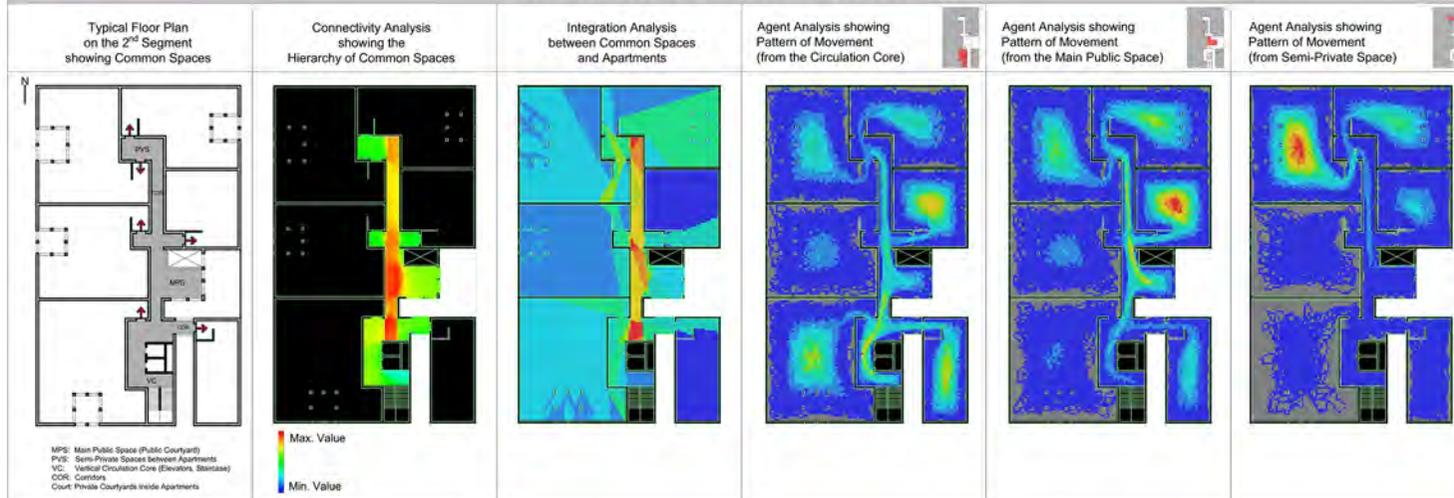
Exp. No. (D): 2<sup>nd</sup> Segment

Visibility Study for a Typical Floor located on the 2<sup>nd</sup> Segment  
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



Exp. No. (D): 2<sup>nd</sup> Segment

Syntactic Analysis (using Visibility Graph Analysis - VGA)  
for a Typical Floor located on the 2<sup>nd</sup> Segment  
(Carried out by Author using 'DepthMapX 0.50 Software')



Appendix (5-C-8)

**Detailed Spatial Calculations for  
All Experiments generated by the Participants**

Exp. No. (A)

## Spatial Calculations



Ground Floor Plan



### Overall Calculations for the Building

|   |      |  |  |
|---|------|--|--|
| Total Allowable Area for the Building (m <sup>2</sup> ) |      | 7000.0   |  |
| Total Designed Area for the Building (m <sup>2</sup> )  |      | 6067.26  |  |
| Total Number of Floors                                  | 7    | Total Area of Common Spaces on All Floors (m <sup>2</sup> )          | 990.47 = 16.32 % of the Total Designed Area  |
| Total Height of the Building (meter)                    | 26.4 | Total Area of Residential Apartments on All Floors (m <sup>2</sup> ) | 5076.79 = 83.68 % of the Total Designed Area |

|              | Number of Floors | Total Number of Apartments | Number of Apartments on Each Floor | Designed Area of Each Floor on the Segment (m <sup>2</sup> ) | Total Designed Area for All Floors on Each Segment (m <sup>2</sup> ) | % from the Total Designed Area of the Building |
|--------------|------------------|----------------------------|------------------------------------|--|--|--|
| Ground Floor | 1                | 8                          | 8                                  | 887.8  | 887.8  | 14.6 %   |
| 1st Segment  | 3                | 30                         | 10                                 | 887.8  | 2663.4   | 43.9 %   |
| 2nd Segment  | 2                | 8                          | 4                                  | 814.13   | 1628.2   | 26.8 %   |
| 3rd Segment  | 1                | 5                          | 5                                  | 887.8  | 887.8  | 14.6 %   |
| 4th Segment  | 0                | 0                          | 0                                  | 0.0  | 0.0  | 0.0 %  |
| 5th Segment  | 0                | 0                          | 0                                  | 0.0  | 0.0  | 0.0 %  |
| 6th Segment  | 0                | 0                          | 0                                  | 0.0  | 0.0  | 0.0 %  |
| <b>TOTAL</b> | <b>7</b>         | <b>51</b>                  |                                    |  | <b>6067.26</b>   |  |

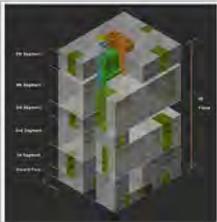
### Detailed Calculations for Residential Apartments

|              | Private Courtyards Inside Apartments |   |                                     |                                   | Area of Apartments (including Courtyards)      |                                      |                               |                                   |  |
|--------------|--------------------------------------|---|-------------------------------------|-----------------------------------|--|--------------------------------------|-------------------------------|-----------------------------------|--|
|              | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Apartments on Each Floor | % from the Total Area of Each Floor | Area on All Floors of the Segment | % from the Total Designed Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Designed Area of the Building |
| Ground Floor | 33.9                                 | 5.18 %                                      | 3.82 %                              | 33.9                              | 0.56 %   | 654.31                               | 65.43 %                       | 654.31                            | 10.78 %  |
| 1st Segment  | 30.4                                 | 41.27 %                                     | 3.42 %                              | 91.2                              | 1.5 %  | 73.67                                | 7.37 %                        | 221.01                            | 3.64 %   |
| 2nd Segment  | 11.6                                 | 1.68 %                                      | 1.42 %                              | 23.2                              | 0.38 %   | 688.56                               | 68.86 %                       | 1377.1                            | 22.7 %   |
| 3rd Segment  | 32.7                                 | 44.39 %                                     | 3.68 %                              | 32.7                              | 0.54 %   | 73.67                                | 7.37 %                        | 73.67                             | 1.21 %   |
| 4th Segment  | 0.0                                  | 0.0 %                                       | 0.0 %                               | 0.0                               | 0.0 %  | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %  |
| 5th Segment  | 0.0                                  | 0.0 %                                       | 0.0 %                               | 0.0                               | 0.0 %  | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %  |
| 6th Segment  | 0.0                                  | 0.0 %                                       | 0.0 %                               | 0.0                               | 0.0 %  | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %  |
| <b>TOTAL</b> |                                      |   |                                     | <b>181</b>                        | <b>2.98 %</b>                                  |                                      |                               | <b>5076.79</b>                    | <b>83.68 %</b>                                 |

### Detailed Calculations for Common Spaces inside the Building

|              | Main Public Space (MPS)              |                               |                                   |                                       | Semi-Private Spaces (PVS)            |                               |                                   |                                       | Entry Hall (EN)        |                              |                                       | Corridors (COR)                      |                               |                                   |                                       | Vertical Core (VC)                   |                               |                                   |                                       |
|--------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|------------------------|------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|
|              | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area (m <sup>2</sup> ) | % from the Area of the Floor | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building |
| Ground Floor | 58.72                                | 6.61 %                        | 58.72                             | 0.97 %                                | 35.25                                | 3.97 %                        | 35.25                             | 0.58 %                                | 33.36                  | 3.76 %                       | 0.55 %                                | 51.7                                 | 5.82 %                        | 51.7                              | 0.85 %                                | 54.45                                | 6.13 %                        | 54.45                             | 0.9 %                                 |
| 1st Segment  | 58.72                                | 6.61 %                        | 176.16                            | 2.9 %                                 | 35.25                                | 3.97 %                        | 105.75                            | 1.74 %                                |                        |                              |                                       | 51.7                                 | 5.82 %                        | 155.1                             | 2.56 %                                | 54.45                                | 6.13 %                        | 163.35                            | 2.69 %                                |
| 2nd Segment  | 38.41                                | 4.72 %                        | 76.82                             | 1.27 %                                | 31.62                                | 3.88 %                        | 63.24                             | 1.04 %                                |                        |                              |                                       | 54.45                                | 6.69 %                        | 108.9                             | 1.79 %                                | 54.45                                | 6.69 %                        | 108.9                             | 1.79 %                                |
| 3rd Segment  | 39.12                                | 4.41 %                        | 39.12                             | 0.64 %                                | 35.25                                | 3.97 %                        | 35.25                             | 0.58 %                                |                        |                              |                                       | 51.7                                 | 5.82 %                        | 51.7                              | 0.85 %                                | 54.45                                | 6.13 %                        | 54.45                             | 0.9 %                                 |
| 4th Segment  | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 |                        |                              |                                       | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 |
| 5th Segment  | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 |                        |                              |                                       | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 |
| 6th Segment  | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 |                        |                              |                                       | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 |
| <b>TOTAL</b> |                                      |                               | <b>350.82</b>                     | <b>5.78 %</b>                         |                                      |                               | <b>239.49</b>                     | <b>3.94 %</b>                         | <b>33.36</b>           | <b>3.76 %</b>                | <b>0.55 %</b>                         |                                      |                               | <b>367.4</b>                      | <b>6.05 %</b>                         |                                      |                               | <b>381.15</b>                     | <b>6.28 %</b>                         |





Overall Calculations for the Building

|   |      |  |          |
|---|------|--|----------|
| Total Allowable Area for the Building (m <sup>2</sup> ) |      | 16800.0  |          |
| Total Designed Area for the Building (m <sup>2</sup> )  |      | 14704.01   |          |
| Total Number of Floors                                  | 16   | Total Area of Common Spaces on All Floors (m <sup>2</sup> )          | 2372.79  |
|   |      | = 16.14 % of the Total Designed Area                                 |          |
| Total Height of the Building (meters)                   | 58.2 | Total Area of Residential Apartments on All Floors (m <sup>2</sup> ) | 12331.22 |
|   |      | = 83.86 % of the Total Designed Area                                 |          |

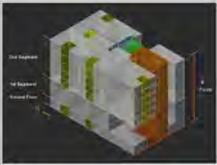
|              | Number of Floors | Total Number of Apartments | Number of Apartments on Each Floor | Designed Area of Each Floor on the Segment (m <sup>2</sup> ) | Total Designed Area for All Floors on Each Segment (m <sup>2</sup> ) | % from the Total Designed Area of the Building |
|--------------|------------------|----------------------------|------------------------------------|--|--|--|
| Ground Floor | 1                | 8                          | 8                                  | 995.38   | 995.38   | 6.77 %   |
| 1st Segment  | 3                | 30                         | 1                                  | 921.47   | 2764.4   | 18.8 %   |
| 2nd Segment  | 4                | 20                         | 5                                  | 995.38   | 3981.5   | 27.0 %   |
| 3rd Segment  | 2                | 8                          | 4                                  | 686.2  | 1372.4   | 9.3 %  |
| 4th Segment  | 4                | 20                         | 5                                  | 995.38   | 3981.5   | 27.0 %   |
| 5th Segment  | 2                | 8                          | 4                                  | 804.39   | 1608.7   | 10.9 %   |
| 6th Segment  | 0                | 0                          | 5                                  | 995.38   | 0.0  | 0.0 %  |
| <b>TOTAL</b> | <b>16</b>        | <b>94</b>                  |                                    |  | <b>14704.01</b>  | <b>100 %</b>                                   |

Detailed Calculations for Residential Apartments

|              | Private Courtyards inside Apartments |   |                                     |                                   |  | Area of Apartments (including Courtyards) |                               |                                   |  |
|--------------|--------------------------------------|---|-------------------------------------|-----------------------------------|--|---|-------------------------------|-----------------------------------|--|
|              | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Apartments on Each Floor | % from the Total Area of Each Floor | Area on All Floors of the Segment | % from the Total Designed Area of the Building | Area on Each Floor (m <sup>2</sup> )      | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Designed Area of the Building |
| Ground Floor | 78.5                                 | 9.72 %                                      | 7.89 %                              | 78.5                              | 0.53 %   | 807.6                                     | 76.91 %                       | 807.6                             | 5.49 %   |
| 1st Segment  | 67.1                                 | 87.23 %                                     | 7.28 %                              | 201.3                             | 1.37 %   | 76.92                                     | 7.33 %                        | 230.76                            | 1.57 %   |
| 2nd Segment  | 50.2                                 | 5.99 %                                      | 5.04 %                              | 200.8                             | 1.37 %   | 838.68                                    | 79.87 %                       | 3354.72                           | 22.82 %  |
| 3rd Segment  | 52.3                                 | 67.99 %                                     | 7.62 %                              | 104.6                             | 0.71 %   | 76.92                                     | 7.33 %                        | 153.84                            | 1.05 %   |
| 4th Segment  | 68.5                                 | 8.2 %                                       | 6.88 %                              | 274.0                             | 1.86 %   | 835.01                                    | 79.52 %                       | 3340.04                           | 22.72 %  |
| 5th Segment  | 62.9                                 | 9.02 %                                      | 7.82 %                              | 125.8                             | 0.86 %   | 697.27                                    | 66.41 %                       | 1394.54                           | 9.48 %   |
| 6th Segment  | 163.1                                | 19.05 %                                     | 16.39 %                             | 0.0                               | 0.0 %  | 856.03                                    | 81.53 %                       | 0.0                               | 0.0 %  |
| <b>TOTAL</b> |                                      |   |                                     | <b>985</b>                        | <b>6.7 %</b>                                   |   |                               | <b>12331.22</b>                   | <b>83.86 %</b>                                 |

Detailed Calculations for Common Spaces inside the Building

|              | Main Public Space (MPS)              |                               |                                   |                                       | Semi-Private Spaces (PVS)            |                               |                                   |                                       | Entry Hall (EN)        |                              |                                       | Corridors (COR)                      |                               |                                   |                                       | Vertical Core (VC)                   |                               |                                   |                                       |
|--------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|------------------------|------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|
|              | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area (m <sup>2</sup> ) | % from the Area of the Floor | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building |
| Ground Floor | 52.48                                | 5.27 %                        | 52.48                             | 0.36 %                                | 13.13                                | 1.32 %                        | 13.13                             | 0.09 %                                | 35.0                   | 3.52 %                       | 0.24 %                                | 34.67                                | 3.48 %                        | 34.67                             | 0.24 %                                | 52.5                                 | 5.27 %                        | 52.5                              | 0.36 %                                |
| 1st Segment  | 52.48                                | 5.7 %                         | 157.44                            | 1.07 %                                | 13.13                                | 1.42 %                        | 39.39                             | 0.27 %                                |                        |                              |                                       | 29.17                                | 3.17 %                        | 87.51                             | 0.6 %                                 | 52.5                                 | 5.7 %                         | 157.5                             | 1.07 %                                |
| 2nd Segment  | 21.76                                | 2.19 %                        | 87.04                             | 0.59 %                                | 26.27                                | 2.64 %                        | 105.08                            | 0.71 %                                |                        |                              |                                       | 42.25                                | 4.24 %                        | 169.0                             | 1.15 %                                | 52.5                                 | 5.27 %                        | 210.0                             | 1.43 %                                |
| 3rd Segment  | 26.94                                | 3.93 %                        | 53.88                             | 0.37 %                                | 13.13                                | 1.91 %                        | 26.26                             | 0.18 %                                |                        |                              |                                       | 29.17                                | 4.25 %                        | 58.34                             | 0.4 %                                 | 52.5                                 | 7.65 %                        | 105.0                             | 0.71 %                                |
| 4th Segment  | 24.26                                | 2.44 %                        | 97.04                             | 0.66 %                                | 26.27                                | 2.64 %                        | 105.08                            | 0.71 %                                |                        |                              |                                       | 42.25                                | 4.24 %                        | 169.0                             | 1.15 %                                | 52.5                                 | 5.27 %                        | 210.0                             | 1.43 %                                |
| 5th Segment  | 19.79                                | 2.46 %                        | 39.58                             | 0.27 %                                | 13.13                                | 1.63 %                        | 26.26                             | 0.18 %                                |                        |                              |                                       | 29.17                                | 3.63 %                        | 58.34                             | 0.4 %                                 | 52.5                                 | 6.53 %                        | 105.0                             | 0.71 %                                |
| 6th Segment  | 27.84                                | 2.8 %                         | 0.0                               | 0.0 %                                 | 0                                    | 0.0 %                         | 0.0                               | 0.0 %                                 |                        |                              |                                       | 0                                    | 0.0 %                         | 0.0                               | 0.0 %                                 | 52.5                                 | 5.27 %                        | 0.0                               | 0.0 %                                 |
| <b>TOTAL</b> |                                      |                               | <b>487.46</b>                     | <b>3.32 %</b>                         |                                      |                               | <b>315.2</b>                      | <b>2.14 %</b>                         | <b>35.0</b>            | <b>3.52 %</b>                | <b>0.24 %</b>                         |                                      |                               | <b>576.86</b>                     | <b>3.94 %</b>                         |                                      |                               | <b>840.0</b>                      | <b>5.71 %</b>                         |



Ground Floor Plan



Overall Calculations for the Building

|   |      |  |  |
|---|------|--|--|
| Total Allowable Area for the Building (m <sup>2</sup> ) |      | 13500.0  |  |
| Total Designed Area for the Building (m <sup>2</sup> )  |      | 11605.15   |  |
| Total Number of Floors                                  | 9    | Total Area of Common Spaces on All Floors (m <sup>2</sup> )          | 2327.52 = 20.06 % of the Total Designed Area |
| Total Height of the Building (meters)                   | 34.4 | Total Area of Residential Apartments on All Floors (m <sup>2</sup> ) | 9277.63 = 79.94 % of the Total Designed Area |

|              | Number of Floors | Total Number of Apartments | Number of Apartments on Each Floor | Designed Area of Each Floor on the Segment (m <sup>2</sup> ) | Total Designed Area for All Floors on Each Segment (m <sup>2</sup> ) | % from the Total Designed Area of the Building |
|--------------|------------------|----------------------------|------------------------------------|--|--|--|
| Ground Floor | 1                | 8                          | 8                                  | 1439.4   | 1439.4   | 13.0 %   |
| 1st Segment  | 3                | 30                         | 10                                 | 1071.9   | 3215.8   | 29.0 %   |
| 2nd Segment  | 5                | 30                         | 6                                  | 1284.2   | 6421.0   | 57.9 %   |
| 3rd Segment  | 0                | 0                          | 0                                  | 0.0  | 0.0  | 0.0 %  |
| 4th Segment  | 0                | 0                          | 0                                  | 0.0  | 0.0  | 0.0 %  |
| 5th Segment  | 0                | 0                          | 0                                  | 0.0  | 0.0  | 0.0 %  |
| 6th Segment  | 0                | 0                          | 0                                  | 0.0  | 0.0  | 0.0 %  |
| <b>TOTAL</b> | <b>9</b>         | <b>68</b>                  |                                    |  | <b>11076.35</b>  |  |

Area of Double Volume = 528.8  
Total Designed Area = 11605.15

Detailed Calculations for Residential Apartments

|              | Private Courtyards inside Apartments |   |                                     |                                   |  | Area of Apartments (including Courtyards) |                               |                                   |  |
|--------------|--------------------------------------|---|-------------------------------------|-----------------------------------|--|---|-------------------------------|-----------------------------------|--|
|              | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Apartments on Each Floor | % from the Total Area of Each Floor | Area on All Floors of the Segment | % from the Total Designed Area of the Building | Area on Each Floor (m <sup>2</sup> )      | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Designed Area of the Building |
| Ground Floor | 44.5                                 | 4.06 %                                      | 3.09 %                              | 44.5                              | 0.38 %   | 1095.1                                    | 73.01 %                       | 1095.1                            | 9.44 %   |
| 1st Segment  | 0                                    | 0.0 %                                       | 0.0 %                               | 0.0                               | 0.0 %  | 814.33                                    | 54.29 %                       | 2442.99                           | 21.05 %  |
| 2nd Segment  | 84.3                                 | 8.3 %                                       | 6.56 %                              | 421.5                             | 3.63 %   | 1015.8                                    | 67.73 %                       | 5079.45                           | 43.77 %  |
| 3rd Segment  | 0                                    | 0.0 %                                       | 0.0 %                               | 0.0                               | 0.0 %  | 0   | 0.0 %                         | 0.0                               | 0.0 %  |
| 4th Segment  | 0                                    | 0.0 %                                       | 0.0 %                               | 0.0                               | 0.0 %  | 0   | 0.0 %                         | 0.0                               | 0.0 %  |
| 5th Segment  | 0                                    | 0.0 %                                       | 0.0 %                               | 0.0                               | 0.0 %  | 0   | 0.0 %                         | 0.0                               | 0.0 %  |
| 6th Segment  | 0                                    | 0.0 %                                       | 0.0 %                               | 0.0                               | 0.0 %  | 0   | 0.0 %                         | 0.0                               | 0.0 %  |
| <b>TOTAL</b> |                                      |   |                                     | <b>466</b>                        | <b>4.01 %</b>                                  |   |                               | <b>9277.63</b>                    | <b>79.94 %</b>                                 |

Area of Double Volume = 528.8  
% from the Total Area of Apartments = 5.02 %

Detailed Calculations for Common Spaces inside the Building

|              | Main Public Space (MPS)              |                               |                                   |                                       | Semi-Private Spaces (PVS)            |                               |                                   |                                       | Entry Hall (EN)        |                              |                                       | Corridors (COR)                      |                               |                                   |                                       | Vertical Core (VC)                   |                               |                                   |                                       |
|--------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|------------------------|------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------------------|
|              | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area (m <sup>2</sup> ) | % from the Area of the Floor | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building | Area on Each Floor (m <sup>2</sup> ) | % from the Area of Each Floor | Area on All Floors of the Segment | % from the Total Area of the Building |
| Ground Floor | 88.08                                | 6.12 %                        | 88.08                             | 0.8 %                                 | 40.51                                | 2.82 %                        | 40.51                             | 0.37 %                                | 45.0                   | 3.13 %                       | 0.41 %                                | 58.15                                | 4.04 %                        | 58.15                             | 0.52 %                                | 112.5                                | 7.82 %                        | 112.5                             | 1.02 %                                |
| 1st Segment  | 88.08                                | 8.22 %                        | 264.24                            | 2.39 %                                | 40.51                                | 3.78 %                        | 121.59                            | 1.1 %                                 |                        |                              |                                       | 46.51                                | 4.34 %                        | 139.53                            | 1.26 %                                | 112.5                                | 10.49 %                       | 337.5                             | 3.05 %                                |
| 2nd Segment  | 32.98                                | 2.57 %                        | 164.9                             | 1.49 %                                | 22.04                                | 1.72 %                        | 110.2                             | 0.99 %                                |                        |                              |                                       | 56.56                                | 4.4 %                         | 282.8                             | 2.55 %                                | 112.5                                | 8.76 %                        | 562.5                             | 5.08 %                                |
| 3rd Segment  | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 | 0                                    | 0.0 %                         | 0.0                               | 0.0 %                                 |                        |                              |                                       | 0                                    | 0.0 %                         | 0.0                               | 0.0 %                                 | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 |
| 4th Segment  | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 | 0                                    | 0.0 %                         | 0.0                               | 0.0 %                                 |                        |                              |                                       | 0                                    | 0.0 %                         | 0.0                               | 0.0 %                                 | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 |
| 5th Segment  | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 | 0                                    | 0.0 %                         | 0.0                               | 0.0 %                                 |                        |                              |                                       | 0                                    | 0.0 %                         | 0.0                               | 0.0 %                                 | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 |
| 6th Segment  | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 | 0                                    | 0.0 %                         | 0.0                               | 0.0 %                                 |                        |                              |                                       | 0                                    | 0.0 %                         | 0.0                               | 0.0 %                                 | 0.0                                  | 0.0 %                         | 0.0                               | 0.0 %                                 |
| <b>TOTAL</b> |                                      |                               | <b>517.22</b>                     | <b>4.68 %</b>                         |                                      |                               | <b>272.32</b>                     | <b>2.46 %</b>                         | <b>45.0</b>            | <b>3.13 %</b>                | <b>0.41 %</b>                         |                                      |                               | <b>480.48</b>                     | <b>4.33 %</b>                         |                                      |                               | <b>1012.5</b>                     | <b>9.15 %</b>                         |

% of Double Volume = -0.97 %