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

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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,
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For their continuous support

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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 parametrs, 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 repsonses 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

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

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).

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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.

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Chapter One

Introduction and Overview

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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[1] (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).

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

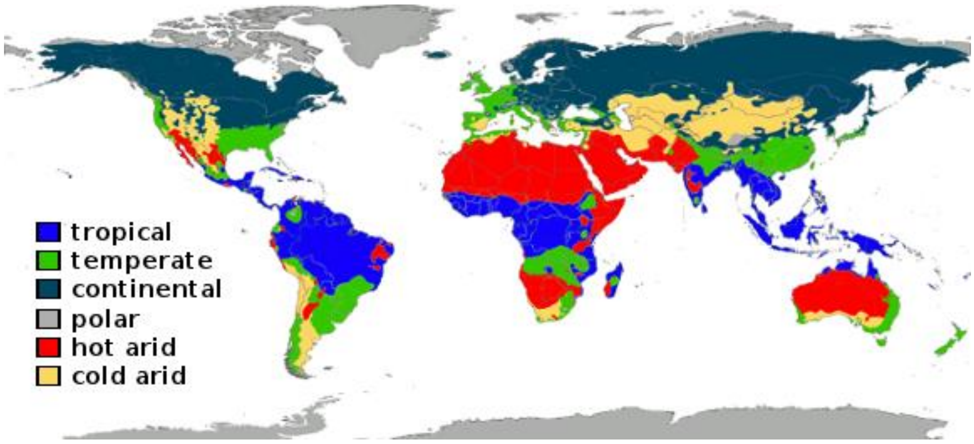


Figure 1.1: Köppen classification World climate map
(Source: http://www.essential-humanities.net/history-supplementary/climates-biomes/)
(accessed on 15/10/2015)

The climate in hot-arid regions is characterised by the following[2]:

- 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[3]. This percentage, which is expected to reach to nearly 400 million by 2050 (The World Bank

[2] http://www.essential-humanities.net/history-supplementary/climates-biomes/ (accessed on 15/10/2015)
[3] 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).

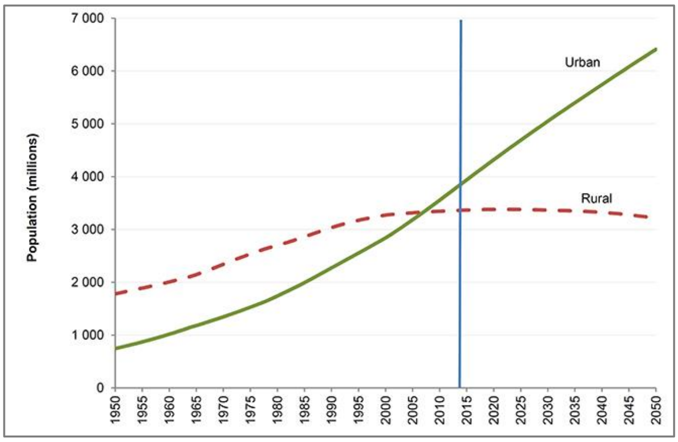


Figure 1.2: The world's urban and rural population (1950-2050)
(United Nations 2015)

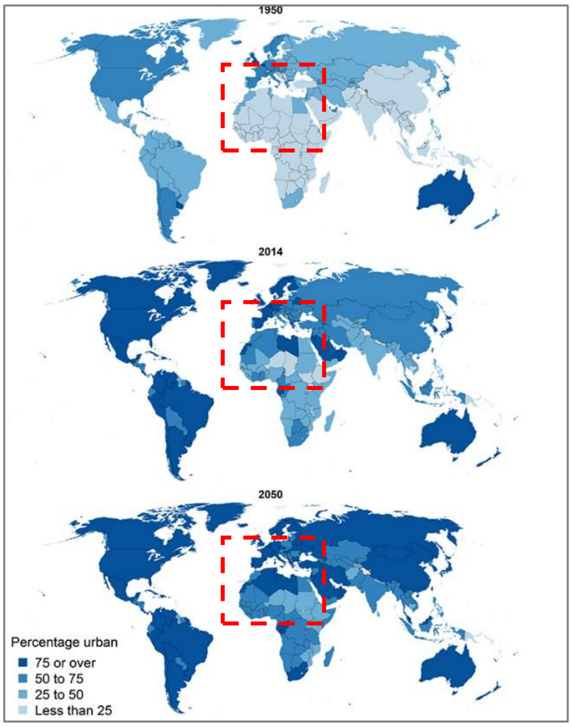


Figure 1.3: Percentage of the population residing in urban areas in the Middle East and North Africa, 1950, 2014 and 2050.
(United Nations 2015)

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 32nd, 33rd, and 58th respectively[4] (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 km² = (407 mi²)	7,827	136,960
2	New York City	8,336,697	800 km² = (309 mi²)	6,198	44,027
3	Chongqing	6,300,000	82,403 km² = (31,816 mi²)	1,719	40,250
4	Shenzhen	3,538,275	2,020 km² = (780 mi²)	1,091	28,811
5	Seoul	10,581,728	616 km² = (238 mi²)	4,148	26,841
6	Singapore	5,312,400	710 km² = (274 mi²)	4,916	26,605
7	Guangzhou	6,560,500	7,434 km² = (2,870 mi²)	910	23,702
8	Moscow	11,503,501	1,080 km² = (417 mi²)	11,697	23,218
9	Dubai	2,104,895	3,885 km² = (1,500 mi²)	1,025	23,112
10	São Paulo	11,316,149	1,523 km² = (588 mi²)	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*'[5]. 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

[4] http://www.emporis.com/statistics/skyline-ranking (accessed on 12/4/2016)
[5] 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[6]. 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)

[6] 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, 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)).

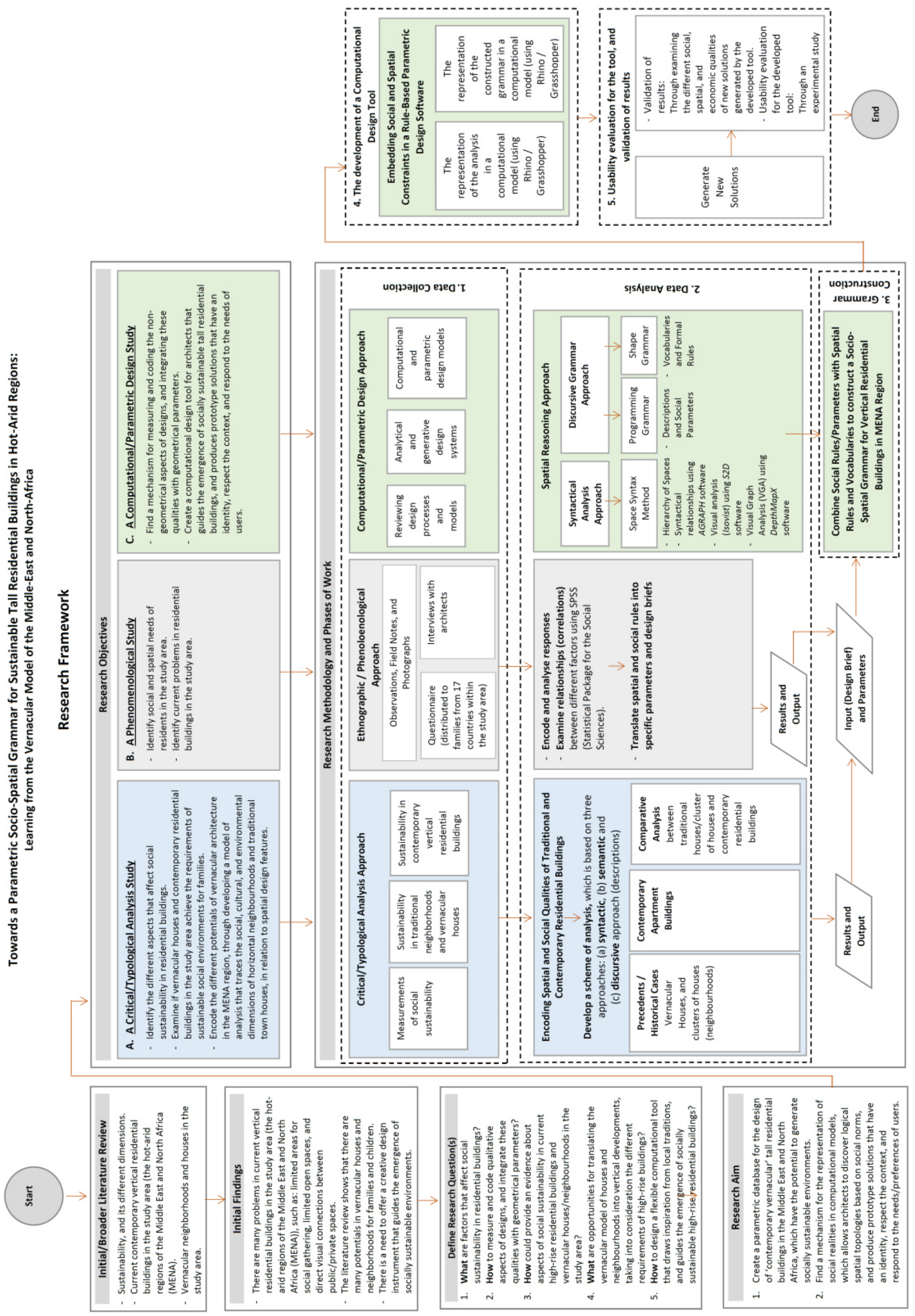


Figure 1.6: Research framework

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.

Volume One

Chapter One: Introduction and Overview

- Research Context and Background
- Research Aim, Questions and Objectives
- Research Design and Methodology

Chapter Two: Literature Review

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

- The Concept of Sustainable Development and Social Sustainability
- Sustainability in Contemporary Residential Developments
- Spatial Principles in Traditional Neighbourhoods and Vernacular Houses
- Research Gaps
- Towards a 'Contemporary Vernacular' High-rise Residential Developments: A 'Critical Regionalism' Approach

Part (B): Computational and Parametric Design Models

- Reviewing Design Models and Processes
- Computational Design Process
- Analytical and Generative Design Systems

Chapter Three: Research Design and Methodologies

- Research Paradigms and Theoretical Approaches
- Research Design and Framework
- Phases of the Study and Research Methods

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

- Data Collection (Observations, Interviews, Questionnaires)
- Data Analysis
- Extracting Spatial and Social Preferences from the Survey

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

- Methods of Spatial Analysis
- Data Collection (Case Studies)
- Data Analysis and the Extraction of Socio-Spatial Qualities (Readings from Syntactic and Formal-Geometric Analyses)

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

- The Language of Traditional Neighbourhoods
- The Language of Vernacular Houses

Part (B): The Development of a Computational Design Tool for Socially Sustainable High-rise Residential Buildings

- Requirements of High-rise Buildings
- Sets of Parametric Rules for the Design of High-rise Residential Buildings
- A Computational Design Tool for Socially Sustainable High-rise Residential Buildings

Part (C): Usability Evaluation for the Tool, and Validation of Results

- The Generation of New Solutions
- Validation of Results: Testing Design Qualities of New Solutions generated by the Tool
- Usability Evaluation for the Developed Computational Tool: An Experimental Study

Chapter Six: Research Conclusions

- Summary of Findings
- Contribution to the Body of Knowledge
- Limitations of Research
- Recommendations and Directions for Future Works

Volume Two

Appendices

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.

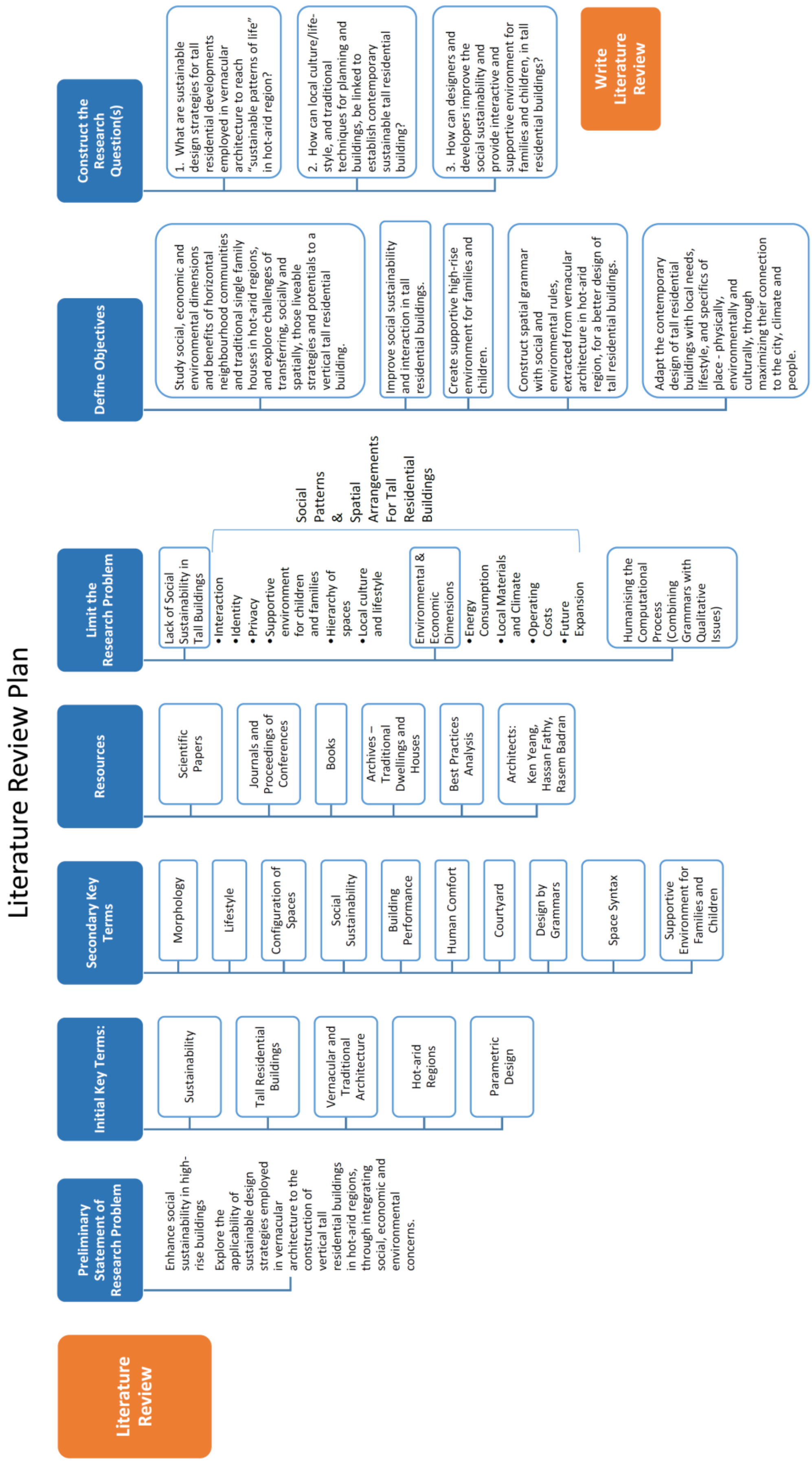


Figure 2.1: The literature review plan

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[1], 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).

[1] 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.

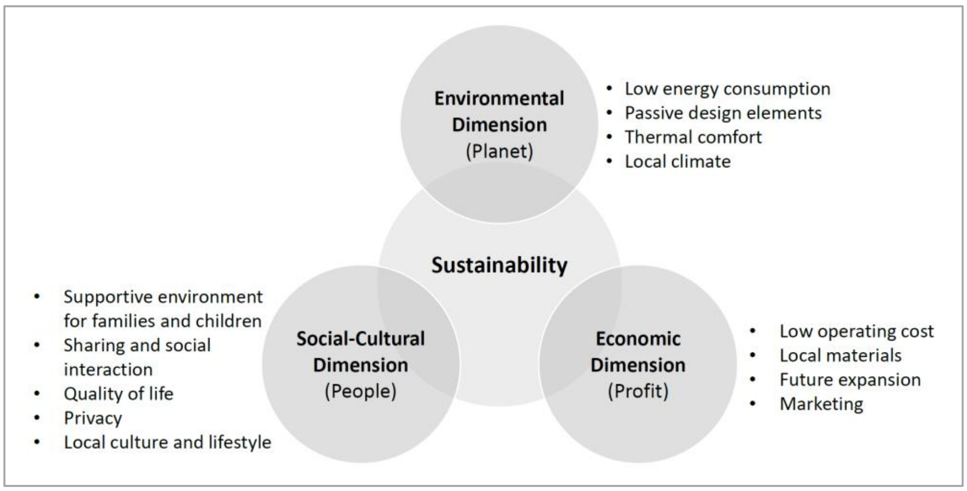


Figure 2.2: Dimensions of sustainability
(Researcher)

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 Gedík 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 20th 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
- **Access:** 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. - **Participation:** front gardens create opportunities for unplanned participation. - **Adaptability**: 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.	- **Footprint:** tall buildings have smaller footprints and consume less land area. This, in principle, leaves more area for green and communal spaces. - **Views**: 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. - **Security:** 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. - **Safety**: movement within a tall building complex is much more comfortable and safer, which can result in more social interactions. - **Pollution:** As one moves higher, the air gets cleaner and purer, and the noise can be reduced through open gardens.	- **Optimisation:** 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. - **Access:** 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. - **Spatial design:** 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.

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^{th}-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^{th}-floor level).	31% lower
A courtyard with low-e glass compared with a courtyard with single clear glass (at the 10^{th}-floor level).	39% lower
A courtyard with clear triple glass compared with a courtyard with single clear glass (at the 10^{th}-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". (Kennedy *et al*. 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.	- 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) - The availability of natural ventilation and outdoor private living spaces (balconies) play an essential role in the perception of liveability in the subtropical areas.	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". (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.	- 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. - 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. - They used the balcony for a wide variety of social and non-social domestic activities. - 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.	Future research could focus on materials and spatial characteristics of private open spaces.

			- A private balcony allowed residents to move to an outdoor space without leaving the apartment. - 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.	
"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.	- Advantages of social spaces in low-rise residential developments: access, participation, hierarchy of spaces, adaptability, and individuality. - Typical advantages of social spaces in high-rise developments: footprint, views, security, pollution, and safety. - Challenges and solutions to the provision of social spaces in residential high-rises: optimization, access, and space design.	
"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.	- 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. - Poor acoustic environment (noise of urban neighbourhood, external and internal sound-proof of dwelling units). - Harsh wind environment in high-rise housing estates. - Lack of public places and facilities within housing estates, - The poor identity of dwelling buildings.	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 *et al*. 2012)	Tianjin, China, temperate climate, 2012			

"'Living the high life'? Residential, social and psychosocial outcomes for high-rise occupants in a deprived context". (Kearns *et al*. 2012)	Glasgow, mild climate with no dry season, 2012	Examine the impacts of living in a high-rise in comparison to other dwelling types.	- Many residential outcomes are worse for people in high-rise buildings, primarily related to noise and security issues. - 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. - 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.
"Guidelines for tall buildings development". (Al-Kodmany 2012)	Different locations and climates. 2012	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.	Issues that should be considered while designing a tall building: - Urban context: The built heritage, view corridors and skyline, figure, gateways, landmarks, social issues. - Spatial clusters design guidelines: Focal points, visual relief, transition, varying building heights and massing, design diversity, visual coherence, ventilation. - 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. - Tall buildings design guidelines: o Base/podium: It should not exceed 5-6 stories in order not to block views to the shaft. A collonaded base also has the advantage of alleviating the wind uplift around the building and providing extra shelter and protection from the weather for pedestrians. o Stairs: the walking distance to an exit staircase must not exceed 30 m.

			○ Refuge floors for super-tall buildings are designed mainly as firebreaks where people can take shelter while waiting for evacuation.	
"Environmental issues in high-rise residential building design in urban areas". (Niu 2004)	Hong Kong, subtropical climate, 2004.	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.	- 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.	
"Tower buildings in Dubai: Are they sustainable". (Al-Sallal 2004)	Dubai, hot-arid climate, 2004.	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.	- 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. - 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.	

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).

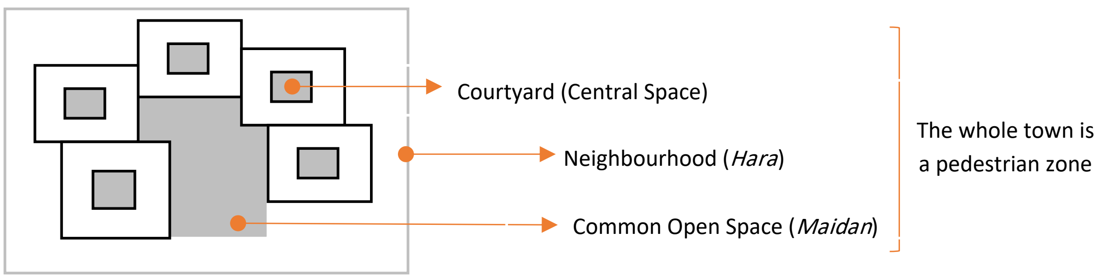


Figure 2.3: A diagram showing the different components of a traditional town in MENA region (Researcher)

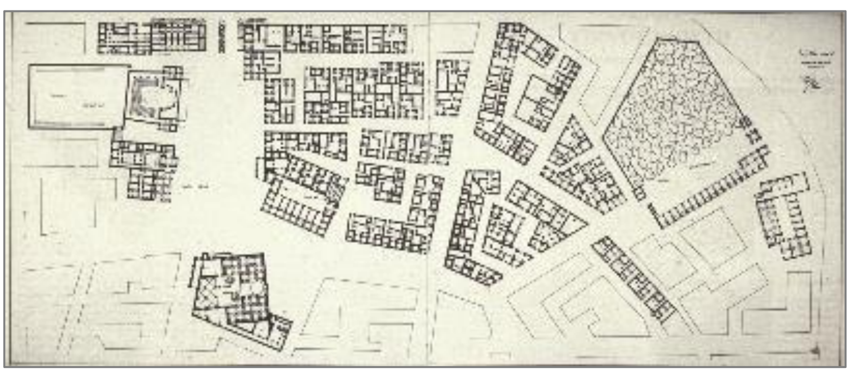


Figure 2.4: The Village of New Gourna, Egypt
(http://web.mit.edu/, accessed on 4/2/2016)

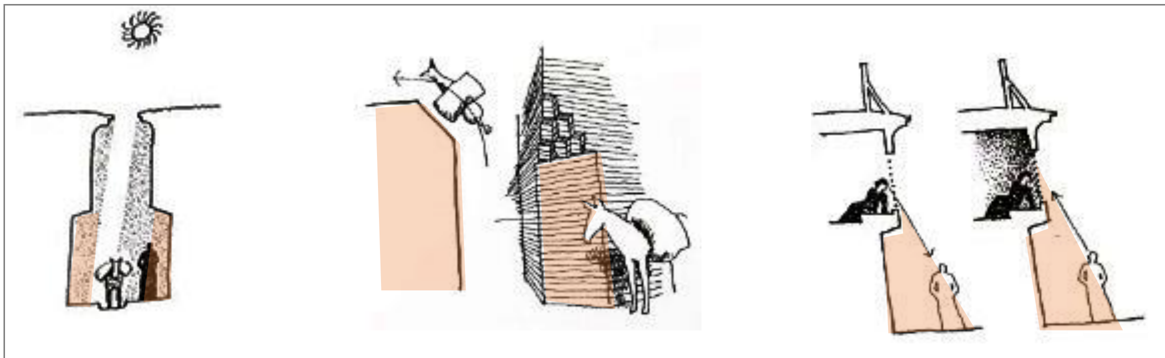
Another example, is the core of old Tunisia, which has a compacted layout. Hakim (1986), in his book: *Arabic-Islamic Cities*, evaluated the urban and the architectural language of this quarter, and concluded that open spaces and private courtyards play a major role in reducing crowding and increasing 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.

(a) Part of Old Town in Tunisia (b) Old Quarter of Aleppo (c) Old Town in Algeria

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



(a) Street Shading (b) Corner Cutting (c) Open and Closed Vision

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

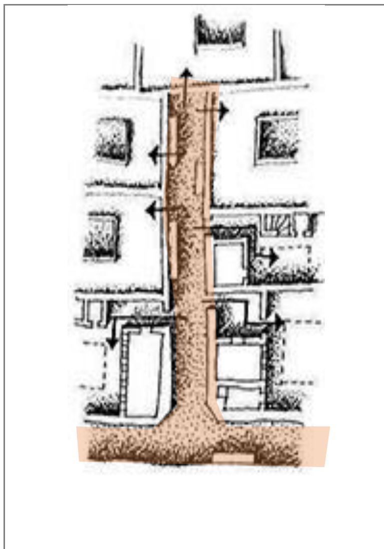


Figure 2.7: The principle of staggered entrances
(Ragette 2003)

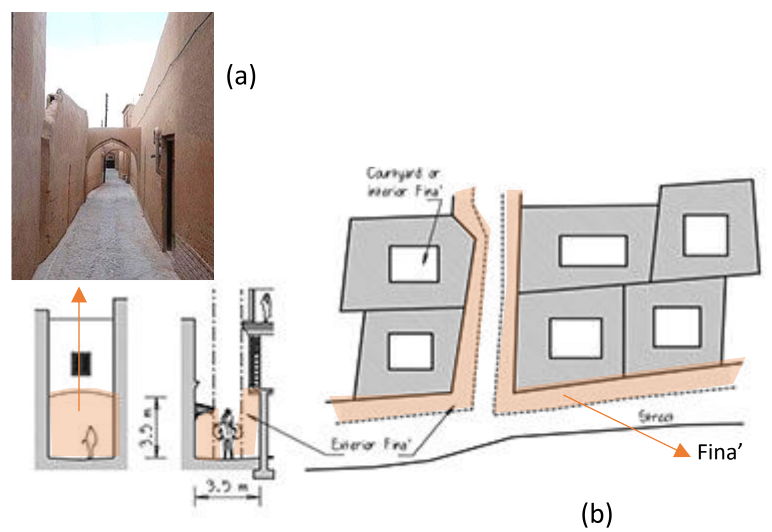


Figure 2.8: Rules for alleys in a traditional residential quarter
((a) Moossavi 2014; (b) Steyn 2012)

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

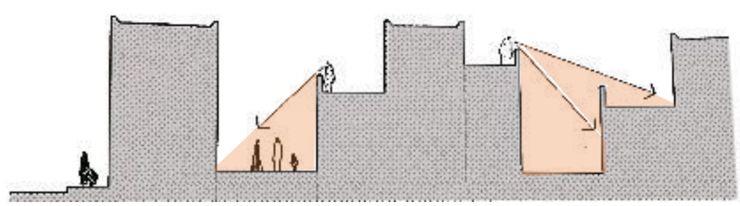


Figure 2.10: A section through adjoining houses showing how setbacks are used to maintain privacy between neighbours
(Bahammam 2006)

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
- A large irregular courtyard (or group of courtyards are interconnected sequentially). - Covered pathways (irregular and narrow passages). - Surrounded walls in public and private spaces. - Dense fabric. - Limiting the size of neighbourhoods and reducing distances between houses.	- The courtyard serves as the village square, where people can celebrate and meet. - Eliminate wasted spaces between buildings. - Appreciate the cultural identity and nostalgia. - Create protected outdoor spaces that enhance interaction between families and children. - A visual barrier to maintain privacy, avoid disputes with neighbours, and increase the sense of community.	- Eliminate external heat gain or loss. - Provide shade. - Block excessive air movement which carries sand and dust.	- Occupy a much larger ground area than modern clusters, which affects the area of green and communal spaces. - Limiting views to the outside - 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.
- Corner Cutting: Corners of buildings are cut at 45 degrees up to shoulder height - *Al-fina'*: which is the exterior space immediately adjacent to the exterior walls of the house. - '*Sabat*': building a room over a street joining two structures owned by the same person.	- To ease people walk and movement. - To allow for loading and unloading.	- Provide shade for pedestrian.	- The problem of ownership when upper floors of houses are extended over streets.
- Avoid entrances facing each other (the principle of staggered entrances). - Windows of neighbours are not supposed to allow a view into adjacent yards. - Houses are built wall-to-wall with introverted courtyards (dense grouping of courtyard houses), and sometimes there are setbacks.	- To maintain privacy between neighbours. - To block the direct view and access.	- Eliminate external heat gain or loss. - Provide shade.	- Reduce the opportunity to see and interact with the outside public areas. - Cause noise, especially for elderly people.

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).

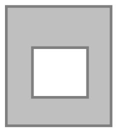
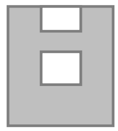
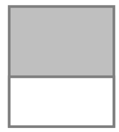
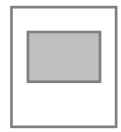
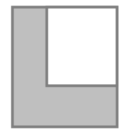
Courtyard houses were used widely throughout the history. In ancient Egypt and Mesopotamian civilisations (Sumerians, Babylonians and the Assyrians), houses were built around one or more courtyards. Later, in Roman and Greek architecture, most of houses have courtyards surrounded by rooms (Islam and Al-Sanafi 2006). In the Middle East and North Africa, the courtyard house has been adopted in the 7th and 8th 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 : Solid : Void					
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.

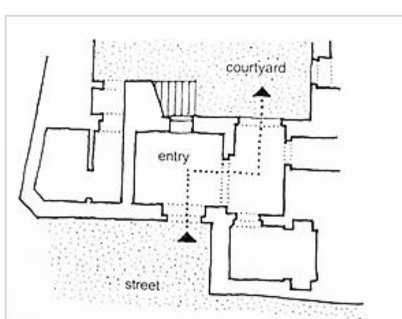
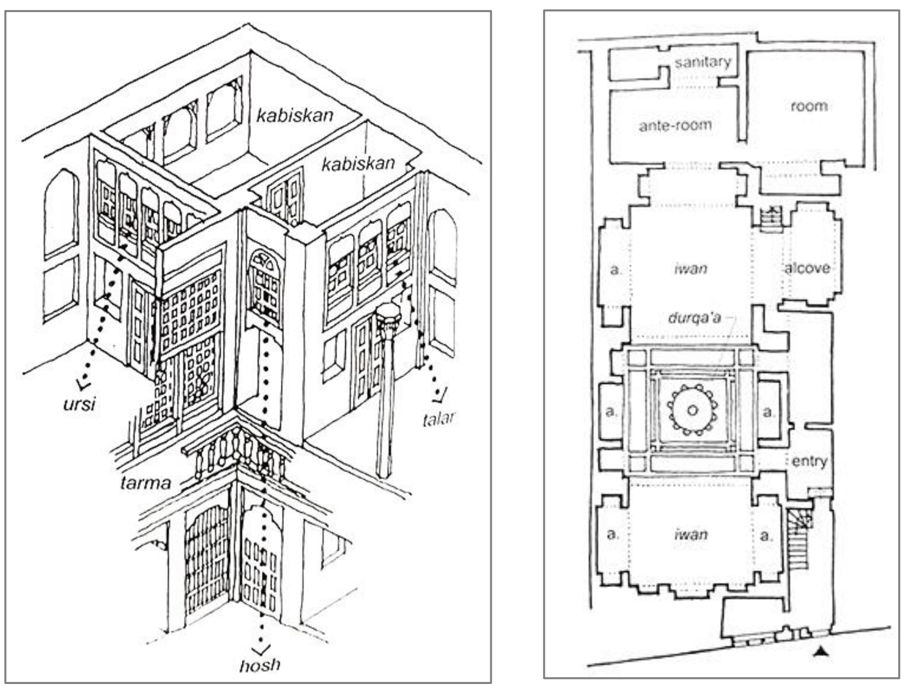


Figure 2.11: The concept of indirect entry to the courtyard
(Ragette 2003)

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.



(a) (b)

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	*Hosh*	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	*Majaz*	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)	*Salamlik* or *Diwaniya*	It is used for male visitors, suited off the entry courtyard.
Portico (Gallery or Balcony) overlooking the courtyard	*Burtal* in North Africa, *Riwaq* in Syria, and *Tarma* 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	*Iwan* in Syria, and *Talar* 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	*Ursi*	It is a specific version of '*talar*'.
Gallery carried with columns all around a courtyard	*Peristyle*	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)	*Majlis or Kabishkan*	A room suspended halfway between upper and lower floors, which is a reception space (*majlis*) for women, and a retreat for the elders (*kabishkan*).
A room with a raised floor and a side open to the courtyard	*Takhtaboush*	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)	*Qa'ah*	It is the main reception hall in the house, consisting of the *durqa'ah* (a central part of the *qa'ah* with a high ceiling covered by the *shukhshakhah* (wooden lantern on the top) and two *iwans* (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
Type (1): ***Maghrebi* type (Morocco and Tunisia)**	- Features the most consistent and formalised typology - Shows an interesting architectural dialectic between the mostly irregular contours of the plot and the perfect geometric form of the courtyard - The size of the house varies with dimensions and proportions of the courtyard - Usually extends over 2 or 3 floors - Height of each main floor is 4 to 5 meters - Tight outer enclosure wall, which creates a total introversion while allowing for lateral attachment of neighbourhood houses. - Materials of walls are sun-dried or baked bricks	Main Courtyard	- Absolute centrality of the courtyard '*wust ad-dar*' (centre of the house), which shaped the building - Symmetrical and balanced order - Length of courtyard walls = 6 to 10 meters	- Can be interpreted as the timeless centre of gravity of the house. - The shape of the courtyard established a strong vertical ambition toward the sky.
		Main rooms '*baits*'	- An ideally symmetrical layout of the main rooms around the courtyard - Follow the geometric pattern of the courtyard - They usually face each other and are accessible from the courtyard or the gallery. - 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. - The very long space allowed for a convenient subdivision into a central access zone and two lateral bays.	- 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). - A depth of around 3 meters provided the right distance to feel comfortable - They had 'door within door', which allow inhabitants of the house to adjust the opening according to different occasions and climate conditions.
		Ancillary (secondary) facilities	- They were relegated to the periphery of the building	- They were used as 'filling material' to absorb the change of directions of irregular plot shape - They can be ventilated by a separate air shaft (if needed).
		Air shafts (small courtyards)		
		Storage rooms	- Injected between two main floors - Height = 2 meters	
		Gallery	- Located on the first floor running around the courtyard	- 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.

		Staircases	- Staircases are more than one, placed in strategic corners of the building without being exposed	
		Balcony	- Used as replacement of collonaded galleries in the case of narrow courtyards - Connecting opposite rooms on the first floor	
<u>Type (2):</u> ***Syrian* Type (Syria, Jordan, Palestine and Lebanon)**	- Has a more complex and less regular structure, especially with regards to the courtyard shape and the interior elevations of the house. - Tight outer enclosure wall, which creates a total introversion while allowing for lateral attachment of neighbourhood houses.	Courtyard	- Less formal in shape - Less concern for symmetry in the facades facing the open space	- Takes the character of a shared family square - Providing the intermediate connection between the various components and sub-units of the house
		Main rooms	- Symmetric layouts were applied, but not extended to the central courtyard. - There is a lower (sunken) circulation space (as an entrance) for every room.	- The lower (sunken) circulation space (*ataba*) was used for cleaning check (to take off one's shoes), while the higher space is used as living and sitting area.
		Reception room '*qa'a*'	- High-domed central space of square shape, which could be entered from one side (through a door from the courtyard) - In modest houses, it was adapted in incomplete form with only one bay and a small anteroom, directly accessible from the main courtyard.	- A fully developed reception, which constitutes a house within the house - The central space of the reception room acts as the 'courtyard' - 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 - Equipped with an interior fountain - Light and air could be entered through openings in the polygonal or circular drum
		Iwan	- In big houses, three *iwans* are located adjacent to the reception room, two facing each other and one facing the entry door - The front of each *iwan* is marked by a wide arch. - In most cases, the floor of the *iwan* is raised by one or two steps from the lower circulation space - Surrounded walls are mostly solid. - The single *iwan* was open and attached directly to the courtyard.	- Lower circulation space to take off one's shoes, and higher living and sitting area. - Open *iwan* could serve as a family sitting area or an open-air reception space. - The open *iwan* was usually oriented northwards to avoid direct sun radiation, and to catch the cool breeze during hot summer days.

			- The single *iwan* could be edged by two lateral rooms, which are accessible via the *iwan*, and form another sub-unit of the house.	
		Separate (independent / individual) living room ("*murabba*" or "square")	- Intermediate sections between 6 to 8 meters high, which include *qa'a* and open *iwan*. - 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.	- Provide separate quarters for family members or guests (for privacy).
<u>Type (3):</u> ***Egyptian* Type**	- More complex houses than *Syrian* and *Maghribi* types	Central open courtyard	- Regular central space with relatively symmetric introverted rooms.	- Open to the sky
		Single *iwan*	- The single *iwan* was open and attached directly to the courtyard (located at the end of the central open courtyard).	- Informal covered reception room
		Bent entrance	- A corridor connected with a small anteroom and a bench "*mastaba*" for doorkeeper.	- 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.
		Formal male reception room ("*qa'a*" or "*mandara*"), which consists of: a. Two deep *iwans* b. Covered / sunken central space (*durqa'a*)	- Formal layouts - Located on the ground floor - It is a roofed over courtyard-*iwan* combination (Ragette 2003) - Sometimes it was T-shape space - Could take monumental proportions, with the central part extending through three floors	- Usually used by male visitors - There was a greater degree of transparency since the rooms could have *mashrabiyya* openings to both sides (to the courtyard and surrounding family rooms, and to the street)
		Two deep *iwans*	- Two deep *iwans* facing each other across a sunken central space (*durqa'a*)	- One of them supplied with fresh air from a *malqaf*
		Private living room	- Located on the upper floor overlooking the central space of the *qa'a* - Located above the *iwans* or around the vertical shaft of the *durqa'a*	- Permitted the female group to watch activities in the male reception room - Densely screened windows (timber lattice screens – "*mashrabiyyas*" or "*rowshans*") to achieve privacy, to project into the street, and to form

				protected bay windows with integrated benches, which allows for glimpses from the outside world. - "Porosity" of large portions of the external walls and internal partitions, to maximise cross ventilation and adequate air circulation. - The principle of "*mashrabiyyas*" depends on keeping water jars of unburned clay close to the screen, to benefit from the natural cooling effect of the draft.
		Wind catchers "*malqaf*"		- Directed cool breezes from the roof into the lower rooms.
		Family loggia "*maq'ad*"	- A covered room located on the upper floor, and overlooked the courtyard	- Predominantly used by women
		smaller scale *qa'a*	- Located on the upper floor - In the case of multi *qa'as*, these small rooms were connected by corridors, staircases, services, and open terraces.	- Used as the nucleus of the family rooms and the female apartments.
		Covered / sunken central space (*durqa'a*)	- An entry space, which allows for an access to the raised *iwans* - 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).	- It contains a central fountain. - The polygonal drum allows for the natural light and air to penetrate.
<u>Type (4):</u> ***Iraqi* Type**	- Ancient Iranian influences - 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. - The upper floor was 5 meters high, which allowed the inclusion of split levels in the corners on both sides of an "*ursi*" and a "*talar*".	Courtyard	- Regular layout of the courtyard without insisting on bi-axial symmetries.	
		Elevated colonnade "*tarma*"	- It is used predominantly on the first floor running around one or several sides of the courtyard - Combined with the iwan-like recesses of the "*talar*"	- Giving access to lateral bays and closed reception rooms "*ursi*" - Linking the main rooms on the first floor
		"*talar*"	- Recessed bay with two front columns which is used on the first floor.	
		Closed reception room "*ursi*"	- It is located on the first floor	
		Shaded recess	- It is located at the level of the courtyard.	- Open-air sitting area and an informal reception.
		Living room "*nim*"	- High living room located at basement level.	- It was used during summer

	- The first floor rooms had front windows to project into the air-space of the street.		Low mezzanine rooms "*kabishkan*"	- It is located on the mezzanine of the first floor (above corner rooms "*ursi*" and "*talar*").	- Used by women if the main first floor was used for a male reception. - Used by women to ensure their privacy. - 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.
			Basement "*sirdab*"	- It is a single shaft-ventilated subterranean room. - Rooms around the courtyard called "*neem*", are dropped down by one meter and have a high window (Ragette 2003).	- 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. - It also keeps the ground floor slab warm and dry. - It collects the fresh morning air and preserves it for the hot afternoon hours (Ragette 2003).
<u>Type (5):</u> ***Anatolian* Type (Turkish Style)**	- The courtyard element may be absent, and replaced by covered halls. - The house formed a pavilion-like structure within an enclosed plot. - The need for protection against the cold and heavy rainfalls produced: ▪ The inclined roof, which contrasts with the roof of North African style and Middle-Eastern houses. ▪ Limited vertical windows.	Type (1)	Covered entrance hall "*hayat*"	- It was raised above the ground floor and was accessible by an open staircase from the garden.	
			Main reception rooms	- Centrality played a major role in the layout and interior design of the main reception rooms. - The front rooms were preceded and connected by a covered hall "*hayat*". - The front rooms oriented towards an enclosed garden space.	- The layout is controlled to ensure their mutual independence.
		Type (2)	Central hall "*sofa*"	- 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*". - 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.	- It performed the function of the courtyard (but being covered)
			Living rooms "*oda*"	- Four main rooms were located at the corners of the building, which produced an incredibly formal layout.	

Type (6): ***South Arabian Tower* House (Sana'a in Yemen) and Red-Sea Type (e.g. Jeddah, Mecca, Soakin in KSA)**	- The courtyard element may be absent, and replaced by covered halls. - Centrality played a significant role in the layout and interior design of the main reception rooms. - Adopted the "*roshen*" system (wooden lattice screens) to protect interior spaces. - Attached from one or two sides. - It was conceived as a solution to protect the family on upper floors, and livestock/agricultural products on the (ground floor. - Windows were tiny (except in the "*mafraj*") to ensure privacy.	Central covered hall	- It was functioned as a covered courtyard.	
		Staircase	- A vertical access corridor entered by the main gate of the house. - There is no direct access or visual connection from the staircase into the rooms.	- 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.
		Foyer hall (enclosed forecourt)	- It was located in front of the main gate.	- It was provided as a buffer between the house and the street.
		Male reception space "*mafraj*"	- Located at the top of the house	- Windows offer generous views of the city skyline. - It was considered the preferred place for the men's social ceremonies.
		Roof terraces	- A recessed space in front of the "*mafraj*" - Enclosed by 2 meters high brick walls	- Made up for the lack of an open courtyard - It could be used by the women for all domestic activities.
		Rooms on different levels	- Entered from the central covered hall	- 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. - A flexible 'individual daylight regulation' system which consists of a small window (just above floor level) with double shutters. - 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.

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, Water, Air and Fire	- Earth: as the base surface, - Water and Air: as a resting place, - Fire: as a ceremony (cooking facilities) to symbolise the end of something.
Animal, Vegetable and Mineral	- Animals: birds, cats, dogs (as a safe place), - Vegetation and plants (as a sign of maturity, health, age, and changes), - Pavements (stone, marble).
Below, On, and Above the Ground	- 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), - 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), - Above the ground: (participation and observation), through balcony and roof.
Cycle of Life and Death	- Seasonal variations in plants (blooming, fruiting harvest and dormancy), - The courtyard sees the cycle of generations as well as seasons (a place that celebrates the family's rites of passage).

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)

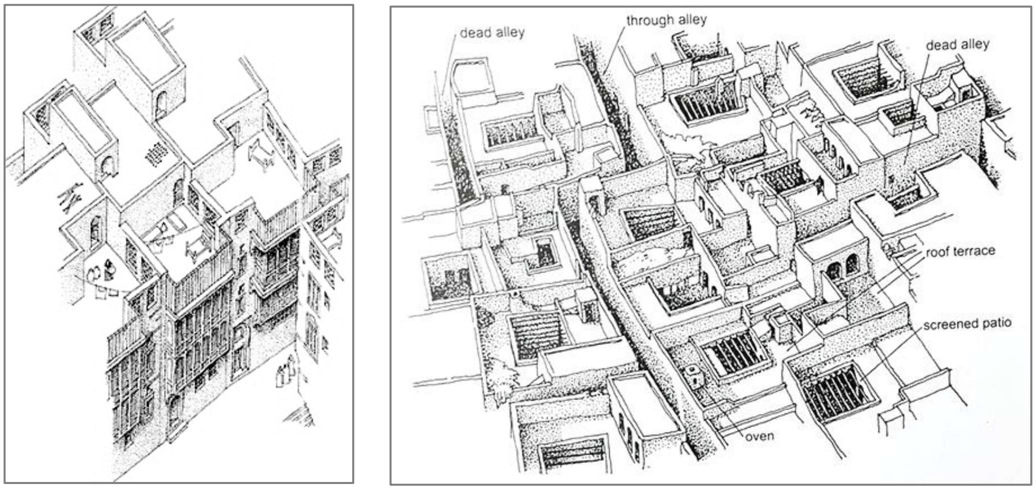


Figure 2.14: Roof terraces in traditional residential buildings in:
(a) Mecca, KSA; (b) Algeria
(Ragette 2003)

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^{th} century, and are made out of mud-brick[2]. 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).

[2] 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 [3])

c. Potentials and Impacts of the Vernacular Model of Houses

Many benifts 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 Gedík 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).

[3] 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.

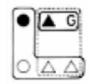
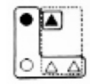
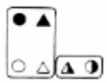
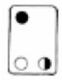
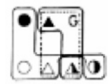
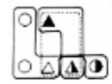
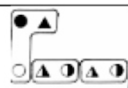
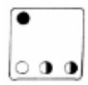
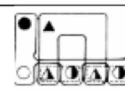
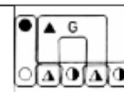
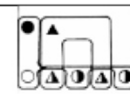
- *Social Indicator (2): Hierarchy of Spaces*

  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 Inetraction 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
Nuclear Family: Father, Mother, 2 Sons, 1 Daughter					
Extended Family: Father, Mother, 1 Son, 1 Daughter, 1 Married Son					
Extended Family: Father, Mother, 1 Daughter, 2 Married Son					
Key	▲ Father	◭ Son, married	G Guest, Male		
	● Mother	○ Daughter	□ Fix Bound		
	△ Son, unmarried	◑ Son's wife	⬚ 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 alnogside 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).

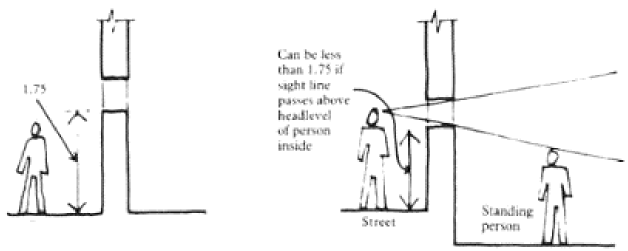


Figure 2.16: Treatments for windows in traditional houses
(Hakim 1986)

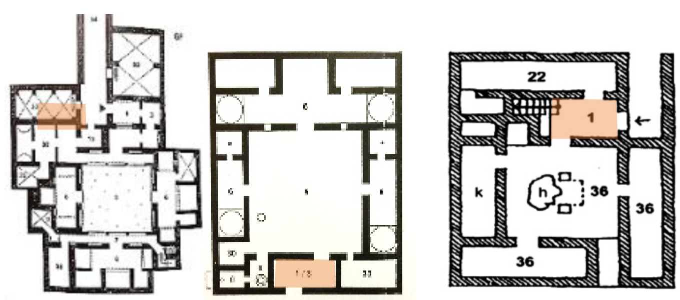


Figure 2.17: The bent-entrance principle in different traditional houses
(Ragette 2003)

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 Gedík 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): Availabilty 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 Gedík 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).

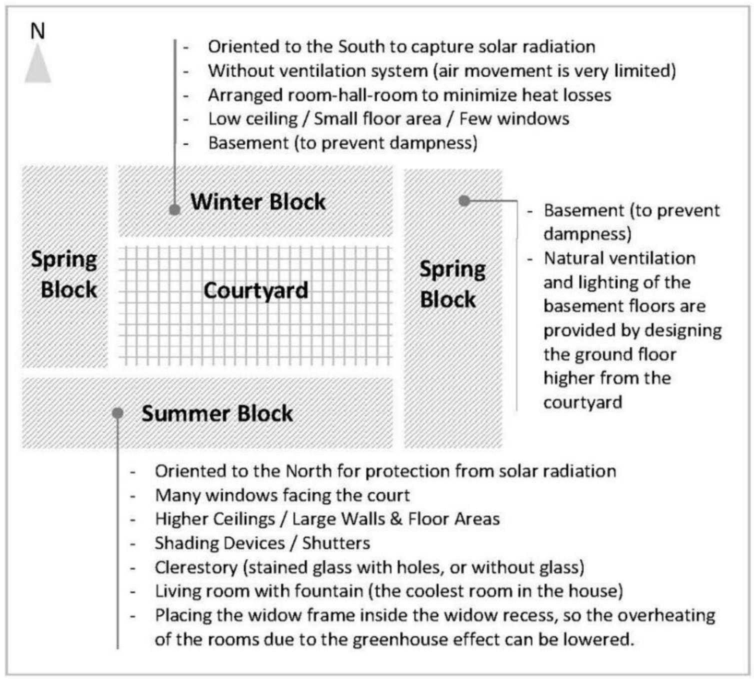


Figure 2.18: Zoning for a typical traditional courtyard house in hot-arid regions
(Researcher)

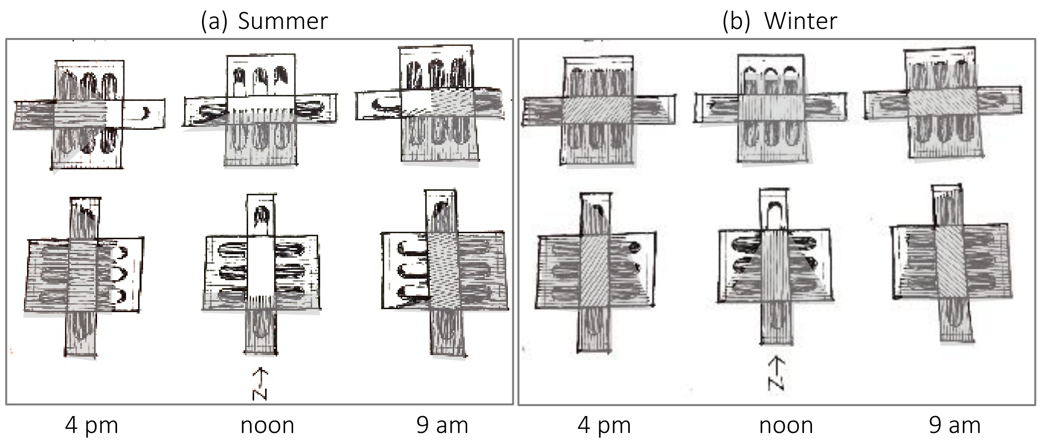


Figure 2.19: Effects of different orientations of courtyard walls
(Reynolds 2002a)

- *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 Gedík 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 Gedík 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	- 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. - 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.
Environmental Dimension	- Many studies show the impact of mechanical heating/cooling systems on energy consumption in high-rise buildings. - Limited studies show how passive design elements could be adopted in the design of high-rise residential buildings.
Economic Dimension	- Limited studies about the financial impact of inserting social gathering spaces in high-rise residential buildings.

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))

Traditional Houses	**Contemporary Houses**
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
- The dominance of technology. - Intensive use of energy. - Centrally controlled. - Concentration of population. - Loss of social equilibrium. - Lack of human scale. - Pollution (noise, fumes, water).	- Low technology (passive design elements). - Energy efficient. - Locally controlled. - Protection from heat, cold and dust. - Crowding behind common walls. - Narrow streets (shade and pedestrian zones). - Internal zoning for privacy. - Organic structure.	- The notion of unity. - Attune architecture to climate with low energy technology. - Live in harmony with nature (the use of local materials). - Create balanced community (elderly and young, poor and wealthy). - Promote the neighbourhood concept, clusters, and integrated services. - Introduce pedestrian zones and avoid grid concepts. - Establish mutual responsibility for common spaces. - Design for privacy without segregation, and carefully zoned into public / semi-public / semi-private / private areas, and design from inside to outside.

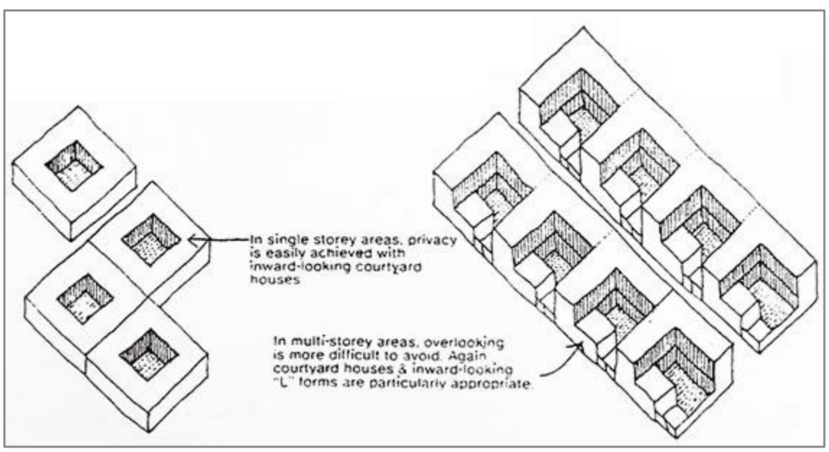


Figure 2.21: A proposal for inserting L-shape courtyard in a multi-storey building
(Ragette 2003)

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 Suadi Arabia, May Al-Jamea (2014) recommended eight principles for achieving social and cultural sustainability. Some of these aspects relate directly to the indicators of sosical sustainabilty that are listed in this chapter (Section 2.2.1, page 23). The eight recommendations accroding 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

Recommendations (accroding to (Al-Jamea 2014))	**How these recommendations are related to social indicators proposed by the researcher**
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: - Social Indicator (2): Hierarchy of Spaces. - Social Indicator (6): Visual Privacy.
2. Social needs: providing a suitable area for family gatherings.	This aspect relates to: 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: Social Indicator (5): Accessibility.
4. Security: high visual control over the family hall, children's activity areas, and outdoor spaces.	This aspect relates to: 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: 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[4] (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.

4 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.

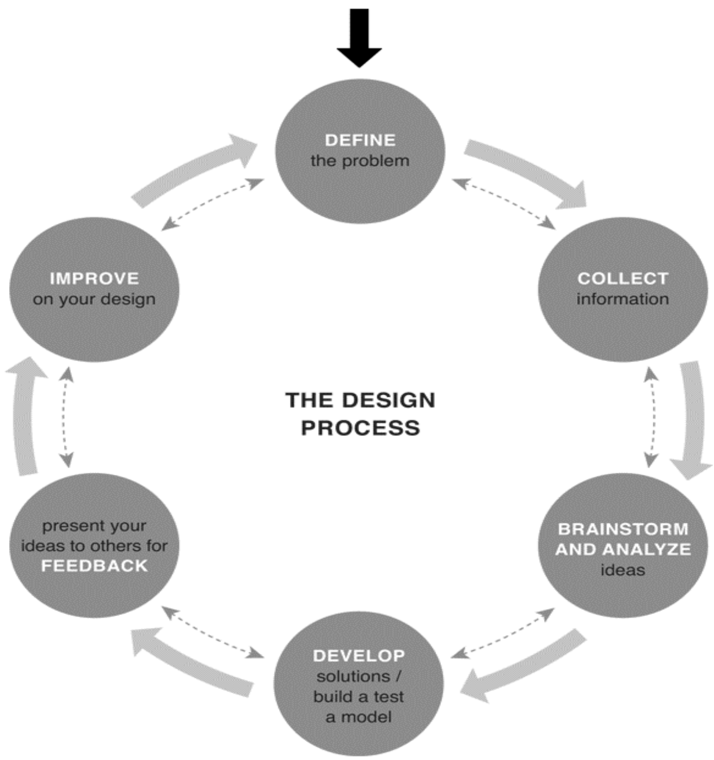


Figure 2.22: The process of architectural design
(http://www.discoverdesign.org/design/process, accessed on 6/4/2016)

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.

3. 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).

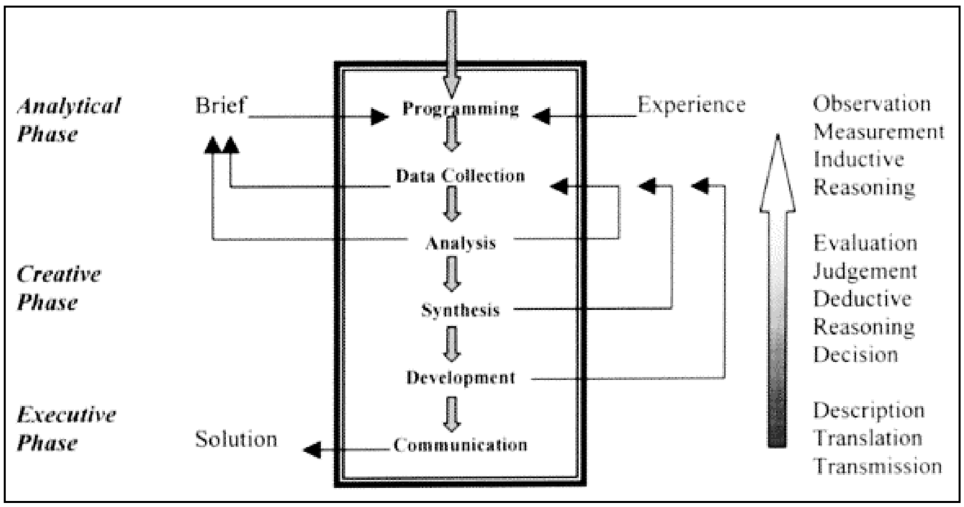


Figure 2.23: Archer's model showing stages of the design process
(Mahmoodi 2001)

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 Hiller'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).

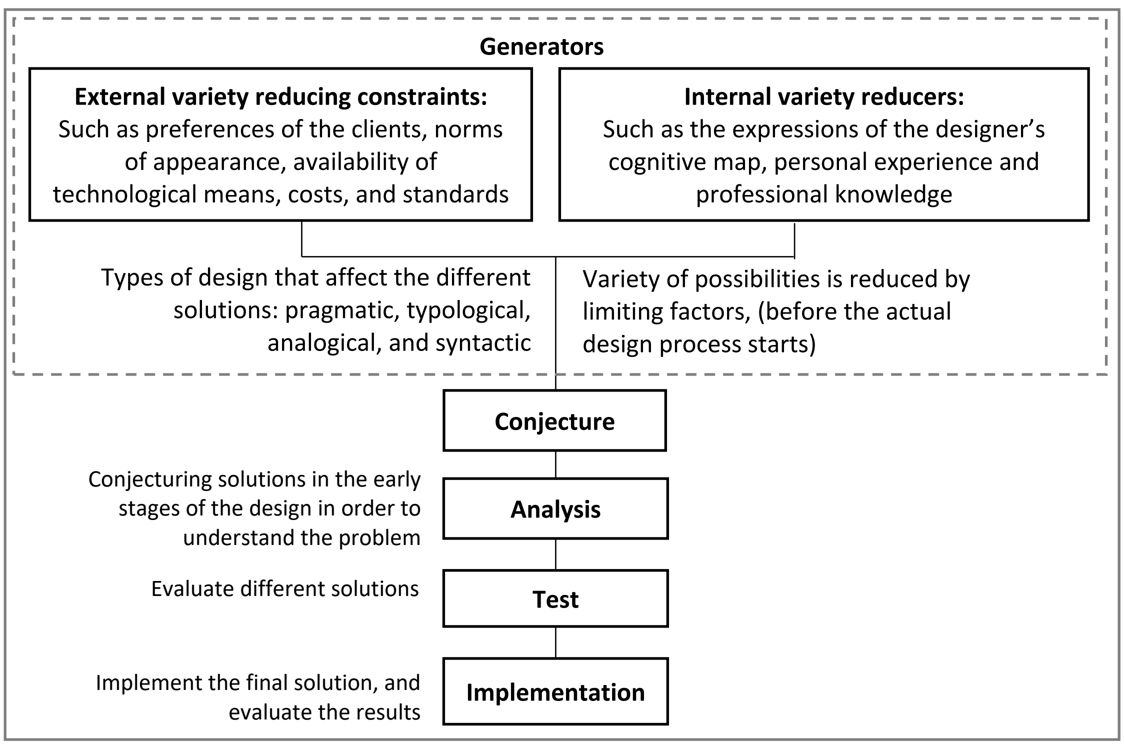


Figure 2.24: Design as a scientific knowledge: The conjecture-analysis-test model
(Adapted by Researcher, after (Maani 2014))

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.

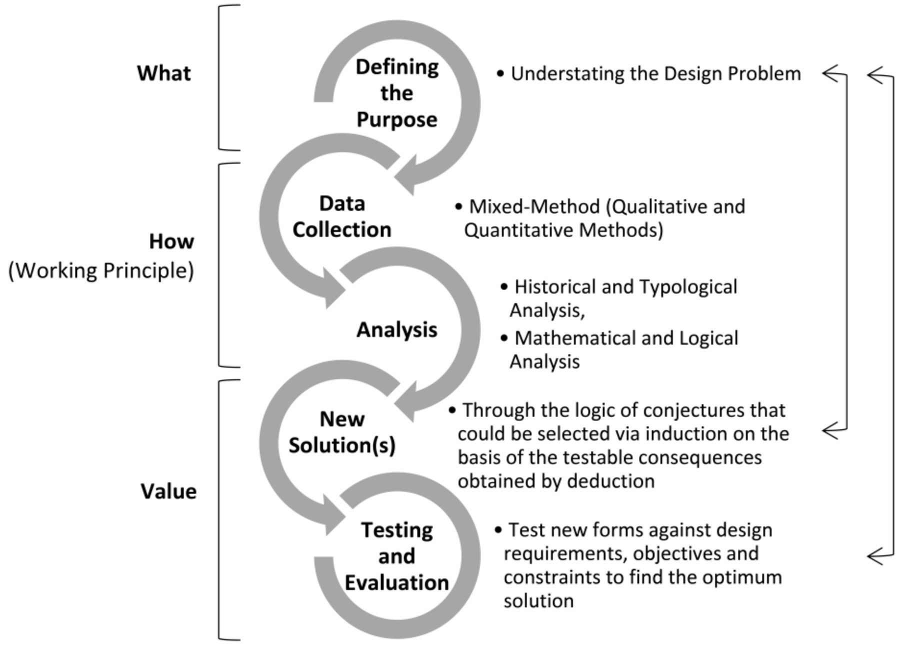


Figure 2.25: The open-form of the abductive model
(Researcher)

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 (Dİno 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 Θ), 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.

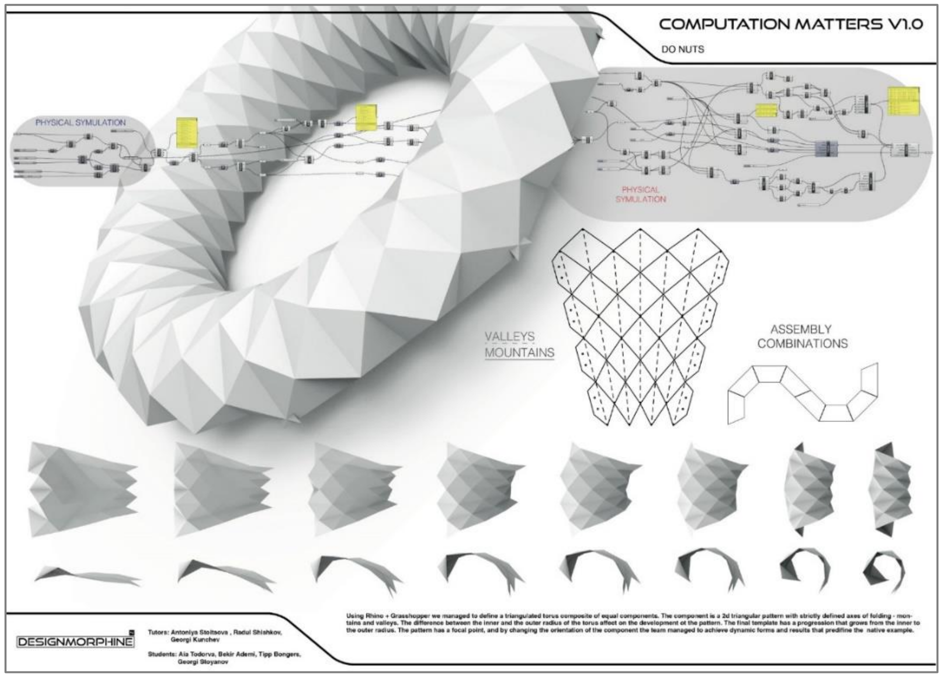


Figure 2.26: Converting a complex structure into basic shapes and components
(Source: Computation Matters V1.0, DesignMorphine, www.arch2o.com (accessed on 3/5/2018))

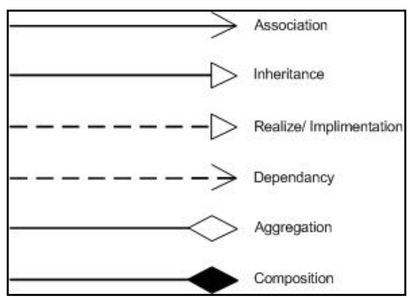


Figure 2.27: Different types of representations in data-flow diagrams
(Nirosh 2015)

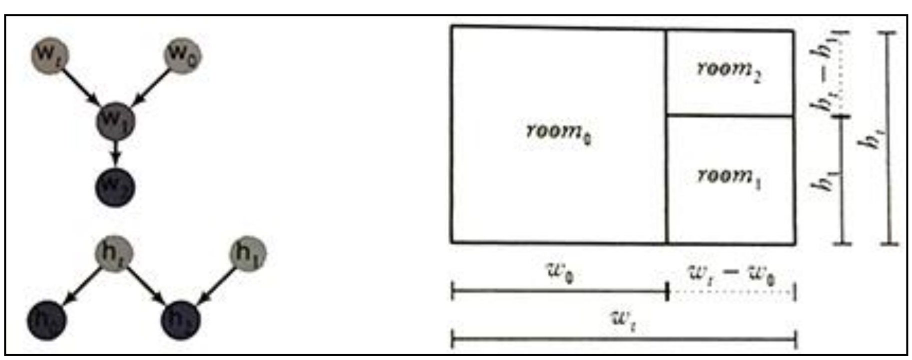


Figure 2.28: An example of the 'propagation-based system'.
(Woodbury 2010)

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; Dİno 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*" (Dİno 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 (Dİno 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.

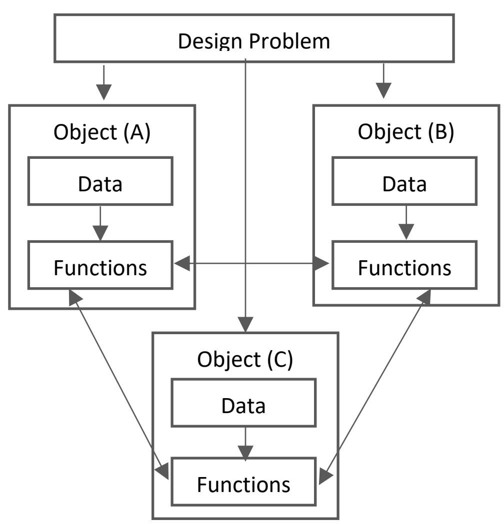


Figure 2.229: Decomposing the design problem into parts (objects)
(Researcher)

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).

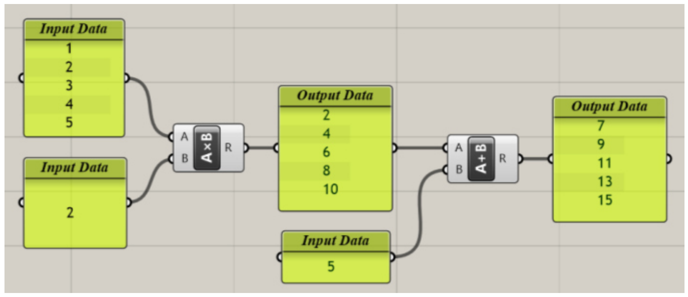


Figure 2.30: A sample of mathematical functions processed by Grasshopper
(Researcher)

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.

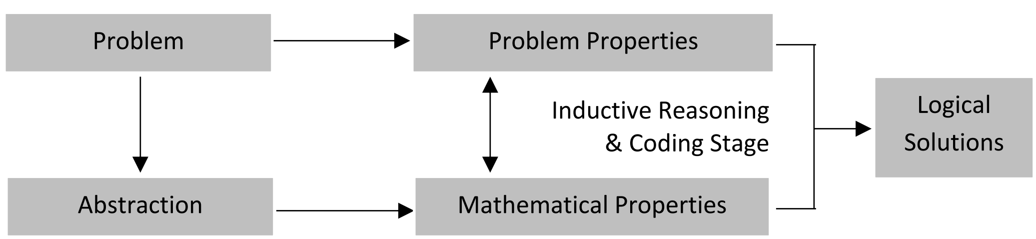


Figure 2.31: The general structure of 'formal methodology' within the computational world
(Adapted by Researcher from (Burgess 1995))

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
Stage 0: Feasibility study	- Technical: is the project technically possible? - Financial: can the business afford to carry out the project? - Organizational: will the new system be compatible with existing practices? - Ethical: is the impact of the new system socially acceptable?	- Define the problem. - Investigate goals and implications of the project.
Stage 1: Investigation of the current environment	- To look at the existing services and requirements and produce a logical view of the processing requirements.	- Establish analysis framework. - Investigate and define projects' requirements, and the current processing and data through a combination of interviewing employees, circulating questionnaires, observations, and existing documentation. - Analyse the current system and process.

Stage 2: Business system options	- To decide the most appropriate development that meets the business needs.	- Define business system options in which the new system could be produced, through a brainstorming session to know all possibilities. - Select business system options.
Stage 3: Definition of requirements	- To take the analysis of requirements and produce the requirements' specification. - It is not about how the system will be implemented, but instead describes what the system will do.	- Develop required data mode and system functions. - Enhance required data model. - Develop specification prototypes. - Develop processing specification. - Confirm system objectives. - Develop three types of diagrams: i. 'Entity Relationship Diagrams' showing full description of the data and its relationships. ii. 'Entity Life-Histories Diagrams' which describe all events through the life of an entity. iii. 'Effect Correspondence Diagrams' which describe how each event interacts with all relevant entities.
Stage 4: Technical system options	- 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.	- Determine the programming language that will be used, the cost and all constraints.
Stage 5: Logical design	- It concentrates on the requirements for the human-computer interface.	- Define user dialogues. - Define inquiry processes and how the system will be implemented.
Stage 6: Physical design	- To convert all logical data structure and specifications to descriptions and real software. - To specify the exact structure of all functions and how they are implemented.	- Create Physical Data Design. - Create Function Component Implementation Map. - Optimize Physical Data Design. - Complete Function Specifications. - Consolidate Process Data Interface.

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 '*Encyclopdie*' at the end of 18th 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.

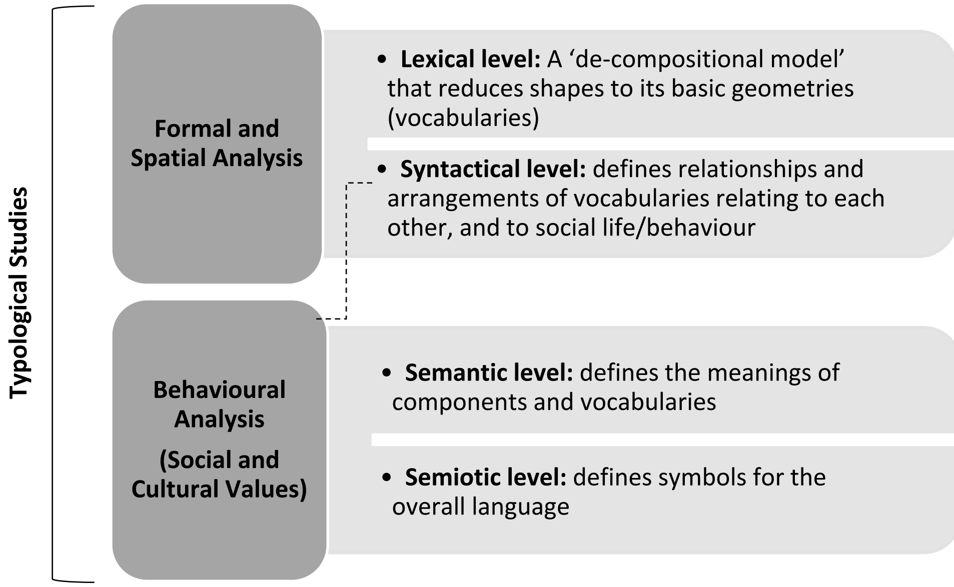


Figure 2.32: Typological analysis approach
(Researcher)

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:

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

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.

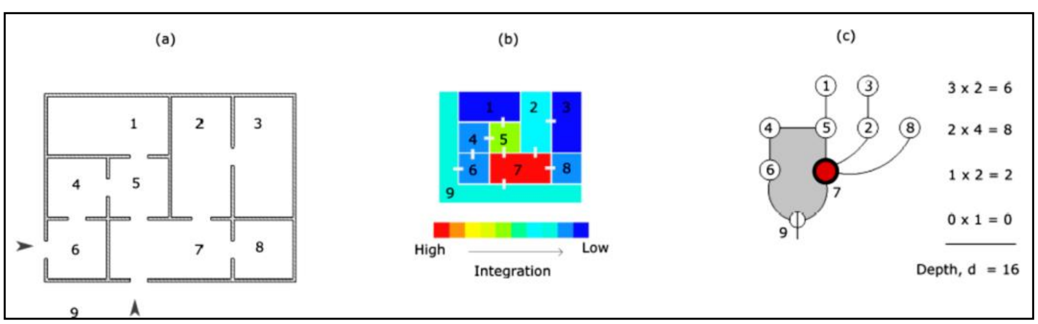


Figure 2.33: A sample of convex map and justified graph for a house
(Maina 2013)

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:

  $Integration\,Value = 1/(\frac{2\,(md-1)}{k-2})$, 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' [5] and 'AGRAPH' [6], 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

[5] https://www.bartlett.ucl.ac.uk/space-syntax/research/projects/ucl-depthmap (accessed on 30/3/2016)
[6] 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 the 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.

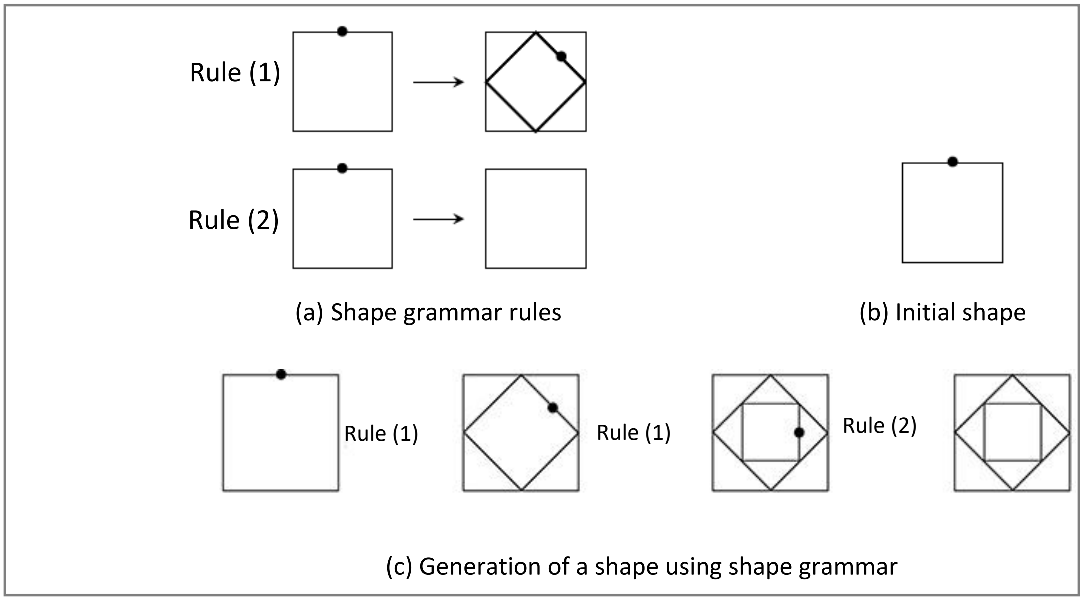


Figure 2.34: A simple shape grammar process
(Correia 2013)

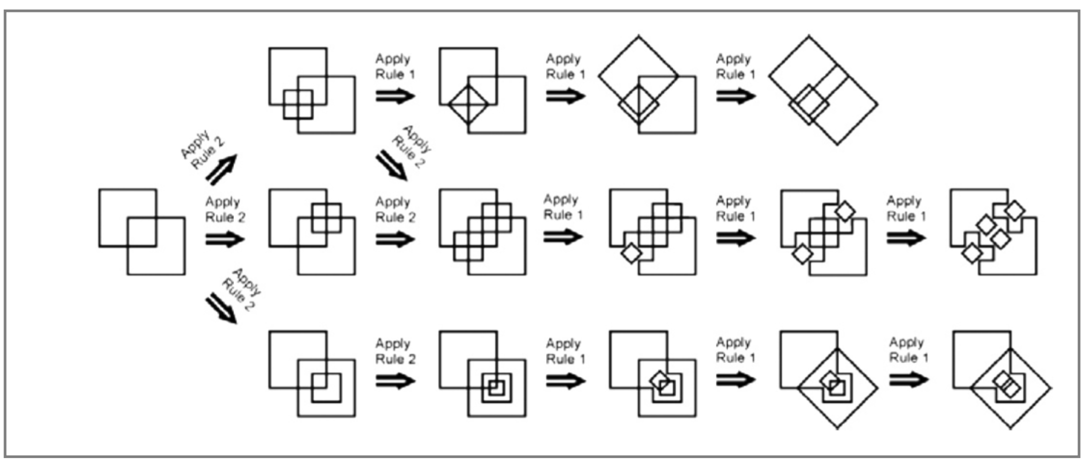


Figure 2.35: An example of shape computation
(McKay *et al*. 2011)

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 Sting (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*

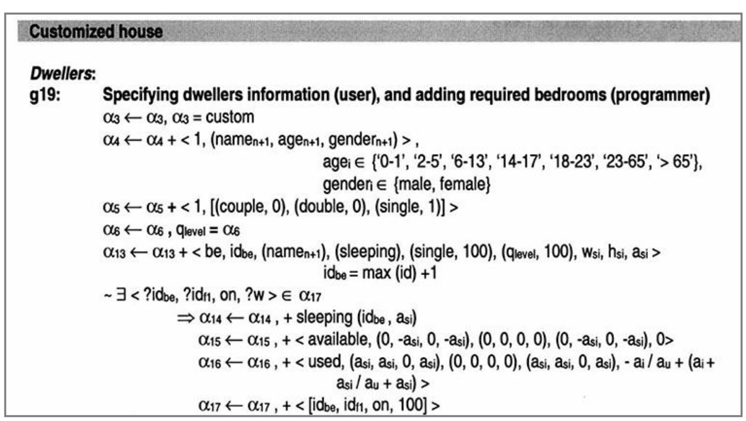
  This type is used to describe some properties such as volume, cost or manufacturing plan. For example, Agarwal (1999), as cited in (Stouffs 2015, p.140)), added cost expressions or equations to evaluate the cost of a design during the generation process. This type of descriptions gives the design feedback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

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

$\alpha_4 \leftarrow \alpha_4 + < 1, (\text{name}_{n+1}, \text{age}_{n+1}, \text{gender}_{n+1}) >,$

$\text{age}_i \in \{\text{'0-1', '2-5', '6-13', '14-17', '18-23', '23-65', '> 65'}\},$

$\text{gender}_i \in \{\text{male, female}\}$

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

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

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

$\text{id}_{be} = \max(\text{id}) + 1$

$\sim \exists < ?\text{id}_{be}, ?\text{id}_{f1}, \text{on}, ?w > \in \alpha_{17}$

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

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

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

$\alpha_{17} \leftarrow \alpha_{17}, + < [\text{id}_{be}, \text{id}_{f1}, \text{on}, 100] >$

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

Variable description (program description)				
Features	**Groups of variables**		α	**Variables**
Contexts	Lot		α_0	< w, l, h, a >
	Urban		α_1	<front, right, back, left>
	Solar orientation		α_2	<front, right, back, left>
Typology	Customization		α_3	< degree >
	Users		α_4	< number, [(name, gender, age, share),...] >
	Bedrooms		α_5	< number, [(couple, number), (double, number), (single, number)] >
	House quality		α_6	< initial quality, current quality >
Morphology	Yard location		α_7	< yard >
	Floors		α_8	< floors >
	Balconies		α_9	< balconies >
Spatiality	Capacity	Minimum obligatory spaces	α_{10}	< [use, number, ((articulation, number)...)]... >
		Initial obligatory spaces	α_{11}	< [use, articulation, weight],... >
		Current optional spaces	α_{12}	< [use, articulation, weight],... >
		Current spaces	α_{13}	< [name, id, (users, functions, (capacity, weight), (articulation, weight), (spaciousness, weight), (insertion point, rotations, width, length, height, area)],... >
		Zones	α_{14}	< [use,rooms, area],... >
	Spaciousn ess	Areas	α_{15}	< available, (max interior gross, min exterior gross, 1st Floor gross), (max interior gross, min exterior gross, 2nd Floor gross), (max interior gross, min exterior gross, house gross), useful/gross>
			α_{16}	< used, (inhabitable, interior useful, exterior useful, 1st Floor useful), (inhabitable, interior useful, exterior useful, 2nd Floor useful), (inhabitable, interior useful, exterior useful, house useful), inhabitable/useful >
Topology	Adjacency graph		α_{17}	<[(room1, room2, relation, weight)] ... >
Building elements	Windows		α_{18}	< [window, (room 1, room 2), (insertion point, depth, width, height, area)],... >
	Doors		α_{19}	< [door, (room 1, room 2), (insertion point, depth, width, height, area)],... >
	Walls		α_{20}	< [wall, (room 1, room 2), (insertion point, thickness, width, height, area)],... >
	Pavements		α_{21}	< [pavement, floor, (insertion point, width, length, thickness, area)],... >
Aesthetics	Proportion		α_{22}	< [proportion1, weight],...>
Quality			α_{23}	< [function, weight], [spatiality, weight], [capacity, weight], [articulation, weight], [spaciousness, weight], [topology, weight], [aesthetics, weight] >
Cost	Cost		α_{24}	c
History	Rule		α_{25}	< r1, r2,..., rm >

Fixed description				
Spaces dimensions	width	β_1	*tables*	width (space, quality)
	height	β_2	*tables*	height (space, quality)
	area	β_3	*tables*	area (space, quality)
Sectional dimensions	Pavement thickness	β_4		thickness (pavement)
	Floor height	β_5		height (floor)
Cost		β_6	*table*	*unit_cost (element, material)*

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

Feature	Feature	α	Feature	Values
Morphology	Lot	α_0	Width	8 m^2
			Length	12 m^2
			Area	96 m^2
	Urban	α_1		Houses on three sides (default), house on one side, house at the back, house on the side and back
	Solar orientation	α_2		N, NE, E, SE, S, SW, W, NW
Typology	Customization	α_3		Custom, type (default)
	Dwellers	α_4	Number	1, 2, 3, 4, 5, 6, 7, 8 , 9
			Name	User prompted Blank (default)
			Gender	Male Female Blank (default)
			Age	0-1, 2-5, 6-13, 14-17, 18-23 23-65, > 65, Blank (default)
			Share	Room Bed Blank (default)
	Bedrooms	α_5	Number	1, 2, 3, 4, 5
	Quality*	α_6	Initial	Minimum (default), medium, maximum (high)
			Current	Minimum (default), medium, maximum (high)
Morphology		α_7	Yard	Front, back
		α_8	Floors	1, 2
		α_9	Balconies	True, False
Spatiality	Capacity (dwelling)	α_{10}	Minimum	List of spaces' IDs
		α_{11}	Initial obligatory	
		α_{12}	Optional	
		α_{13}	Current	
		α_{14}	Zones	
	Spaciousness (dwelling)	α_{15}	Available	See Tables 7.8-7.10
		α_{16}	Used	m^2
	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		α_{17}	Relation	Away, close, adjacent, window, door, passage, merged, any (default)
Aesthetics		α_{23}	Proportion	1:1, 1:√2, 1:2, 2:3, 3:4, 5:6
Quality		α_{22}	Weights	0, 5, 10, 15,…,100
Cost		α_{24}	Construction	USD $ / m^2
History		α_{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.

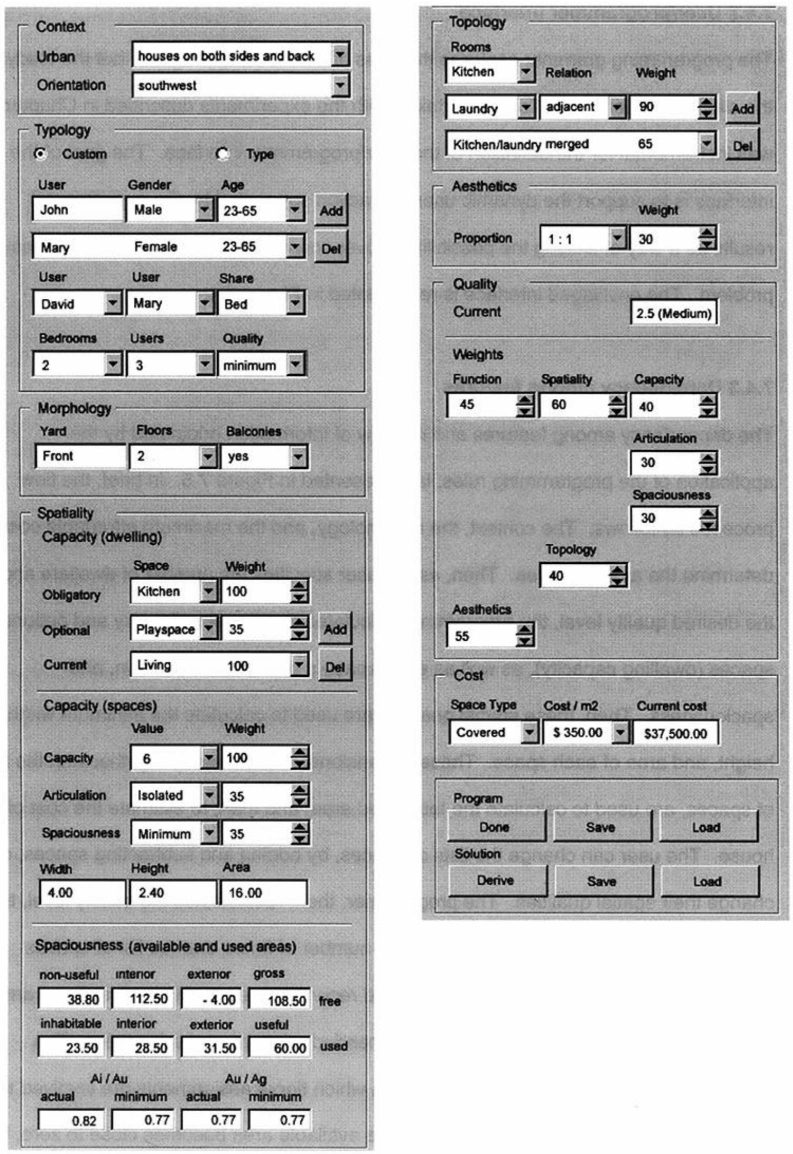


Figure 2.39: A Sample of the interface (MALAG) that translate the requirements of users into a design brief using the programming grammar
(Duarte 2001)

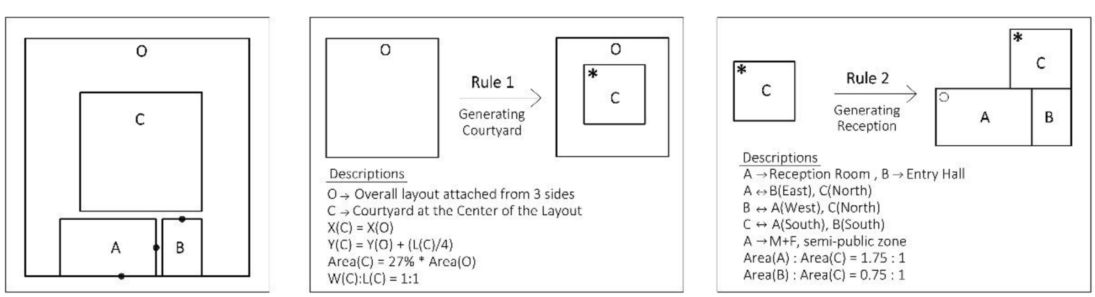


Figure 2.40: Part of a discursive grammar that generates a semi-public zone in a courtyard house
(Researcher)

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).

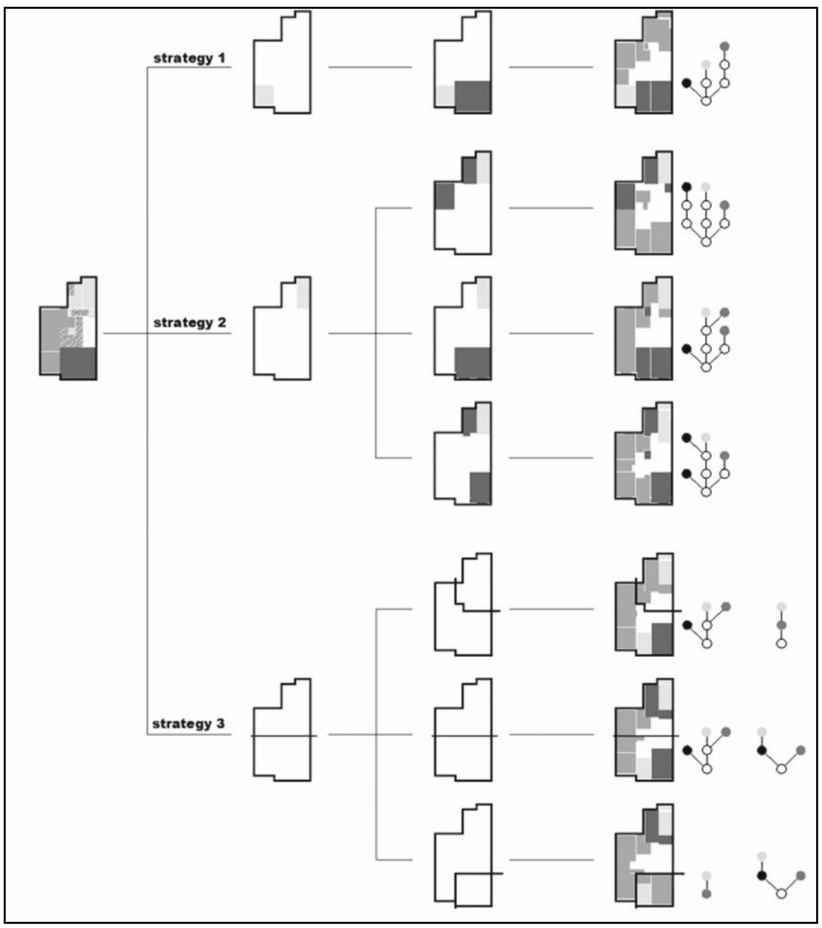


Figure 2.41: Derivation tree for the different rehabilitation strategies, using space syntax approach to test design alternatives
(Eloy and Duarte 2011)

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
Components	- Spaces as abstract bubbles. - Relationships and access between spaces (syntactic step). - Depth.	- Vocabularies (main spaces) of the house. - Proportion. - Geometric relations between spaces.	- Add geometric properties for each space, and its proportion related to other spaces. - Add the exact location of access between spaces.
Type of relationship	- Morphology and spatial configuration refers to topological relationships, interaction patterns and access between rooms rather than metric distances.	- Geometric properties for each space	- Add metric distances to know spatial arrangements and patterns of movement.
	- 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".	- Relations between shapes.	- Combined shapes and functions. - Relationship between the core of the house and other spaces. - Relationship between the entrance and other spaces.
Hierarchy of spaces (depth)	- All spaces that have the same depth values are placed on the same line.	- Physical relationship between spaces (wall-to-wall relation) without considering the function of the space.	- Arrange spaces according to the following hierarchal system: public, semi-public, semi-private, private, and intimate. - Add 'orientation' as an environmental parameter for the distribution of spaces. - Add type of space as: covered, open to the sky, semi-open. - Study the physical-facial relationship between spaces (wall-to-wall relation).
Social interaction and visual privacy	- Relationship between spaces without considering the geometry of each space and could affect the visual interaction between spaces.	- There is no consideration to the social dimension.	- Study the visual privacy between spaces and how could affect the interaction between people inside each space. - Relationship between users through adding the dominant users (male, female, guests).

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
Aim and focus	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.
Source of data	Data derived from observations and overall impressions.	Numerical information derived from statistical interpretations of data that can be manipulated and understood.
Forms of knowledge	Collecting information about phenomena that can be observed (working bottom up).	Deducing hypotheses from theory, and then collecting the appropriate data (working top down).
Ontology	The reality is subjective and multiple as seen by participants.	The reality is objective and apart from the researcher.
Relationship of the researcher to that being researched	Researcher interacts with that being researched.	The researcher is independent of that being researched.
Methodological approach	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).

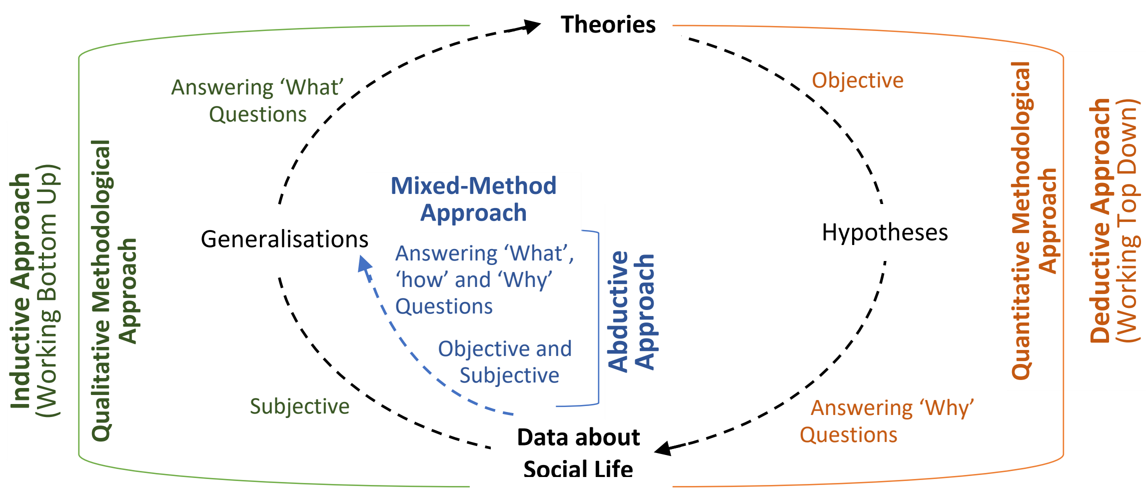


Figure 3.1: The process of inductive, deductive and abductive approaches
(Adapted by Researcher, after (Ly 2012))

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))

	Positivism	**Interpretivism**	**Pragmatism**
Ontology (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.
Epistemology (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.
Axiology (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.
Methodological Approach (modes of inquiry)	Quantitative but can still use qualitative.	Qualitative.	Uses both qualitative and quantitative.

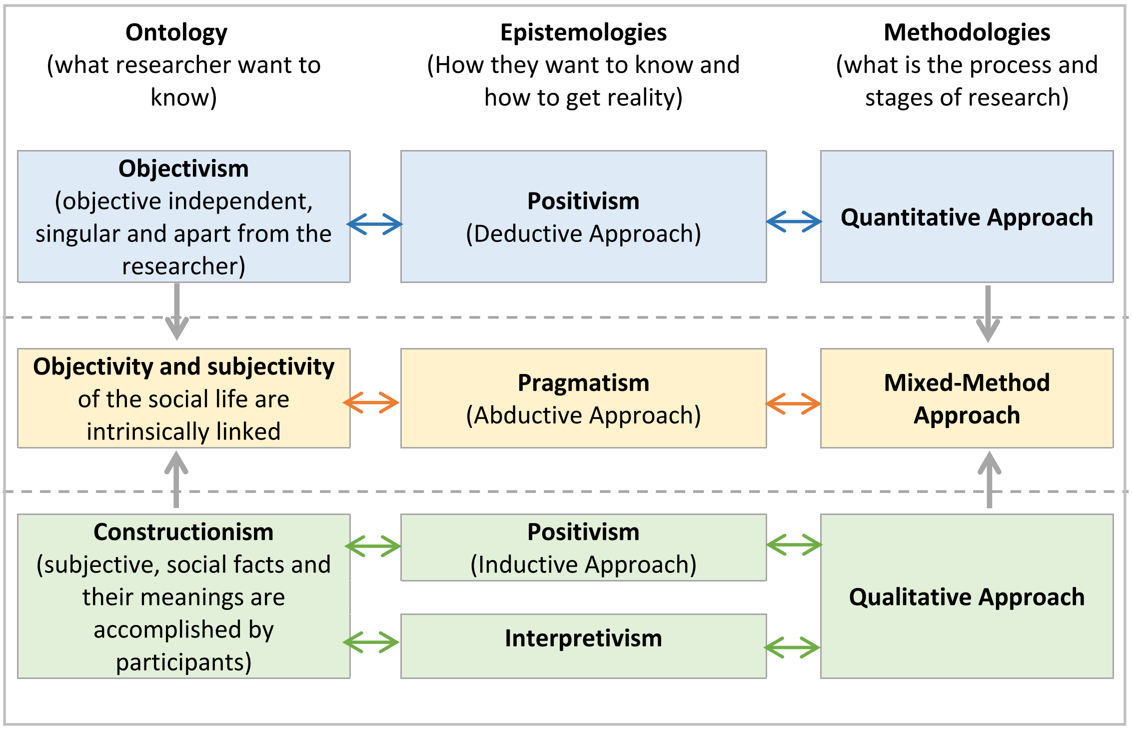


Figure 3.2: Relationships between ontology, epistemology and methodological approach for each school of thought
(Researcher)

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))

	Qualitative Approach	**Quantitative Approach**	**Mixed-Method Approach**
Philosophical worldview	Phenomenological and inductive (grounded theory) knowledge claims (theory emergent).	Deductive knowledge claims (theory testing)	Pragmatic knowledge claims
Ontologies	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.
Approach to inquiry	Unstructured, flexible, open methodology.	Structured, rigid, and pre-determined methodology.	Can be structured, unstructured, or both.
Main purpose of investigation	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.
Sample size	Few cases.	Large sample size.	Different sizes of samples.
Methods	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).
Strategies of inquiry	Interviews, ethnography, observations, documents, archives, or audio-visual data.	Numeric data (experiments and performance, attitudes, and observational data).	Multiple forms of data.
Type of analysis	Text and image analysis to explore meanings.	Statistical analysis to explore behaviour.	Statistical and text analysis.
Type of interpretation	Interpretation of themes and patterns.	Statistical interpretation.	Qualitative and quantitative interpretation.
Practices of research	- Collect participant meanings. - Focus on concepts or phenomena. - Study the context. - Validate the accuracy of findings. - Make interpretations. - Collaborate with participants.	- Test and verify theories and explanations. - Identify variables to study. - Relate variables in questions or hypotheses. - Use standards of validity and reliability. - Observe and measure information numerically. - Use unbiased approaches. - Employ statistical procedures.	- Collect both qualitative and quantitative data. - Develop rationale for mixing data. - Integrate data at different stages of inquiry. - Employ the practices of both qualitative and quantitative research.

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 comoutational 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 Gedík 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).

Howerver, addressing the different preferences of users, assessing the current situation of residential buildings, and exploring potentails 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 databse for the design of high-rise buildings inlcude 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 familes 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

Phases of the study	In which chapter the phase is presented
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. Moreoever, 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).

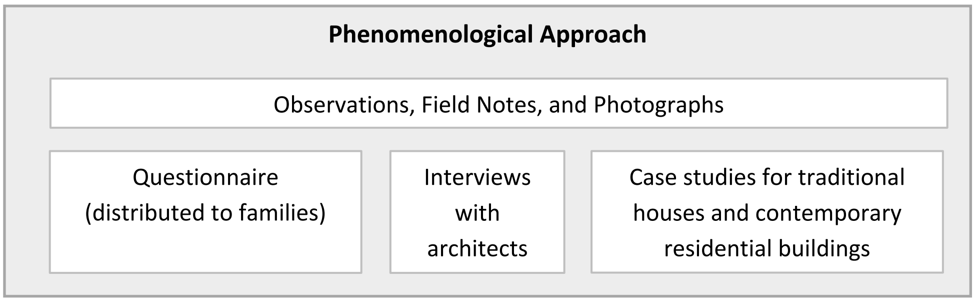


Figure 3.3: Data collection phase

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 putdoor 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/neighbourhhods 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.

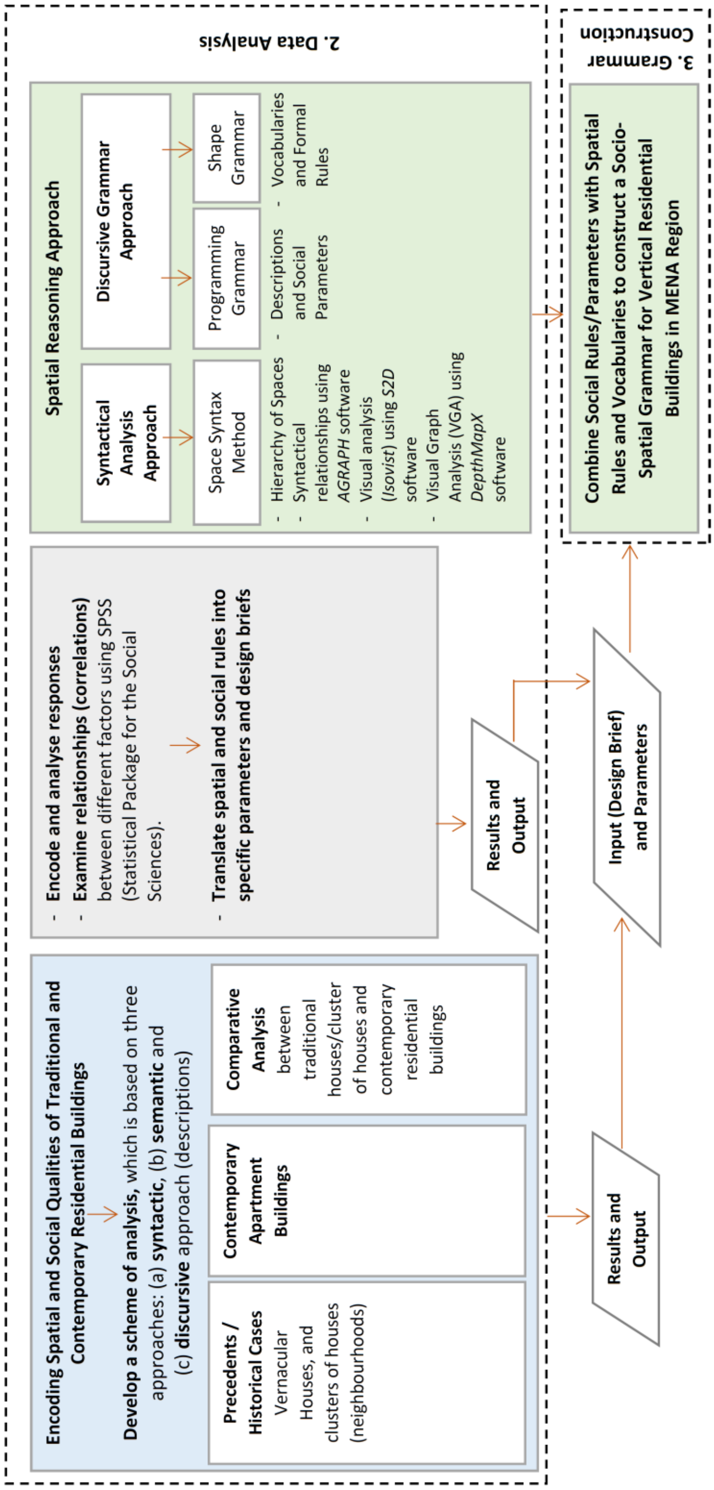


Figure 3.4: A diagram showing relationships between Phase 2: Data analysis, and Phase 3: Grammar construction

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 'Rhinoceros 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).

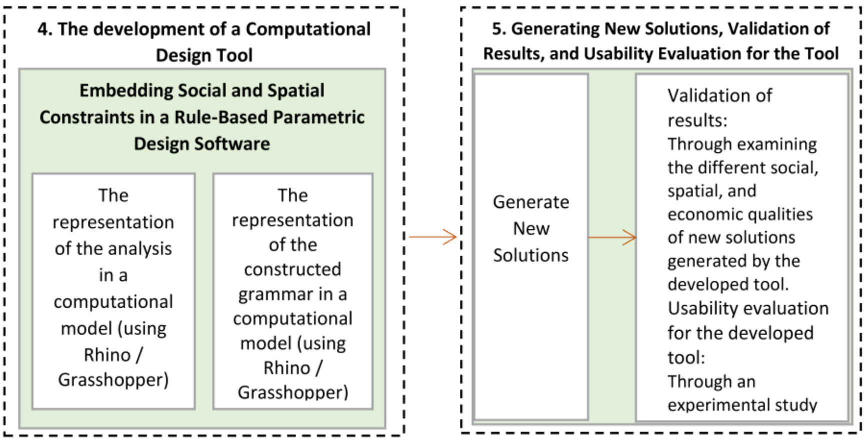


Figure 3.5: A diagram showing (Phase 4: Developing a computational tool), and (Phase 5: Generating new layouts, testing, and evaluation)

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
- ***Social Indicator (1): Population Density and Crowding***	
- 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^2)
- Number of apartments/houses in the building/cluster.	Number
- Area of common spaces in the building/neighbourhood.	Number (m^2)
- Width of alleys and transitional spaces between houses.	Number (m)

- ***Social Indicator (2): Hierarchy of Spaces***	
- 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)
- ***Social Indicator (3): Social Interaction and Area of Living Spaces***	
- Area of common and gathering spaces in buildings and neighbourhoods.	Number (m^2)
- Area of living spaces inside the house.	Number (m^2)
- ***Social Indicator (4): Human Comfort***	
- 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^2)
- 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)
- ***Social Indicator (5): Accessibility***	
- 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^2)
- 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
- ***Social Indicator (6): Visual Privacy***	
- 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
- ***Social Indicator (7): Acoustical Privacy***	
- 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)

- ***Social Indicator (8): Olfactory Privacy***	
- Location and orientation of kitchen and sanitary facilities.	Diagrams
- Orientation of open spaces.	Diagrams
- Availability of trees and flowers.	Diagrams
- ***Social Indicator (9): Spirituality***	
- 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
- ***Social Indicator (10): Security and Safety***	
- 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
- ***Social Indicator (11): Views to the Exterior***	
- Area of open spaces, terraces, balconies, and glazed facades that are connected directly with the outside context.	Diagrams
- ***Social Indicator (12): Availability of Services***	
- 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
- ***Social Indicator (13): Hygiene***	
- 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.

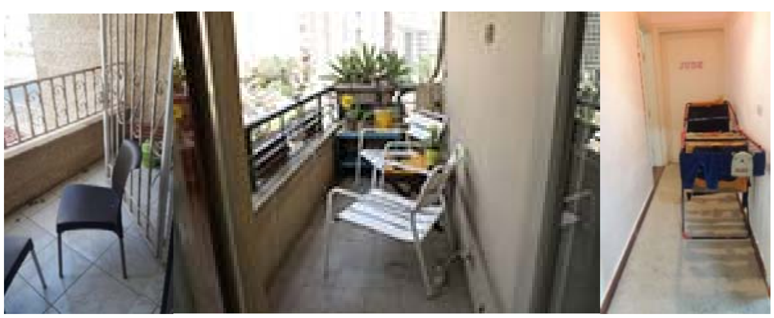


Figure 4.1: Limited open spaces and areas for children

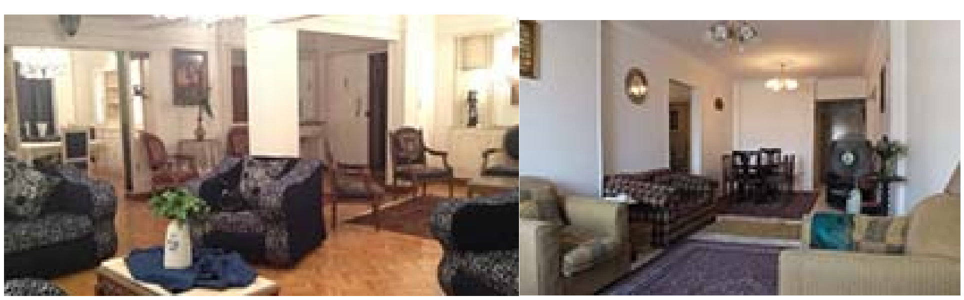


Figure 4.2: Visual/spatial connections between the main entrance, living spaces and areas for the guests

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)[1].

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[2].

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.

[1] See (Volume 2 - Appendix (4-A-1): The Interview Guide with Architects)
[2] 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	1.1. How would you describe the traditional house in the Middle East and North Africa region? What are its key features you visualize?
	1.2. Can you please draw a sketch for a traditional house with all distinctive features?
2. Contemporary Houses and High-rise Residential Developments in the Middle East and North Africa	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?
	2.2 What are the key features that developers want in these developments?
	2.3 What are problems facing the design of a contemporary high-rise building?
3. Design Philosophy	3.1. What do you think the most appropriate house type for this region? Why?
	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? - The culture - The context and the identity of the place - Modernity - Environmental requirements - Functional requirements
	3.5. What are the different treatments for achieving the following qualities in the design of apartment buildings? - Hierarchy of spaces (from public to private zones) - Public spaces inside the building when you have a small footprint - Visual privacy - Controlling sounds - Controlling smells - Playgrounds for children - Accessibility - Social interaction - Separation between male and female zones - Security and safety - Natural lighting - Natural ventilation - Reducing energy consumption for heating and cooling - 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?

c. Responses from Interviews

The following is a highlight for the main responses to the different questions[3].

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*).

[3] 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 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 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^2.
- 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^2 (three bedrooms): two apartments on each floor.
    b. 60 – 80 m^2: 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).

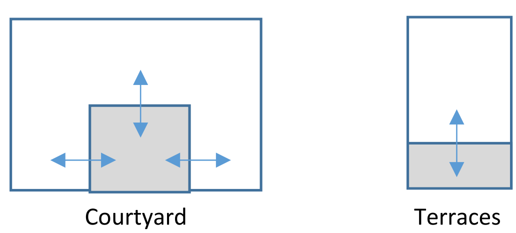


Figure 4.3: Visual connections between the different spaces of the house, and (a) courtyards, (b) terraces

- 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), 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[4]. 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[5].

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[6], more than 42 million families live in urban areas within the study area. To capture the overall picture of residential

[4] See (Volume 2 - Appendix (4-A-2): The Questionnaire (in both languages: Arabic and English))
[5] See (Volume 2 - Appendix (4-A-4): Ethical Approval Forms)
[6] 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	56	16	49	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	92	56	80	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	64	42	44	24.3 %	25.5 %
	Algeria	2		2		1.2 %	
TOTAL			212		173		100.00 %

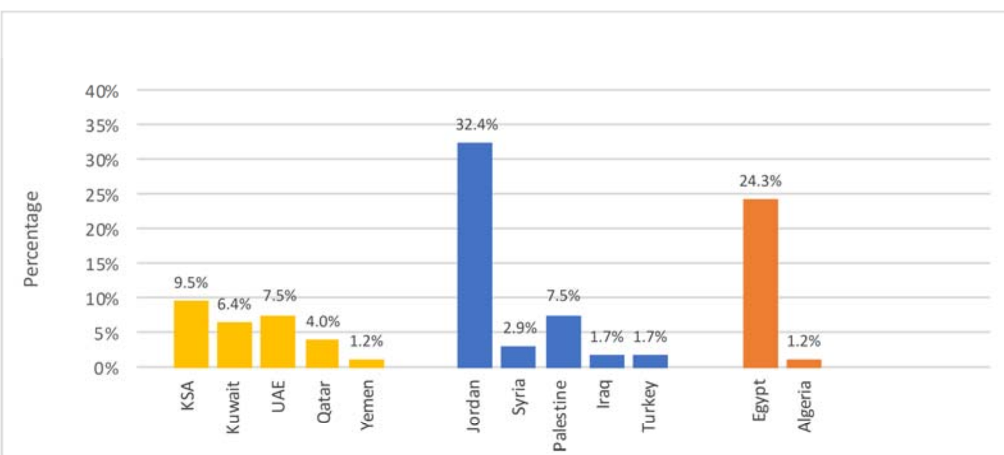


Figure 4.4: Percentages of returned questionnaires that are thoroughly and adequately filled

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).

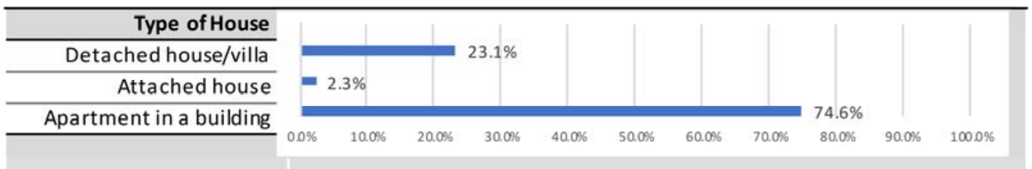


Figure 4.5: Frequencies showing types of houses

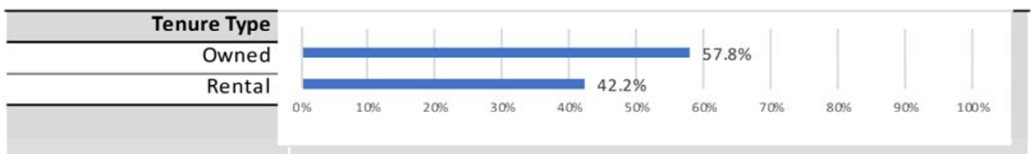


Figure 4.6: Frequencies showing tenure type

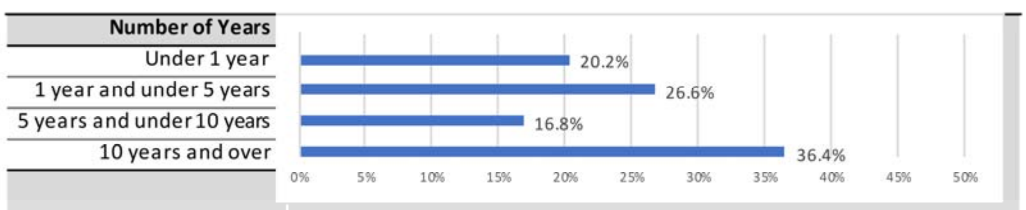


Figure 4.7: Frequencies showing number of years living in the current house

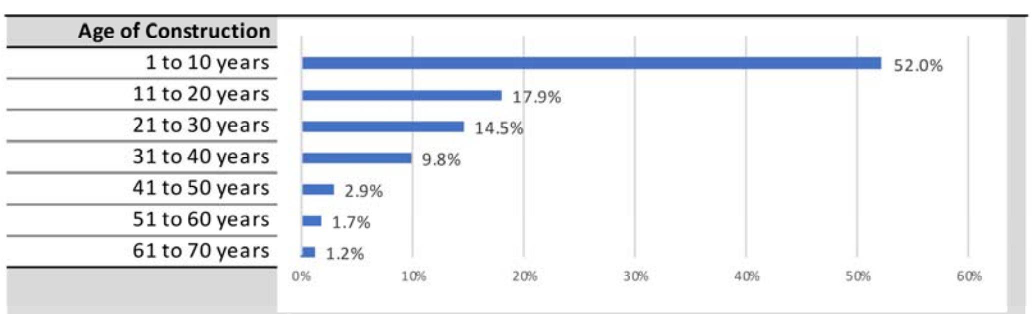


Figure 4.8: Frequencies showing age of construction

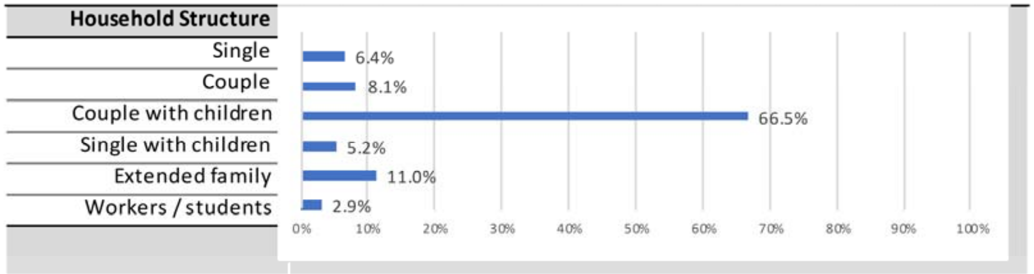


Figure 4.9: Frequencies showing household structure

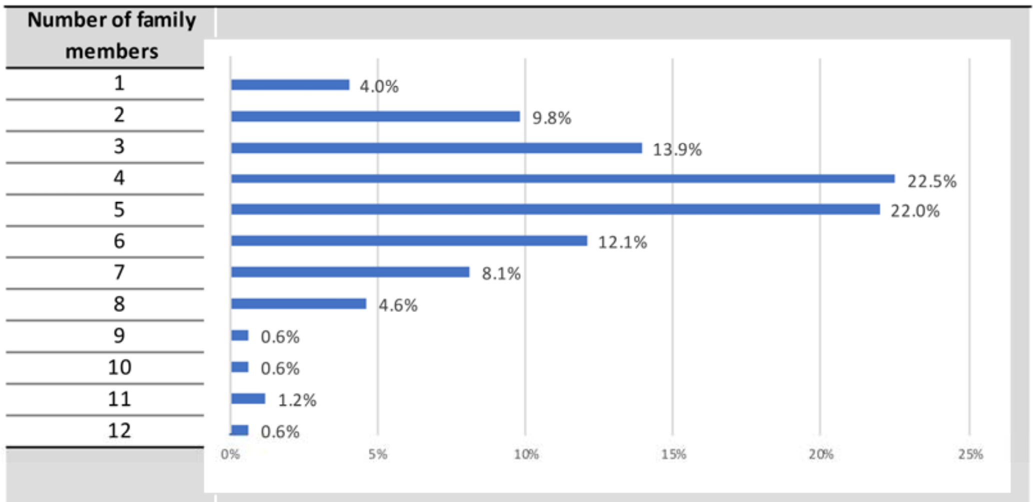


Figure 4.10: Frequencies showing number of family members living in the house

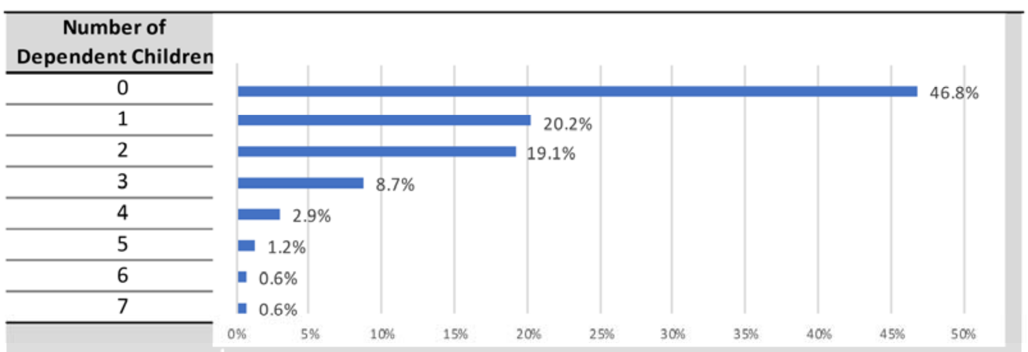


Figure 4.11: Frequencies showing number of dependent children (under 18 years) living in the house

- ***Part 2: Spatial Description***

Results showed that areas of houses are ranged between 100 and 250 m^2. 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).

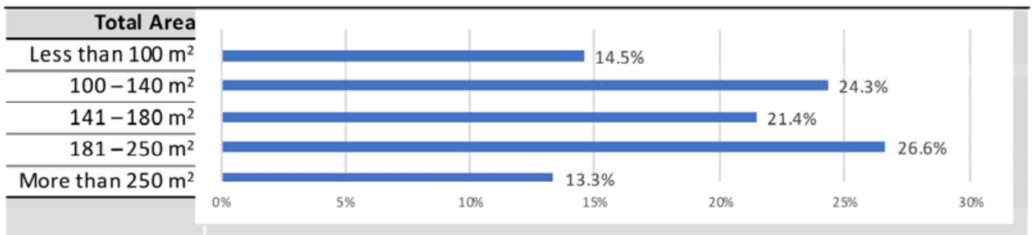


Figure 4.12: Frequencies showing total area of the house

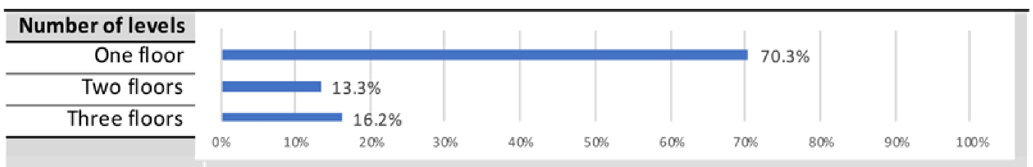


Figure 4.13: Frequencies showing number of levels/floors in the house

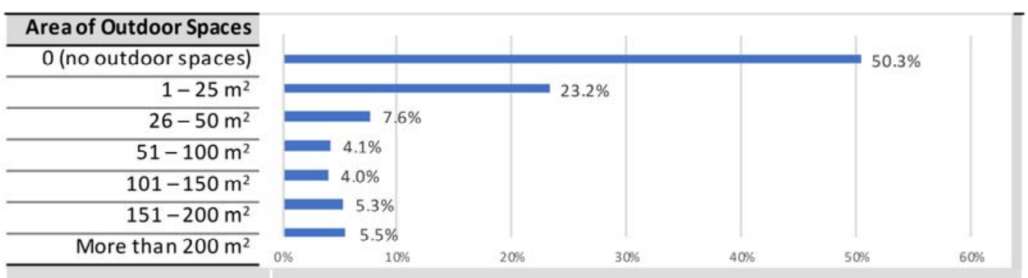


Figure 4.14: Frequencies showing approximate area of outdoor spaces in the house

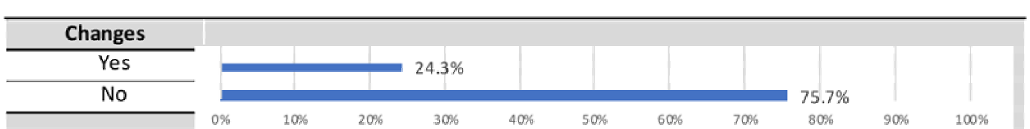


Figure 4.15: Percentages of families who changed the original interior layout of the house

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

Reasons for Changes	Types of Changes
To increase the privacy of livings spaces	- Add a screen wall to increase the privacy of the living space. - Change the location of the entrance to provide privacy for the kitchen. - Change the location of the living space when it is located near bedrooms. - Change the location of the secondary entrance, which is used by the family members, to increase the privacy. - Add a partition between the kitchen and the living space. - Add a secondary entrance for female guests. - Add a partition between the living space and the dining room.
To increase the area of the house	- Close the double volume between the ground floor and the first floor, and use it as a living space. - Demolish the guest toilet and add it to the kitchen. - Demolish the wall between the living room and the kitchen. - Increase the area of the living space. - Increase the area of balconies. - Changes that were mainly implemented in old houses that are aged more than 20 years: o Demolish walls between the guest room and the dining room. o Close the balcony space and add it to a bedroom (as a space for activities). o Close the balcony space (as it needs continuous cleaning due to the dust) and use it as a living space. o Close the terrace near kitchen and use it as a breakfast area.
Change the orientation of some spaces for environmental requirements	- 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. - Increase the area of some windows to benefit from the natural lighting and natural ventilation, especially in old houses.

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 %	

A. Rooms and Spaces for Guests	1st level	2nd level	3rd level	Not Applicable
Entry hall	63.0 %	4.0 %	1.7 %	31.2 %
Guest room (for both male and female)	61.3 %	4.6 %	1.7 %	32.4 %
Guest room (only for male)	12.1 %	2.3 %	0.0 %	85.5 %
Guest room (only for female)	8.7 %	1.2 %	0.6 %	89.6 %
Dining room	59.0 %	5.8 %	1.2 %	34.1 %
Guest toilet	62.4 %	4.0 %	1.2 %	32.4 %

Figure 4.16: Frequencies showing location of rooms for guests

B. Family Spaces	1st level	2nd level	3rd level	Not Applicable
Family living room	73.4 %	6.4 %	0.6 %	19.7 %
Multi-purpose hall	26.0 %	4.0 %	0.0 %	69.9 %
Office/Study area	19.1 %	5.2 %	0.6 %	75.1 %

Figure 4.17: Frequencies showing location of family rooms

C. Bedrooms	1st level	2nd level	3rd level	Not Applicable
Master bedroom (1)	67.6 %	13.3 %	2.9 %	16.2 %
Master bedroom (2)	13.3 %	8.1 %	2.3 %	76.3 %
Master bedroom (3)	9.2 %	2.9 %	2.9 %	85.0 %
Master bedroom (4)	2.9 %	1.7 %	0.6 %	94.8 %
Bedroom (1) for kids	49.1 %	7.5 %	3.5 %	39.9 %
Bedroom (2) for kids	32.9 %	7.5 %	2.3 %	57.2 %
Bedroom (3) for kids	6.4 %	5.8 %	1.7 %	86.1 %
Bedroom (4) for kids	0.6 %	2.3 %	1.7 %	95.4 %
Guest bedroom	9.2 %	1.2 %	1.7 %	87.9 %

Figure 4.18: Frequencies showing location of bedrooms

D. Services	1st level	2nd level	3rd level	Not Applicable
Bathroom (1)	93.1 %	4.6 %	2.3 %	0.0 %
Bathroom (2)	39.9 %	11.6 %	1.7 %	46.8 %
Bathroom (3)	16.2 %	7.5 %	1.7 %	74.6 %
Kitchen	75.1 %	2.9 %	2.3 %	19.7 %
Breakfast area	23.1 %	2.3 %	0.6 %	74.0 %
Storage	31.2 %	1.2 %	2.9 %	64.7 %

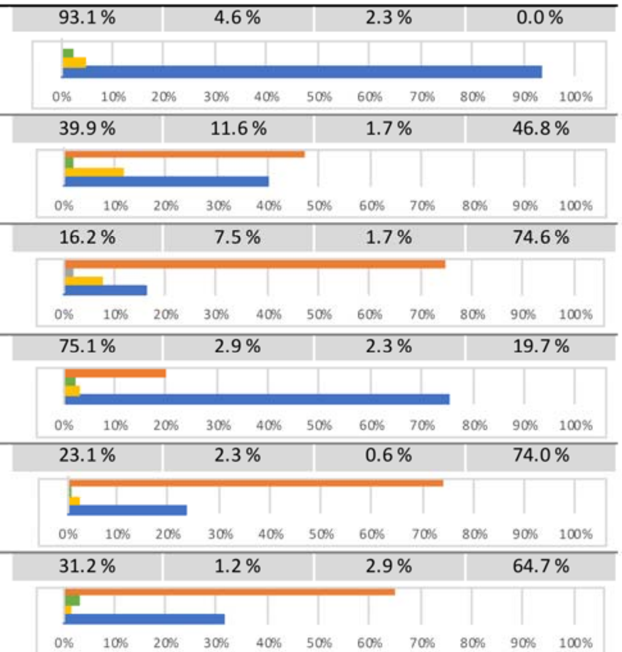


Figure 4.19: Frequencies showing location of services

Outdoor Spaces	1st level	2nd level	3rd level	Not Applicable
Courtyard	14.5 %	0.0 %	0.0 %	85.5 %
Garden surrounded the house	23.7 %	1.2 %	0.0 %	75.1 %
Roof terrace	8.1 %	3.5 %	4.0 %	84.4 %
Balcony (1)	44.5 %	6.4 %	1.1 %	48.0 %
Balcony (2)	17.9 %	5.8 %	2.3 %	74.0 %
Balcony (3)	5.2 %	3.5 %	1.1 %	90.2 %

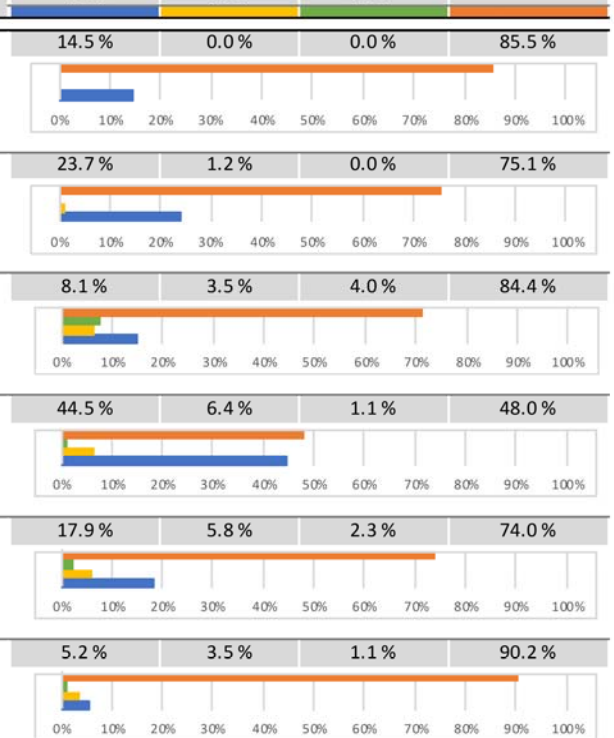
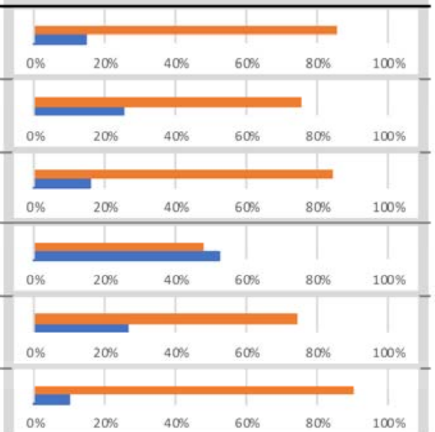


Figure 4.20: Frequencies showing location of outdoor spaces

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).

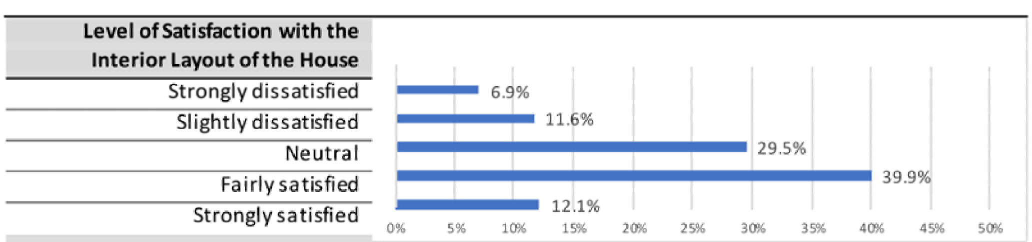


Figure 4.21: Frequencies showing level of satisfaction with the interior layout of the house

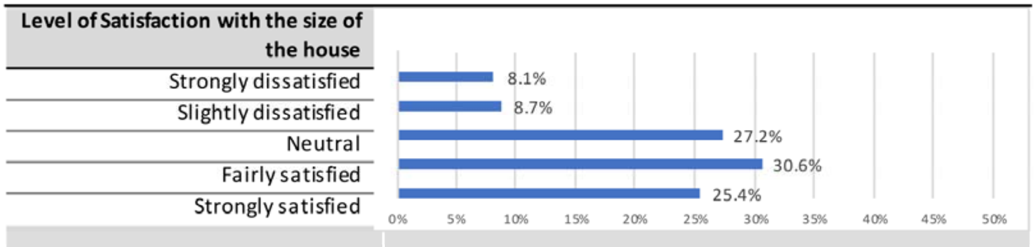


Figure 4.22: Frequencies showing level of satisfaction with the size of the house in comparison to the size of the family

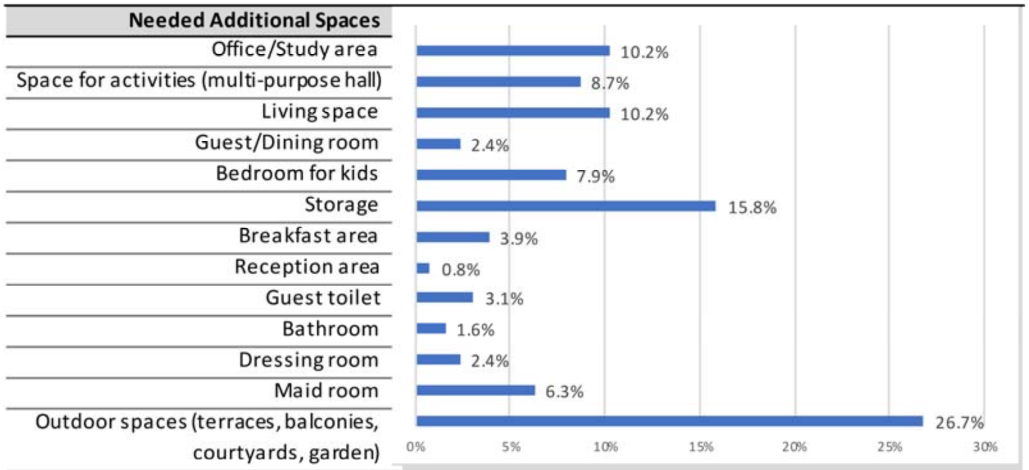


Figure 4.23: Frequencies showing needed additional spaces in current houses

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

Aspects people like the most in the spatial design of their house	**Percentage**
1. Hierarchy of spaces, which preserves the privacy of the family (e.g. separation between guest zone and family spaces, each zone has a separate entrance)	40.7 %
2. Large bedrooms	13.0 %
3. Easy circulation and accessibility between spaces (no lost spaces)	9.3 %
4. Large kitchens	7.4 %
5. Environmental solutions (good orientation, natural ventilation and lighting)	7.4 %
6. Open floor plan (guest room and dining room are opened to each other)	6.5 %
7. Location of the kitchen (far away from bedrooms and near the living area)	4.6 %
8. Central area used as a multi-purpose hall	4.6 %
9. Courtyard and outdoor spaces	2.8 %
10. Entry space is located at the central part of the front façade and near the guest room	1.9 %
11. Connectivity between bedrooms and living space	0.9 %
12. Bedrooms are far from the living space	0.9 %

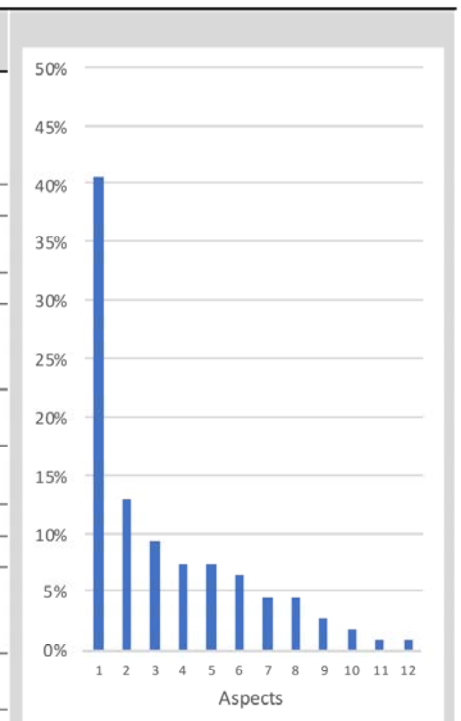
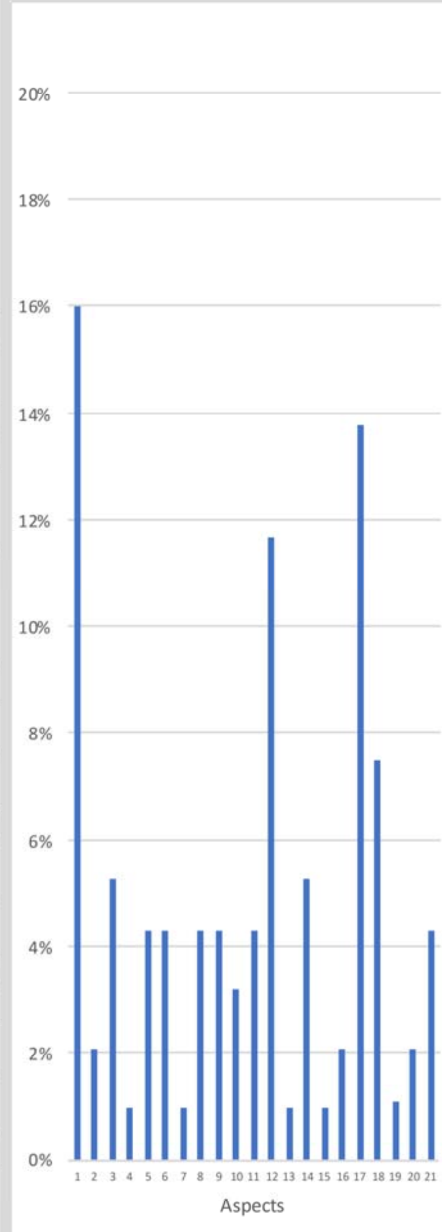


Table 4.8: Aspects that people like the least in the spatial design of their house

Aspects people like the least in the spatial design of their house	Percentage
Size, number, and shape of rooms:	
1. Small bedroom in comparison to the guest space	16.0 %
2. There are no storage spaces	2.1 %
3. Size of living zone is too small	5.3 %
4. There is no study/activity area	1.0 %
5. Size Kitchen is too small	4.3 %
6. Number of toilets is not suitable	4.3 %
7. Irregular shape of bedrooms	1.0 %
Hierarchy of spaces:	
8. The kitchen is far away from the living space and located near the entrance	4.3 %
9. Bedroom are not in the same zone	4.3 %
10. Living room is located near bedrooms	3.2 %
11. Guest toilet is located in front of the storage and near the entrance, and far away from the guest room	4.3 %
Privacy:	
12. There is a visual connection between the living space and the guest room (open plan scheme)	11.7 %
13. There is no guest room for female	1.0 %
14. There is no entry hall (the entrance is opened directly to the inside)	5.3 %
15. There is no direct entrance for the guest room form the outside	1.0 %
Access and circulation	
16. There is no direct entrance from the back garden	2.1 %
17. There are many paths, waste areas, long and narrow corridors	13.8 %
Environmental problems and bad orientation	
18. Lack of natural lighting and ventilation	7.5 %
19. There are no windows for the bathroom (linked with ducts)	1.0 %
20. Kitchen is located on the west façade, so smells are entered all the house	2.1 %
Outdoor spaces	
21. There is a lack in the number and area of outdoor spaces, balconies, and terraces	4.3 %



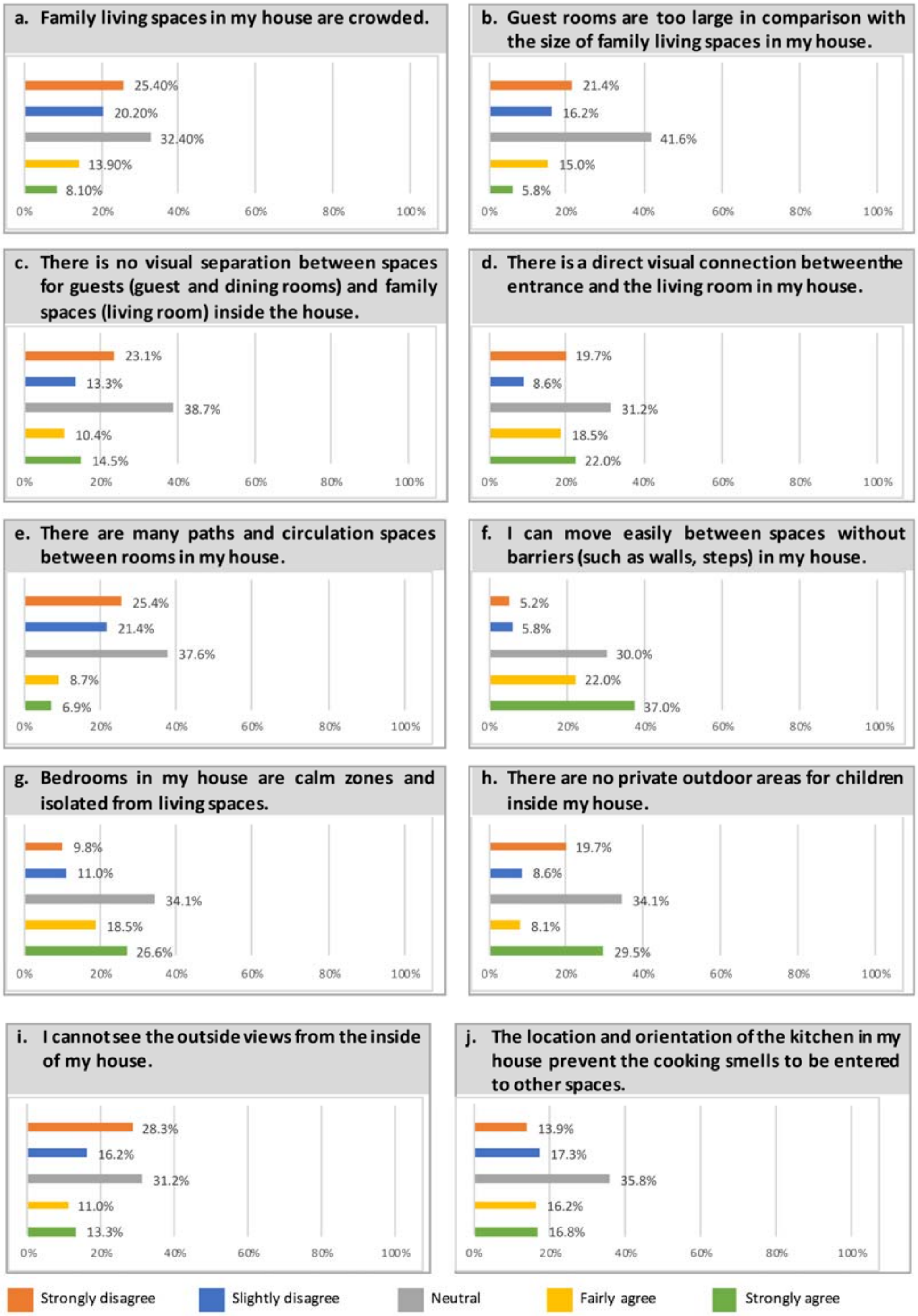


Figure 4.24: Frequencies showing opinion of residents with the different social qualities in their houses

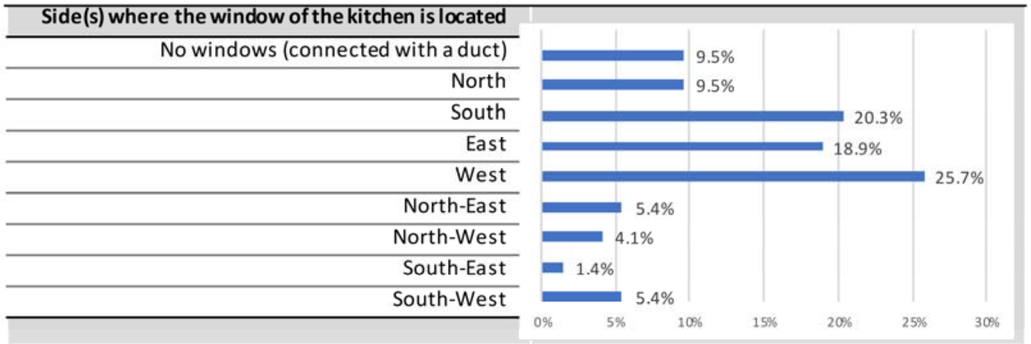


Figure 4.25: Frequencies showing side(s) where the window of the kitchen is located

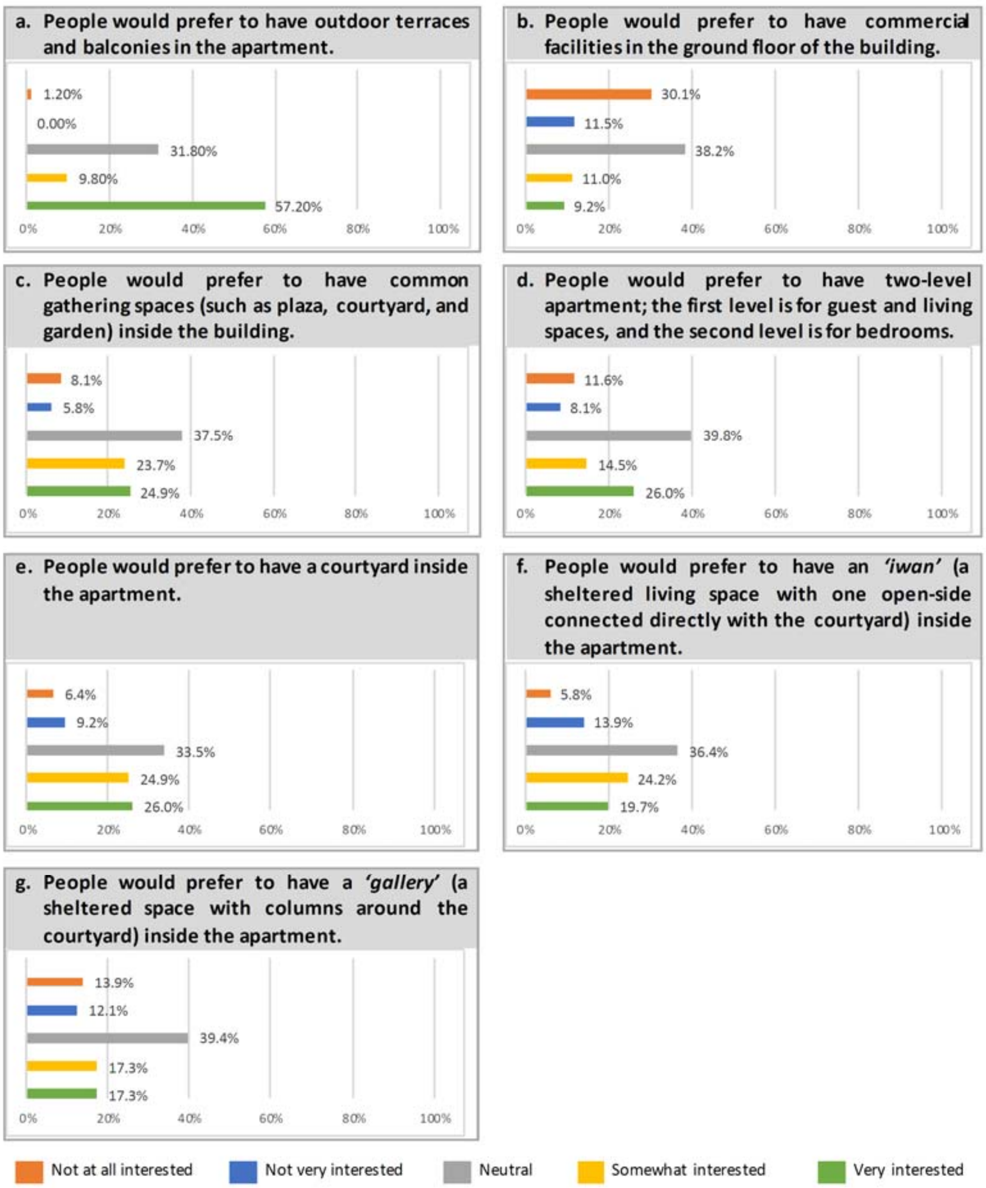
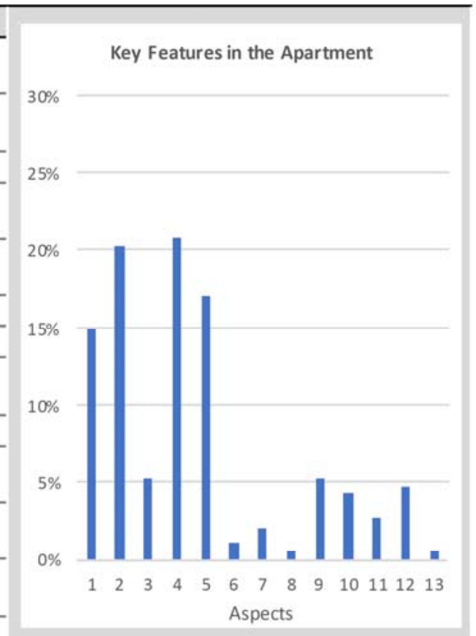


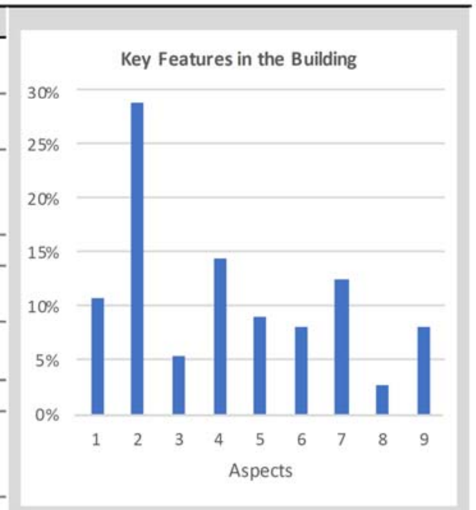
Figure 4.26: Frequencies showing opinions to include certain spaces if people have the chance to buy an apartment in a multi-story (or high-rise) residential building

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

Key Features in the Apartment	Percentage
1. Respecting privacy, and hierarchy of public/private zones	15.0 %
2. Balconies and terraces that increase the access to the outdoor environment	20.3 %
3. Courtyard inside the apartment	5.3 %
4. Increasing number of windows for views, natural lighting and ventilation	20.8 %
5. Large living spaces and bedrooms in comparison to guest/dining zone	17.1 %
6. Open plan	1.1 %
7. Multi-purpose hall for activities	2.1 %
8. Full-floor apartment without sharing walls with neighbours	0.6 %
9. Availability of storage spaces	5.3 %
10. Controlling noise and separating bedrooms from living spaces	4.3 %
11. Accessibility and avoiding waste circulation paths	2.7 %
12. Well defined entrance, with a separated entrance for guests	4.8 %
13. High ceiling	0.6 %



Key Features in the Building	Percentage
1. Secure and safe paly areas for kids inside the building	10.8 %
2. Courtyards, gardens and common spaces for social gathering	28.9 %
3. Commercial facilities in the ground floor with a separation from the entrance of apartments	5.4 %
4. Availability of parking	14.4 %
5. Quiet and not crowded (two apartments in each floor, and a maximum of 5 floors	9.0 %
6. Swimming pool and green areas on the top of the building	8.1 %
7. Well defined entrance	12.6 %
8. Privacy: staggered entrances for apartments in each floor, and terraces are not overlooking other balconies	2.70 %
9. Suitable number of elevators	8.1 %



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

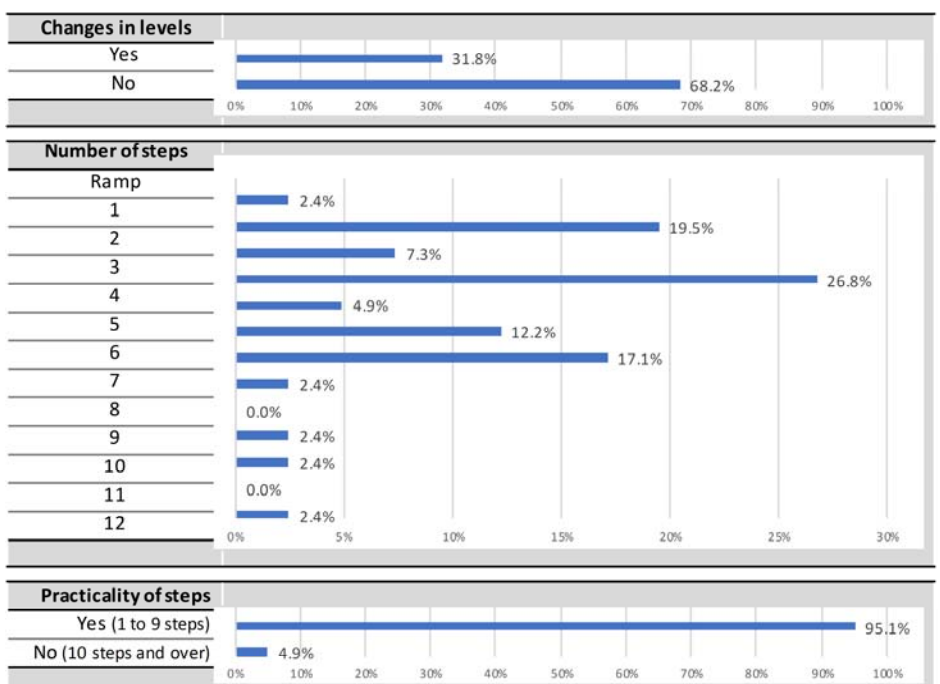


Figure 4.28: Frequencies showing changes in levels between the outside and the entrance of the house

- ***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).

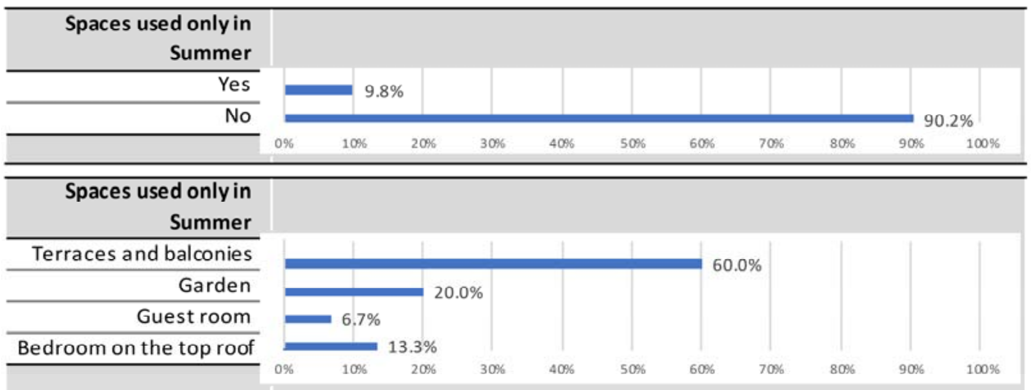


Figure 4.29: Frequencies showing any specific space used only in summer

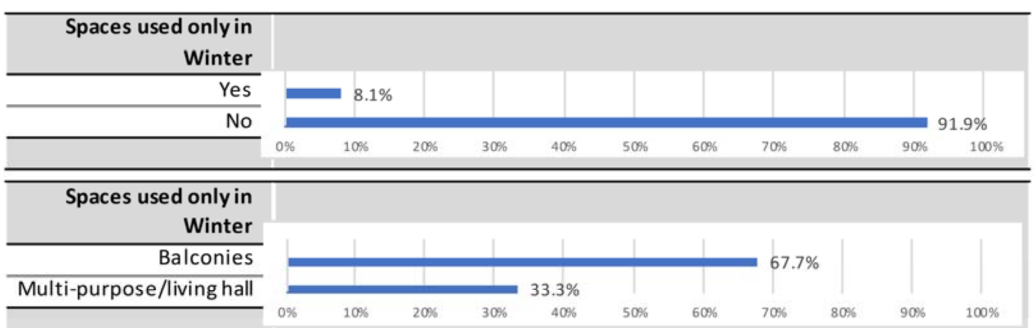


Figure 4.30: Frequencies showing any specific space used only in winter

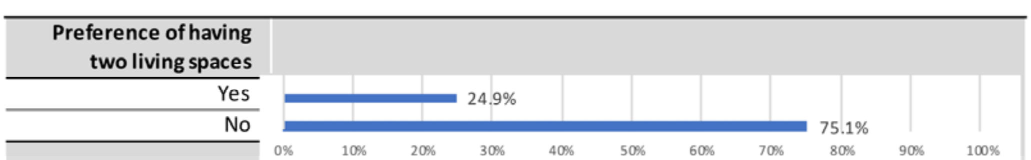


Figure 4.31: Frequencies showing preferences to have two living spaces; one used in winter, and the other in summer, if people move to another house

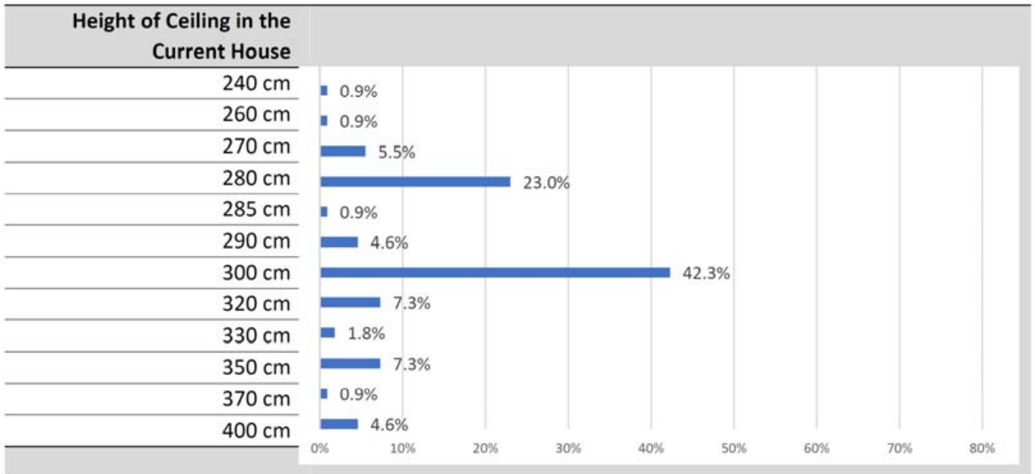


Figure 4.32: Frequencies showing height of ceiling in the house

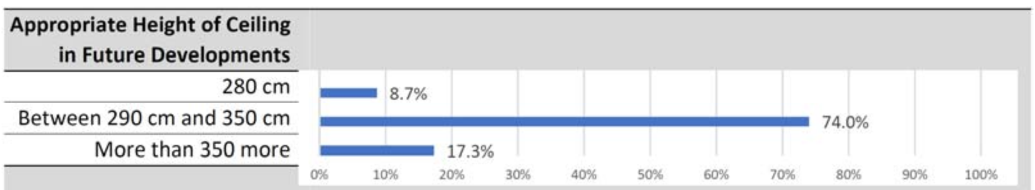


Figure 4.33: Frequencies showing the most appropriate height of ceiling if people move to another house

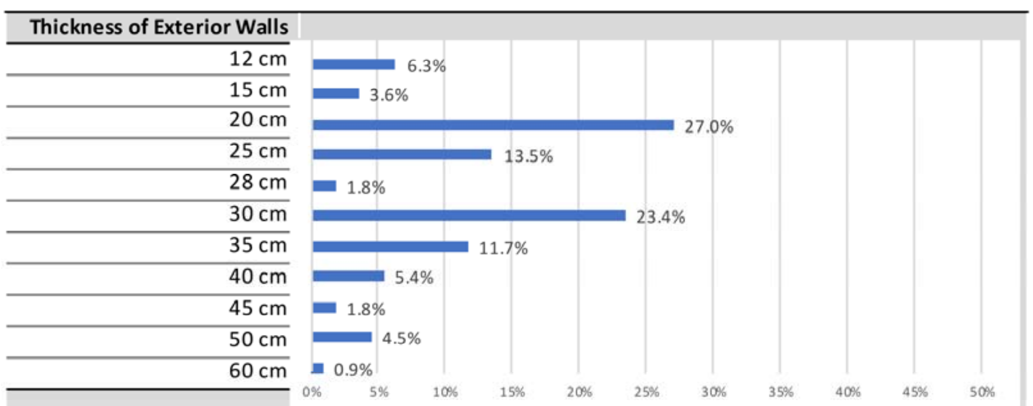
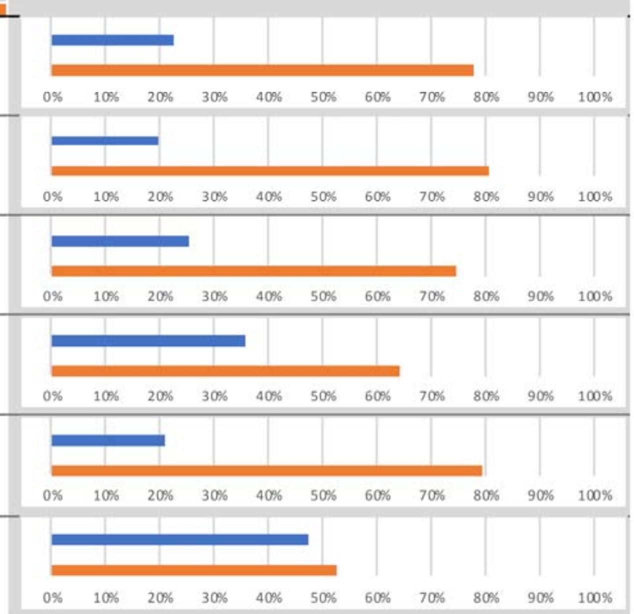


Figure 4.34: Frequencies showing the overall thickness of exterior walls

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

Problems	Responses: Yes	Responses: No
Poor natural ventilation	22.5 %	77.5 %
Poor natural lighting	19.7 %	80.3 %
Too hot and/or too cold	25.4 %	74.6 %
Poor sound insulation	35.8 %	64.2 %
Bad orientation	20.8 %	79.2 %
Lack of green areas and water features	47.4 %	52.6 %



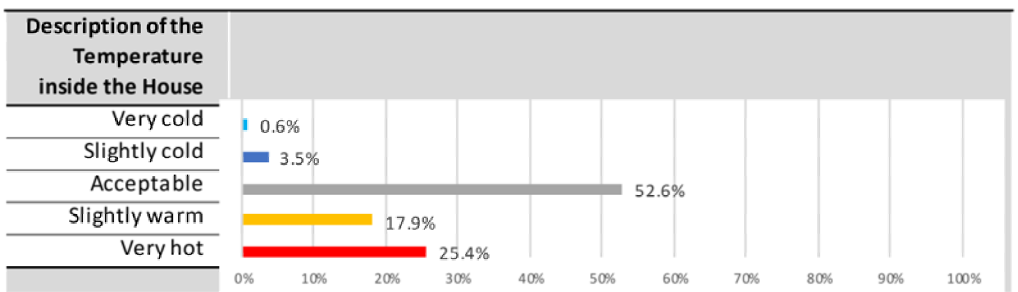


Figure 4.35: Frequencies showing description of the 'temperature' inside the house during summer (without any use of mechanical equipment)

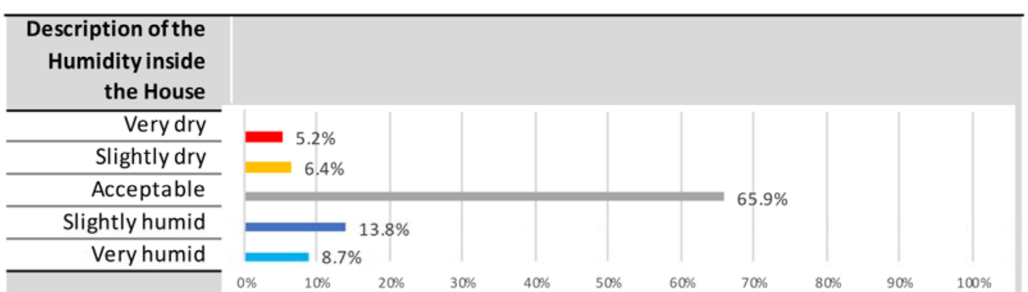


Figure 4.36: Frequencies showing description of the 'humidity' inside the house during summer (without any use of mechanical equipment)

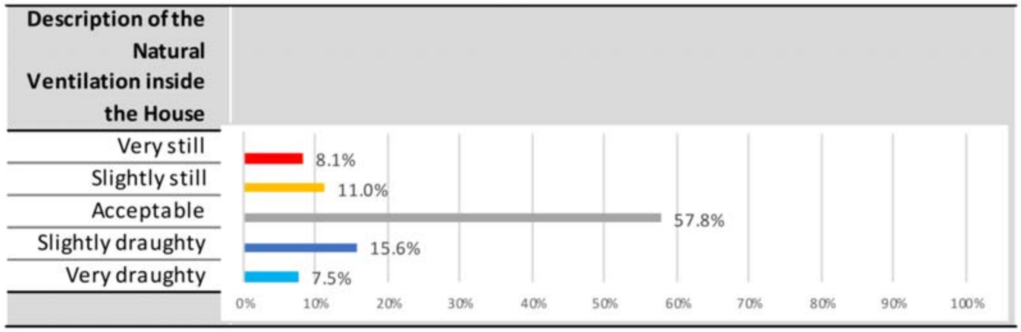


Figure 4.37: Frequencies showing description of the 'air movement and natural ventilation' inside the house during summer (without any use of mechanical equipment)

- ***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).

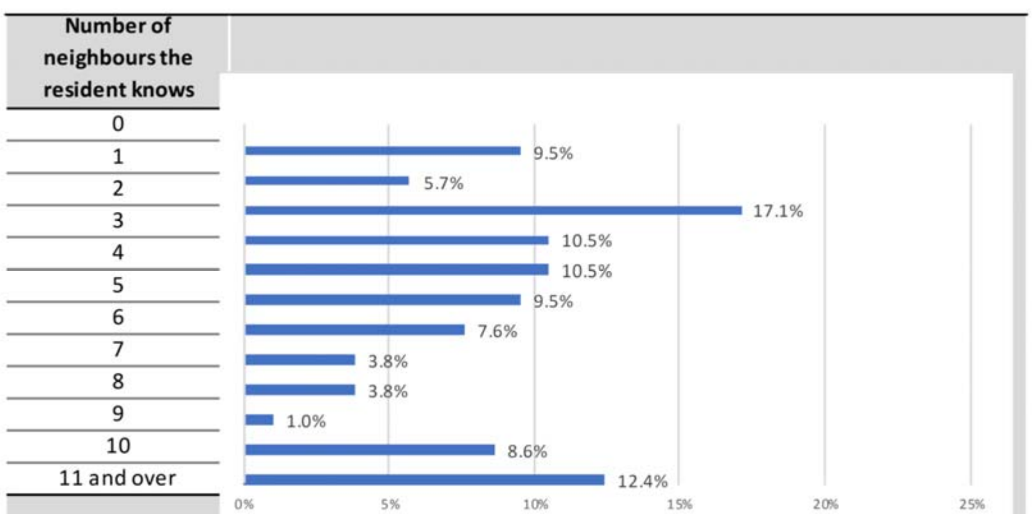


Figure 4.38: Frequencies showing number of neighbours the resident knows

Table 4.11: Percentages showing problems facing the resident

Problems	Responses Yes	Responses No
Noise from neighbours	27.2 %	72.8 %
Lack of privacy due to the huge number of windows	16.8 %	83.2 %
Lack of common gathering spaces	39.3 %	60.7 %
Lack of security and safety issues	20.8 %	79.2 %
Lack of social interaction between neighbours	40.5 %	59.5 %
Residents cannot use the outdoor terraces due to the lack of privacy	30.6 %	69.4 %

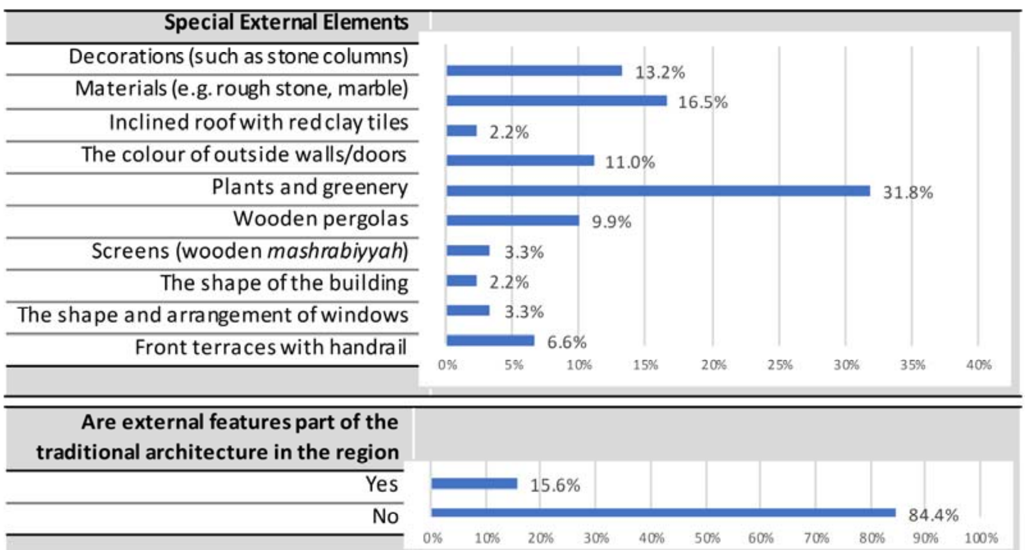


Figure 4.39: Frequencies showing types of external elements that give the house a special character

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 %

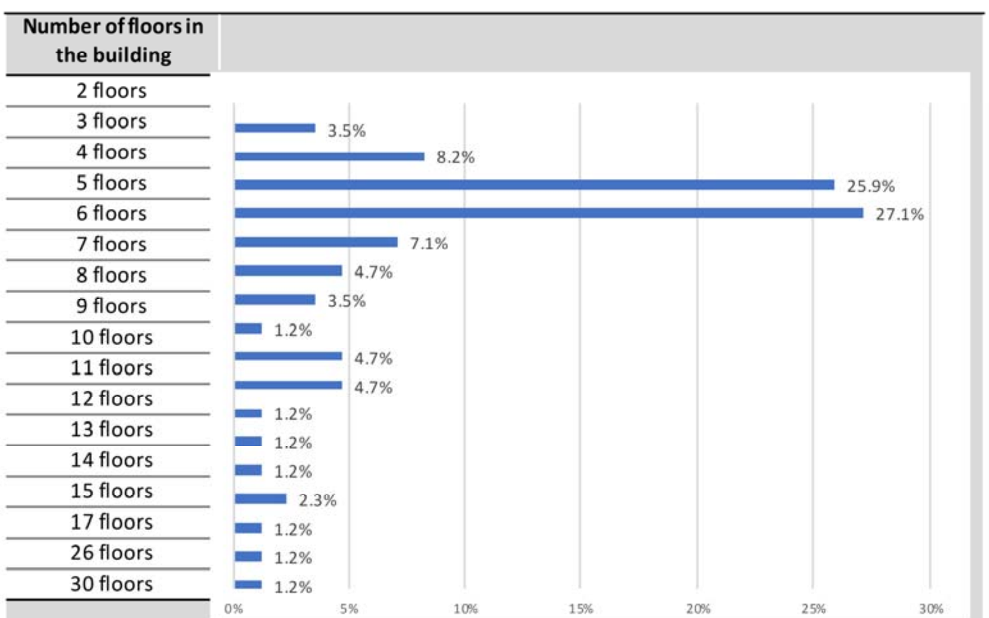


Figure 4.40: Frequencies showing the total number of floors in the apartment building

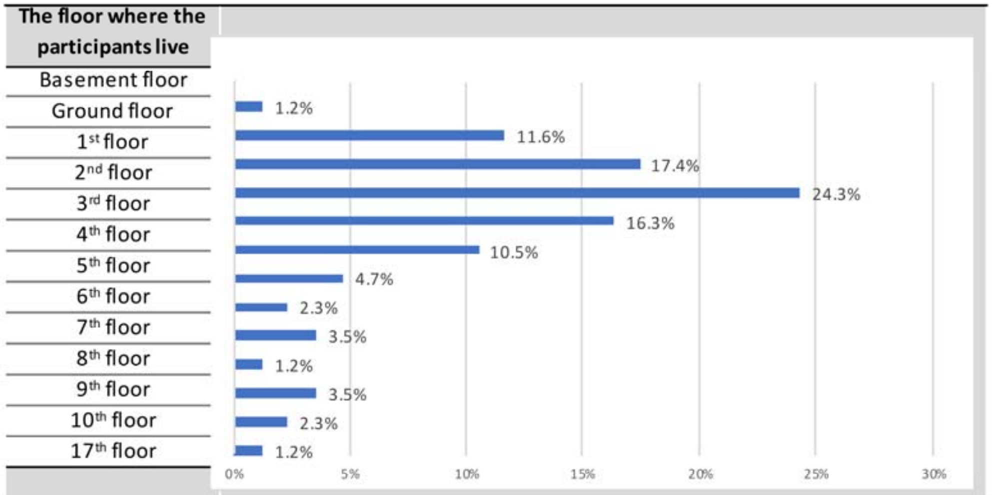


Figure 4.41: Frequencies showing the floor where the participants live

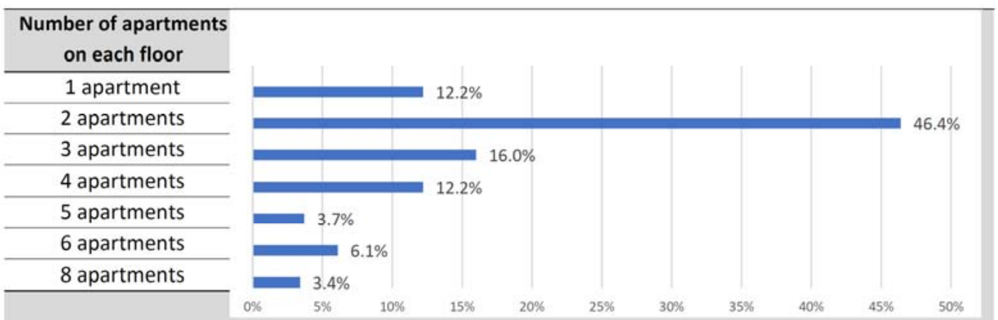


Figure 4.42: Frequencies showing number of apartments on the floor where the participants live

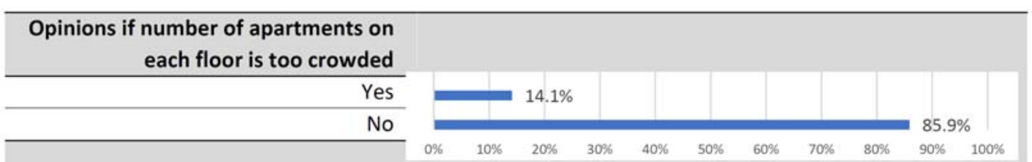


Figure 4.43: Frequencies showing opinions if number of apartments on each floor is too crowded

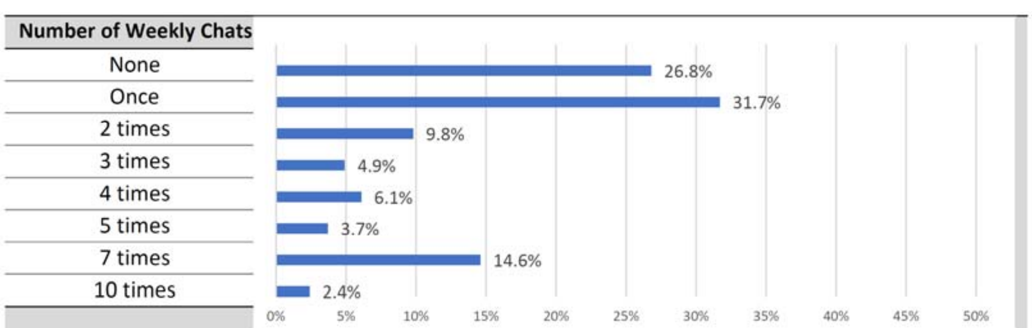


Figure 4.44: Frequencies showing number of weekly chats with neighbours in the building

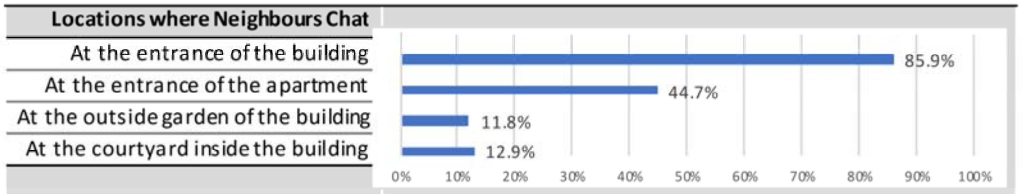


Figure 4.45: Frequencies showing locations where neighbours chat with each other

Table 4.13: Aspects people like the most in their building

Aspects people like the most in their building	Percentage
1. Not crowded / small number of apartments in each floor	17.2 %
2. Availability of balconies and terraces	6.9 %
3. Availability of green areas	3.5 %
4. Availability of entry hall and the suitable size of the staircase	17.2 %
5. Availability of multi-purpose hall and common spaces for social gathering	10.4 %
6. The arrangement of apartments preserve the privacy of each family	13.7 %
7. A separate entrance for apartments located on the ground floor	3.5 %
8. The orientation of apartments benefits from natural lighting and ventilation	8.6 %
9. The design and materials of facades (e.g. stone cladding)	8.6 %
10. Availability of storage spaces and services	3.5 %
11. All toilets have windows to the outdoor for natural ventilation	1.7 %
12. Availability of commercial activities on the ground floor	5.2 %

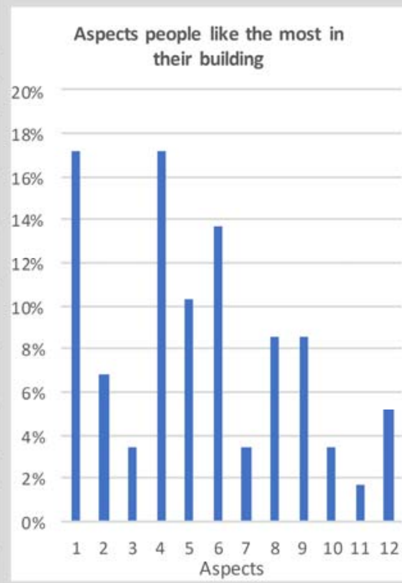
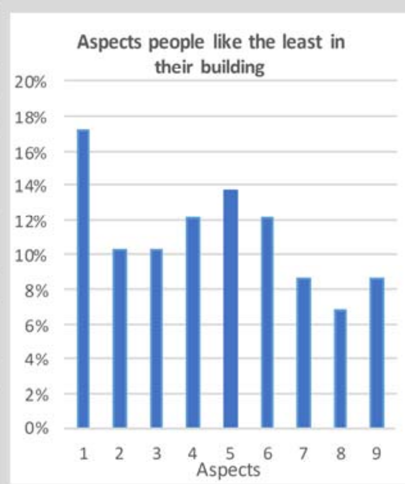


Table 4.14: Aspects people like the least in their building

Aspects people like the least in their building	Percentage
1. Only one entrance for the whole building, and the entry hall is too small	17.2 %
2. Lack number of lifts	10.4 %
3. Lack of decorations	10.4 %
4. Lack of common and gathering spaces, and play areas for children (currently the parking space is used as playground)	12.1 %
5. The design and the number of parking spaces are not efficient	13.7 %
6. Linear, long and narrow circulation paths	12.1 %
7. Lack of privacy due to the bad sound insulation	8.6 %
8. Small size of apartments	6.9 %
9. Bad orientation / lack of natural lighting and ventilation, especially toilets as the design depends on mechanical ducts not on windows	8.6 %



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.

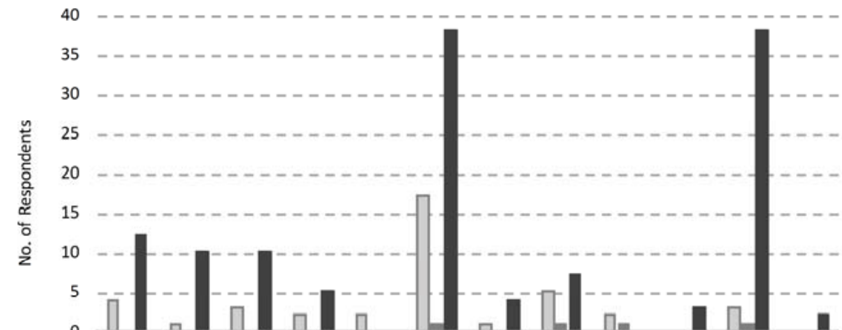
4.4.1. Social/Spatial Qualities

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^2, 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).



	KSA	Kuwait	UAE	Qatar	Yemen	Jordan	Syria	Palest.	Iraq	Turkey	Egypt	Algeria
Detached house/villa	4	1	3	2	2	17	1	5	2	0	3	0
Attached house	0	0	0	0	0	1	0	1	1	0	1	0
Apartment in a building	12	10	10	5	0	38	4	7	0	3	38	2

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

Table 4.15: Factors related to the context (region)

Variables		Significant Value (according to SPSS Chi-Square Tests)	Association between the Two Variables	
			Yes	No
Region	Type of house	0.012 (< 0.05)	X	
	Total Area of the house	0.125 (≥ 0.05)		X
	Availability of a courtyard	0.351 (≥ 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 (according to SPSS Chi-Square Tests)**	**Association between the Two Variables**	
			Yes	**No**
Availability of a courtyard	Region	0.351 (≥ 0.05)		X
	Type of house	0.000 (< 0.05)	X	
	Area of the house	0.117 (≥ 0.05)		X
	People prefer to have a courtyard 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^2 and 250 m^2. Moreover, the survey concluded that there is a need to offer three different types of areas (100-140 m^2, 141-181 m^2, and 181-250 m^2), 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 (according to SPSS Chi-Square Tests)**	**Association between the Two Variables**	
			Yes	**No**
The area of the house	Number of people living in the house	0.000 (< 0.05)	X	
	Number of dependent children (under 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 male visitors)	0.008 (< 0.05)	X	
	Availability of a guest room (only for female visitors)	0.018 (< 0.05)	X	
	Availability of a guest room (for both 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^2 of outdoor areas. The total area of those houses ranged between 100 m^2 and 250 m^2. 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 (according to SPSS Chi-Square Tests)	Association between the Two Variables	
			Yes	No
Level of satisfaction with 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^2	2.96
101 – 140 m^2	3.74
141 – 180 m^2	4.65
181 – 250 m^2	4.91
250 m^2 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 [7]	Percentages represent if the density in the study area is above (or below) the international standards
1-room apartment	3.93	1.25	+314 %
2-rooms apartment	5.00		+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

7 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 prestegious 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 (according to SPSS Chi-Square Tests)	Association between the Two Variables	
			Yes	No
Level of satisfaction with the spatial design of the 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 (according to SPSS Chi-Square Tests)	Association between the 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 (according to SPSS Chi-Square Tests)	Association between the Two Variables	
			Yes	No
Number of floors/levels of the house	The household structure	0.782 (≥ 0.05)		X
	Number of dependent children (under 18 years) living in the house	0.761 (≥ 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 (according to SPSS Chi-Square Tests)	Association between the Two Variables	
			Yes	No
Number of apartments on each floor	Opinion of residents if there are too many apartments on each 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 (according to SPSS Chi-Square Tests)	Association between the Two Variables	
			Yes	No
Lack of security and safety	Lack of private outdoor spaces for children	0.018 (< 0.05)	X	
	People prefer to have a secure outdoor gathering spaces in their houses and the building	0.011 (< 0.05)	X	
Lack of common spaces in the building	People prefer to have a courtyard in their buildings	0.000 (< 0.05)	X	
	People prefer to have common spaces in their buildings	0.000 (< 0.05)	X	
Lack of green areas in the building	People prefer to have common 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 (according to SPSS Chi-Square Tests)	Association between the Two 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 (according to SPSS Chi-Square Tests)**	**Association between the Two Variables**	
			Yes	**No**
Seeing the outside views from the house	Privacy	0.014 (< 0.05)	X	
	Poor lighting (due to the small size of windows)	0.000 (< 0.05)	X	
	Level of satisfaction with the 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 (2nd and 3rd 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 (according to SPSS Chi-Square Tests)	Association between the Two Variables	
			Yes	**No**
Availability of a courtyard	The house is too hot and/or too cold (the temperature inside the house)	1.000 (≥ 0.05)		X
	The problem of humidity inside the house	0.133 (≥ 0.05)		X
	Bad ventilation inside the house	0.117 (≥ 0.05)		X
	Poor natural lighting inside the house	0.052 (≥ 0.05)		X
	Poor sound insulation	0.259 (≥ 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 (according to SPSS Chi-Square Tests)	Association between the Two Variables	
			Yes	**No**
Age of construction	Very hot/cold atmosphere inside the house	0.995 (≥ 0.05)		X
	Humidity inside the house	0.216 (≥ 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^{th} 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).

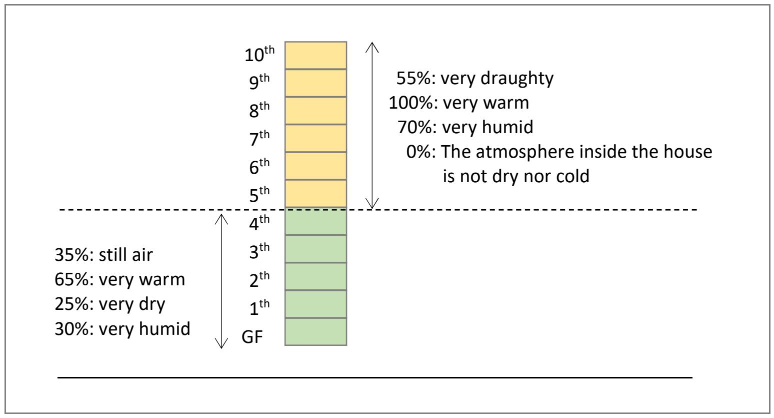


Figure 4.47: A diagram showing qualities of the indoor environment based on the floor where participants live

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	

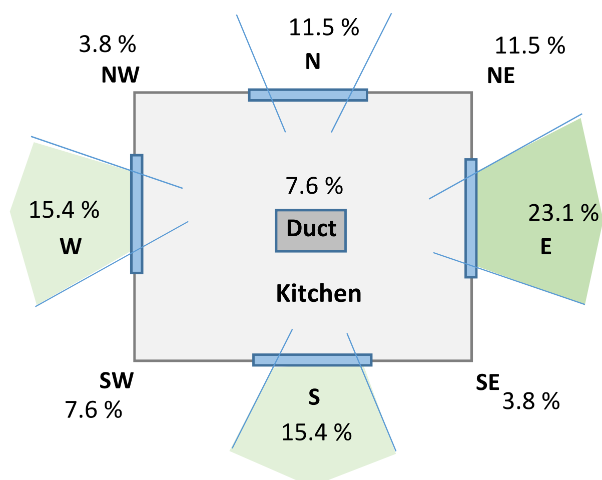


Figure 4.48: Percentages of residents who are satisfied with the location of windows in their kitchens

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 (according to SPSS Chi-Square Tests)	Association between the Two Variables	
			Yes	No
The height of the ceiling	Age of construction	0.573 (≥ 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 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

<table>
<tr><th colspan="2" rowspan="2">Variables</th><th rowspan="2">Significant Value (according to SPSS Chi-Square Tests)</th><th colspan="2">Association between the Two Variables</th></tr>
<tr><th>Yes</th><th>No</th></tr>
<tr><td rowspan="2">People prefer to have two living zones in their houses: one for summer and the other for winter</td><td>People currently have spaces used only in summer</td><td>0.894 (≥ 0.05)</td><td></td><td>X</td></tr>
<tr><td>People currently have spaces used only in winter</td><td>0.104 (≥ 0.05)</td><td></td><td>X</td></tr>
</table>

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		
1. Spatial Qualities of the Apartment			
1.1. Area of the house in relation to the household structure	Different sizes of apartments ranged from 100 m^2 to 250 m^2 are needed. Residents prefer the following areas based on the household structure:		
	Single-users and workers: 100-140 m^2 (10% of total number of apartments)	Couple, and couple with children: 141-180 m^2 (25% of the total number of apartments)	Couple with children: 181-250 m^2 (65% of the total number of apartments)
1.2. Areas of spaces (the principle of modest spaces)	- Area of guest spaces should not be exaggerated in comparison to the area of living zones and bedrooms - The area of living space should be reasonable with the number of people living in the house		
1.3. Number of family members	For areas range between 100 and 140 m^2: 1 - 4 members	For areas range between 141 and 180 m^2: 3 - 6 members	For areas range between 181 to 250 m^2: 4 - 8 members
1.4. Number of floors for the apartment	For areas range between 100 and 140 m^2: One floor	For areas range between 141 and 180 m^2: One floor (70%), and Two floors (30%)	For areas range between 181 to 250 m^2: One floor (40%), and Two floors (60%)
1.5. Spaces for guests	Houses for single-users and workers: - Entry hall	Houses for a couple, and a couple with children: - Entry hall, - Guest room for both male and female, - Dining room, - Toilet for guests	
1.6. Family Spaces	Houses for single-users and workers (100-140 m^2): - Living room with a breakfast corner	Houses for a couple, and couple with children: (141-180 m^2): - Family living room, - Office/Study area (optional)	Houses for a couple with children (181-250 m^2): - Family living room, - Office/Study area - Multi-purpose hall

1.7.	Bedrooms	<u>Houses for single-users and workers (100-140 m^2):</u> - 1 to 2 Master bedrooms	<u>Houses for a couple, and couple with children: (141-180 m^2):</u> - 1 Master bedrooms - 1 to 2 Bedrooms for kids	<u>Houses for a couple with children (181-250 m^2):</u> - 1 to 2 Master bedrooms - 2 to 3 Bedrooms for kids - 1 Guest bedroom (optional)
1.8.	Services	<u>Houses for single-users and workers (100-140 m^2):</u> - 1 Bathroom - Kitchen - Storage area	<u>Houses for a couple, and couple with children: (141-180 m^2):</u> - 2 Bathrooms - Kitchen - Breakfast area - Storage area	<u>Houses for a couple with children (181-250 m^2):</u> - 3 Bathrooms - Kitchen - Breakfast area - Storage area
1.9.	Type and area of outdoor spaces	<u>For areas range between 100 and 140 m^2:</u> - Terrace/Balcony Area of outdoor spaces = 10-15% of the total area of the house.	<u>For areas range between 141 and 180 m^2:</u> - Terrace/Balcony (one for the living space, and one for the kitchen) - Courtyard (for 30% of apartments (two-floors) Area of outdoor spaces = 10-18% of the total area of the house.	<u>For areas range between 181 to 250 m^2:</u> - Terrace/Balcony (one for the living space, and one for the kitchen) - Courtyard (for 60% of apartments (two-floors) - *Iwan* and covered paths/gallery (optional) for the two-floors apartment Area of outdoor spaces = 12-20% of the total area of the house.
1.10.	Accessibility and Circulation	- No lost spaces and long corridors between rooms - Steps inside the house (1 to 5 steps) between different zones (e.g. living space and guest room, living space and bedrooms) - 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		
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> Ranged between 7 and 30 floors	<u>Middle East:</u> Ranged between 4 and 6 floors	<u>North Africa and Turkey:</u> 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		- No lost spaces and long corridors - Suitable number of elevators based on the number of residents - In buildings that have more than 8 floors, two elevators should be designed: o Low-rise elevator shaft ends at 8^{th} floor (serves from the ground floor to the 7^{th} floor) o High-rise elevator serves the ground floor and from the 8^{th} floor to the 14^{th} floor - 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. - The width of circulation paths between apartments needs to serve the number of people living on that floor. - The entrance and the entry hall for the building should be identified.
3. Social-Cultural Qualities		
3.1. Privacy	Olfactory privacy	- Closed kitchen (not to be opened on the living zone), and separate it from the living space and bedrooms - 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
	Acoustical privacy	- Separate bedrooms from living area to control the noise between private and intimate zones
	Visual privacy and spatial hierarchy	- Add a visual separation between the entrance and the family living zone (bent entrance) - Add a visual barrier between the guest zone (guest and dining rooms) and the living family room - Separate the entrance from the kitchen or storage area - Bedrooms should be located in the same zone - Two entrances: one for guests (bent entrance), and the other for the family (which could also be used for female guests) - Hierarchy of spaces (from public zones to private and intimate zones) - Guest toilet should be located near the guest room - Use screens (such as louvres and *mashrabiyya*) in front of large windows to increase the privacy for the family - 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 - Staggered entrance for apartments on each floor, to preserve the privacy of each family. - Terraces should not overlook other balconies - 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
3.2. Social interaction between family members, and between residents and neighbours		- 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.

	- 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. - Outside playgrounds, plazas, and gardens are useful features for encouraging the social interaction between neighbours.
3.3. Hygiene	- 1 to 3 steps between the entry hall and other zones to increase the hygiene inside the house - 1 to 3 steps between the kitchen and the living space to increase the hygiene
3.4. Security and safety	- Outdoor spaces for children (such as courtyards, balconies with handrail) near the living zone, to increase the security and safety
3.5. Views to the outside	- Terraces and large windows (with screens, such as louvres and *mashrabiyyah*) to increase the connection with the outside context, through offering the resident to see the outside views from the inside.
3.6. The identity of the place	- The use of local materials (such as stone) - It is recommended to understand the meaning and purpose of traditional elements, and use contemporary materials. For instance, *mashrabiyyah* could be replaced with steel louvres or patterned glass, as a method for preserving privacy without copying the past as it. - Different natural colours could be used to identify apartments from each other, and a method to have variations with a unity.

4. Environmental Qualities	
4.1. Orientation	- 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 - 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. - The orientation of the courtyard: 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. 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.
4.2. Natural ventilation	- All toilets need to have a window (not on a duct)
4.3. Greenery	- 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)
4.4. Seasonal zones	- 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. - Particular areas, such as roof terraces, and balconies, could be used only during summer season.
4.5. Treatments for upper floors	- 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.

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-Ghazzeh 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-Ghazzeh 1997).
- Connected spaces, which mostly represent the link between private spaces (living room, kitchen and dining room).

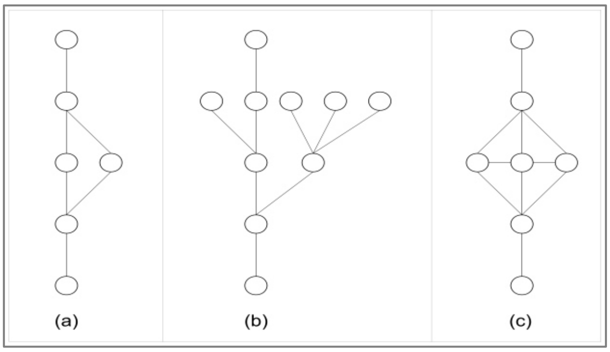


Figure 4.49: Types of connections between spaces: (a) linear, (b) fan-shape, (c) connected
(Researcher)

b. Mathematical Representation

Different measurements could be used to quantify syntactic relationships between spatial components of the design. Such measurements include:

- Connectivity (*NCn*): 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-Ghazzeh 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:

- *TDn*: Total Depth (TD) for each node
- *MDn*: 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.

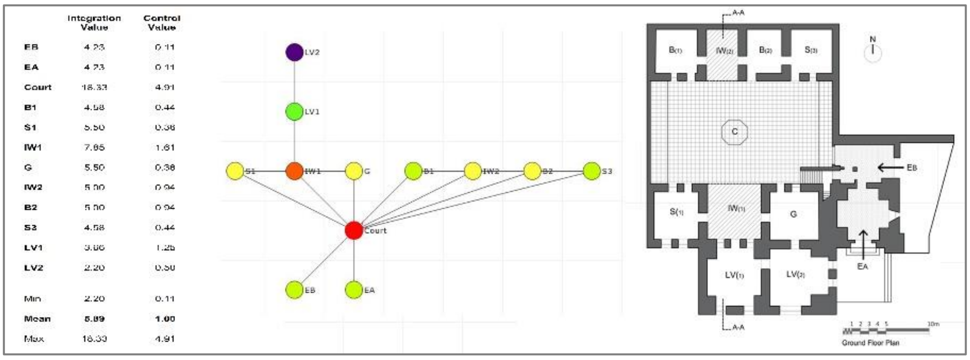


Figure 4.50: A justified graph showing the integration value for each space, produced by *AGraph* software

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).

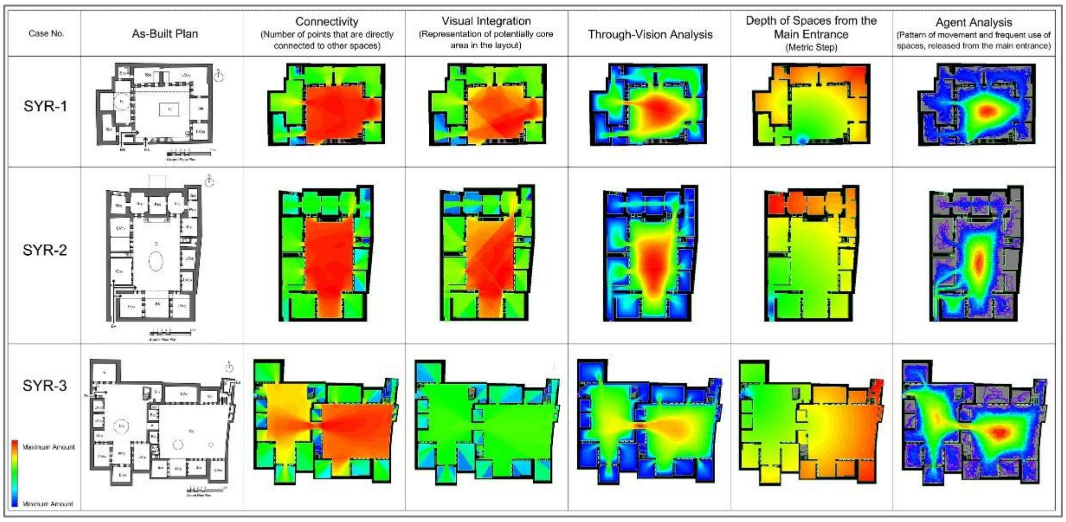


Figure 4.13: Samples of ‘visibility graph analysis’ for three traditional courtyard houses located in Syria, produced by ‘*DepthmapX 0.50*’ software

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

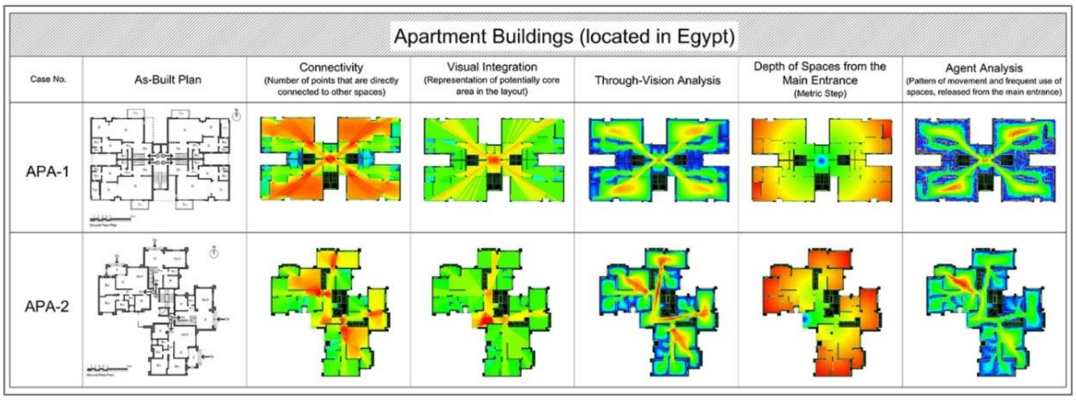


Figure 4.55: Samples of ‘visibility graph analysis’ for two contemporary apartment buildings located in Egypt, produced by ‘*DepthmapX 0.50*’ software

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^2)	- Numbers (syntactic values) - Diagrams	- Numbers (m^2)	- Numbers (%, m^2, m, cm, X:Y) - Diagrams - Text	- Numbers (m^2, m) - Diagrams	- Diagrams	- Numbers (m, cm) - Diagrams - Text	- Diagrams	- Diagrams - Text	- Diagrams	- Diagrams	- Numbers (%) - Diagrams	- Numbers (m) - 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 Hiller 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.

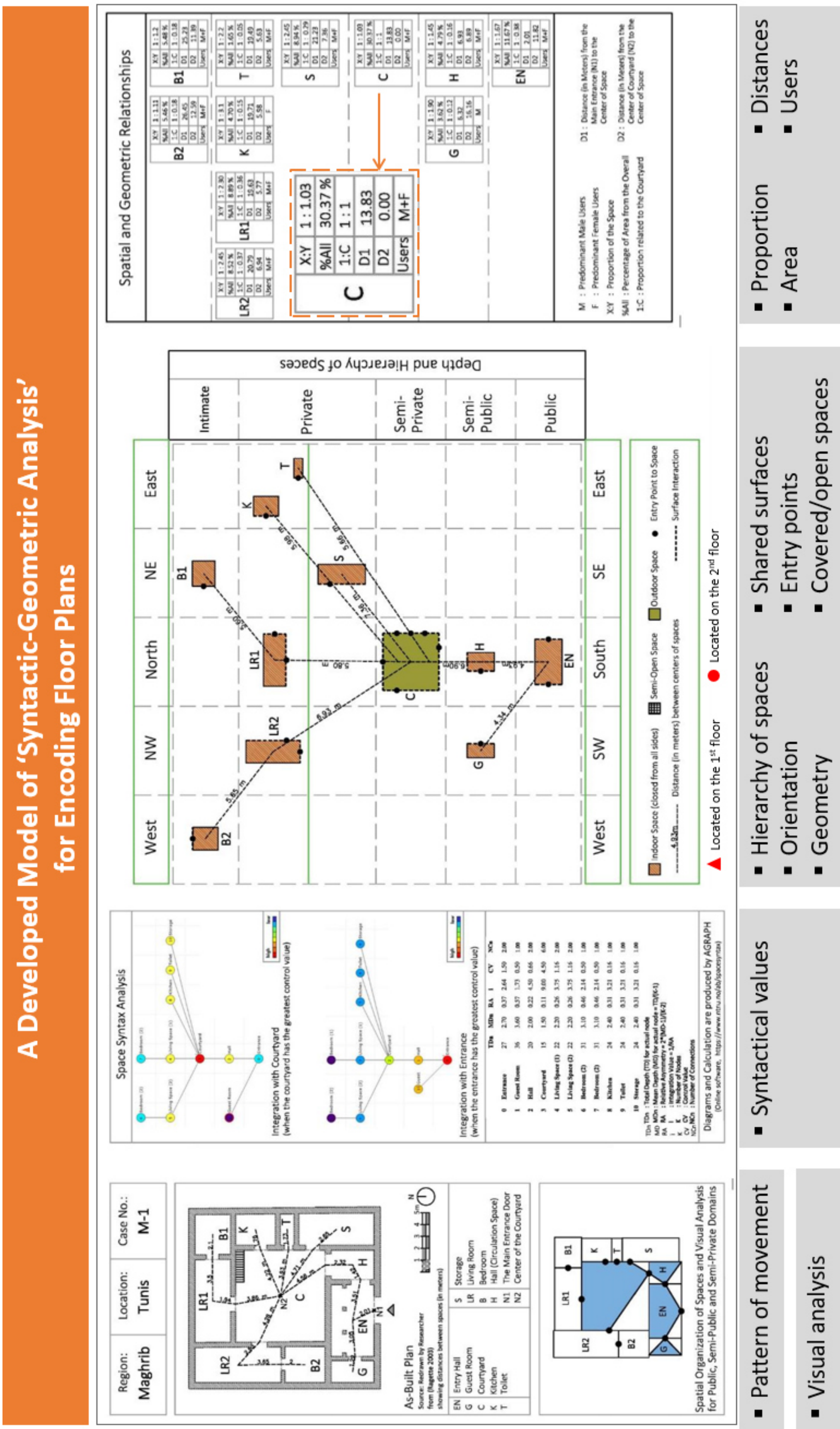


Figure 4.56: A developed model of syntactic-geometric analysis for encoding floor plans to address formal and social realities

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).

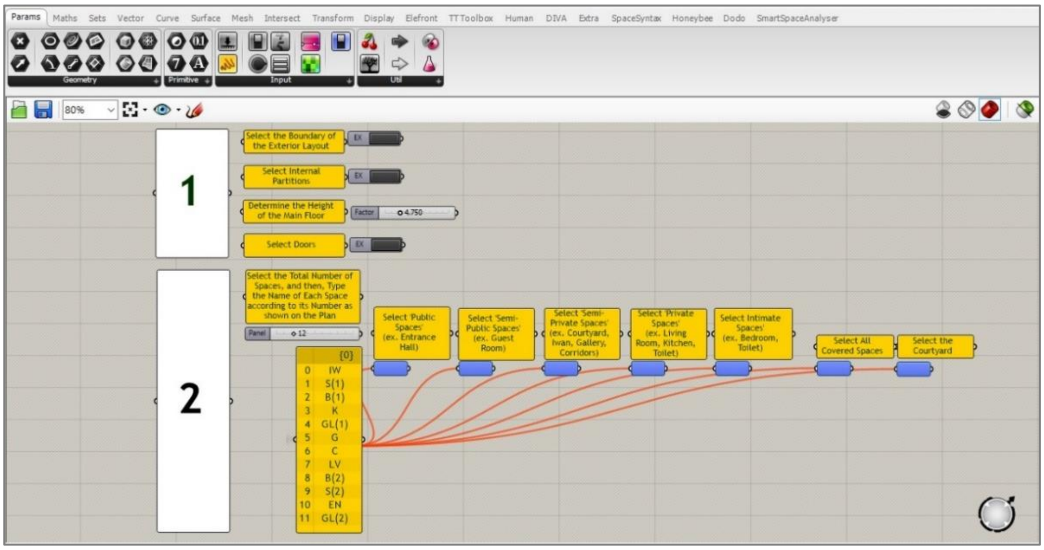


Figure 4.57: A screenshot for the interface in Grasshopper showing the required inputs from the user

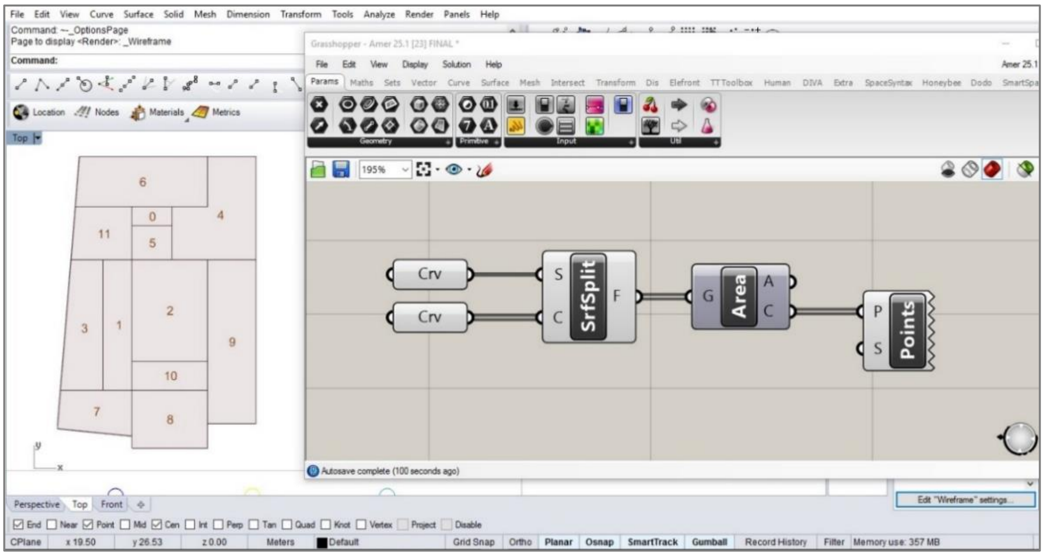


Figure 4.58: A screenshot for the interface in Grasshopper showing functions to carry out the partitioning process, using non-manifold topology (NMT)

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.

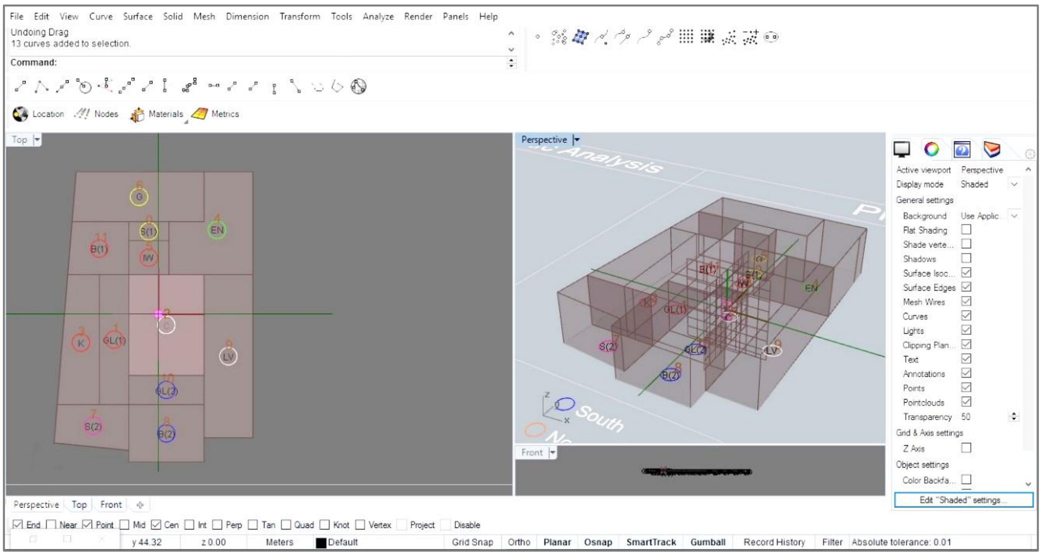


Figure 4.59: A screenshot showing the output of the partitioning process

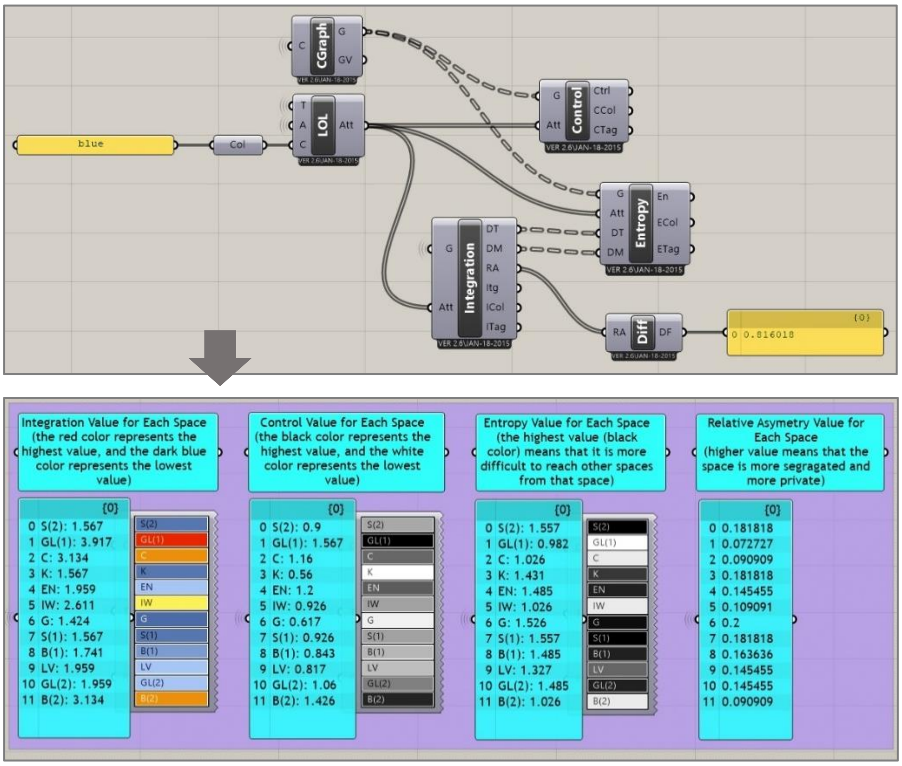
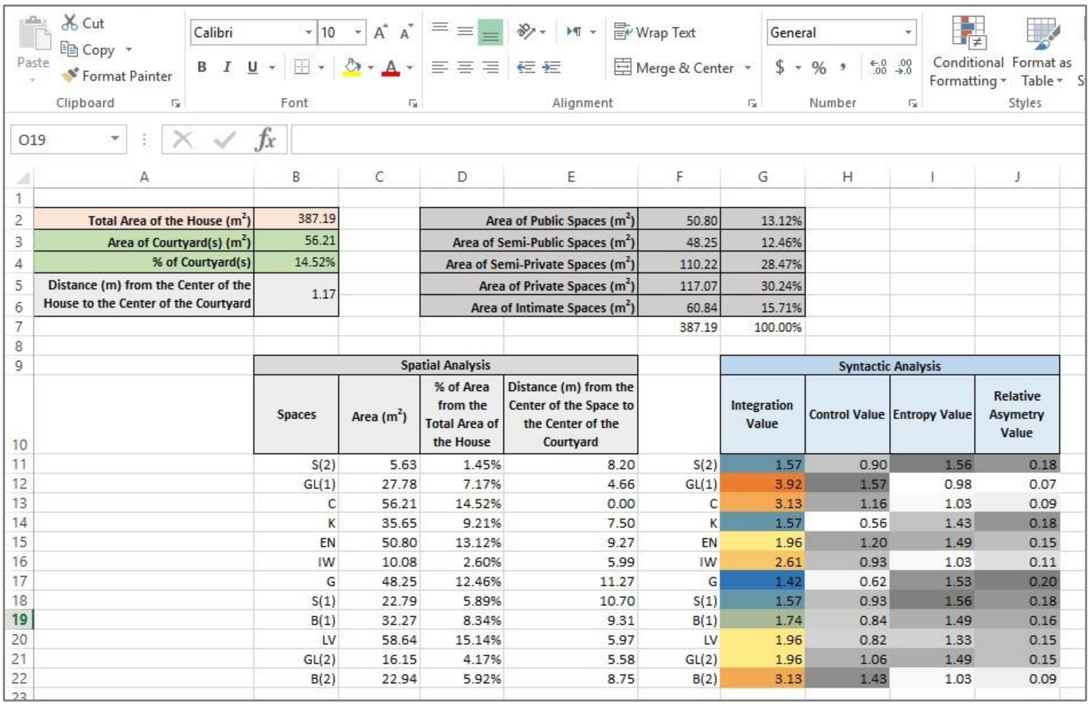


Figure 4.60: A screenshot showing the output of the partitioning process



Total Area of the House (m^2)	387.19
Area of Courtyard(s) (m^2)	56.21
% of Courtyard(s)	14.52%
Distance (m) from the Center of the House to the Center of the Courtyard	1.17

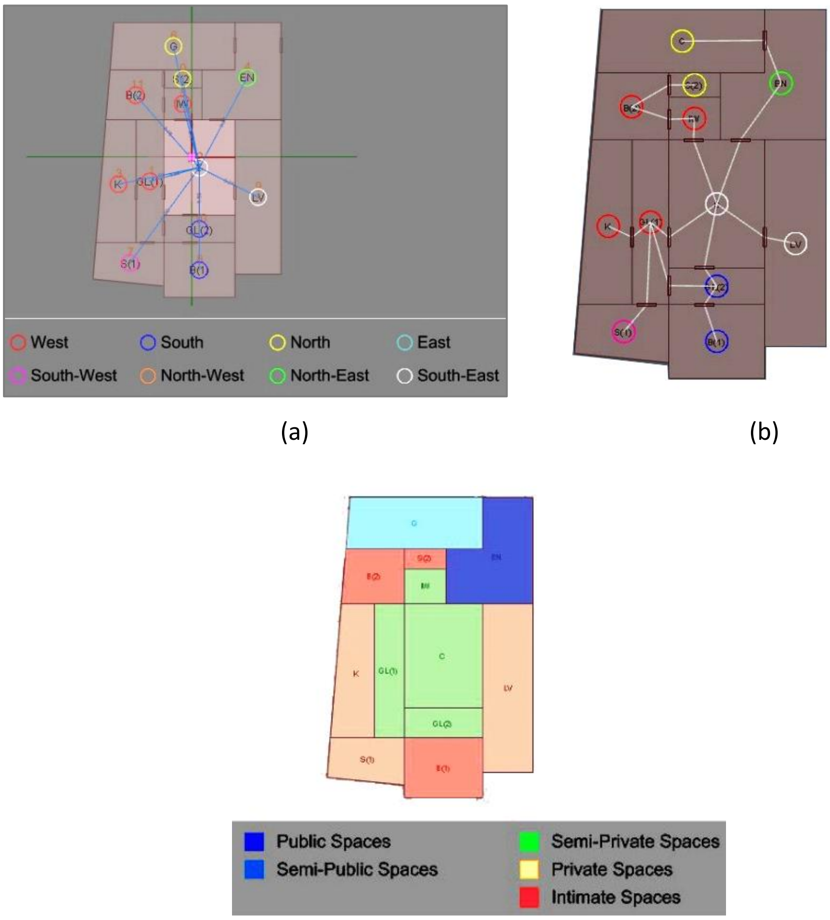
Area of Public Spaces (m^2)	50.80	13.12%
Area of Semi-Public Spaces (m^2)	48.25	12.46%
Area of Semi-Private Spaces (m^2)	110.22	28.47%
Area of Private Spaces (m^2)	117.07	30.24%
Area of Intimate Spaces (m^2)	60.84	15.71%
	387.19	100.00%

Spatial Analysis					Syntactic Analysis			
Spaces	Area (m^2)	% 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 Asymetry Value
S(2)	5.63	1.45%	8.20	S(2)	1.57	0.90	1.56	0.18
GL(1)	27.78	7.17%	4.66	GL(1)	3.92	1.57	0.98	0.07
C	56.21	14.52%	0.00	C	3.13	1.16	1.03	0.09
K	35.65	9.21%	7.50	K	1.57	0.56	1.43	0.18
EN	50.80	13.12%	9.27	EN	1.96	1.20	1.49	0.15
IW	10.08	2.60%	5.99	IW	2.61	0.93	1.03	0.11
G	48.25	12.46%	11.27	G	1.42	0.62	1.53	0.20
S(1)	22.79	5.89%	10.70	S(1)	1.57	0.93	1.56	0.18
B(1)	32.27	8.34%	9.31	B(1)	1.74	0.84	1.49	0.16
LV	58.64	15.14%	5.97	LV	1.96	0.82	1.33	0.15
GL(2)	16.15	4.17%	5.58	GL(2)	1.96	1.06	1.49	0.15
B(2)	22.94	5.92%	8.75	B(2)	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.



(a) (b) (c)

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

Input	Output
- Overall layout (as polyline). Coordinates of the left bottom corner is (0,0,0) - Internal partitions (as lines) - Height of the house	- Split the overall layout into masses (each mass represents a space) - Draw X-axis and Y-axis at the center of the house
- Select all covered spaces - Select the main hall (e.g. the courtyard)	- Area of the house - Area of each space and the area of the main hall (courtyard), and the percentage of each area relative to the total area of the house - Distances between the center of the main hall (courtyard), and both the center of other spaces, and the center of the house

- Select 'public' spaces (e.g. the entry hall)
- Select 'semi-public' spaces (e.g. guest room, dining room, toilet for guests)
- Select 'semi-private' spaces (e.g. the main hall, courtyard, gallery, *iwan*, corridors)
- Select 'private' spaces (e.g. living room, multi-purpose hall, kitchen, storage areas, toilets, office)
- Select 'intimate' spaces (e.g. bedrooms, master bedrooms)
	- Area of each zone (public, semi-public, semi-private, private, and intimate zones)
	- Percentage of each zone relative to the total area of the house
	- Color-coded syntactic values for each space, which include: integration value, control value, entropy value, relative asymmetry, and difference factor.
	- Visual diagrams:
	  - The orientation of spaces
	  - A node-and-connection syntactic diagram
	  - Hierarchy of spaces
	  - Distances between 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	
Vernacular Houses (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
		15		**12**		**17**
Clusters of Houses / Neighbourhoods (4 cases)	Egypt	1			Syria	1
					Iraq	2
		1		**-**		**3**
Contemporary Apartment Buildings (5 cases)	Egypt	2	Kuwait	1	Jordan	2
		2		**1**		**2**
TOTAL		**18**		**13**		**22**
	Total cases = 53					

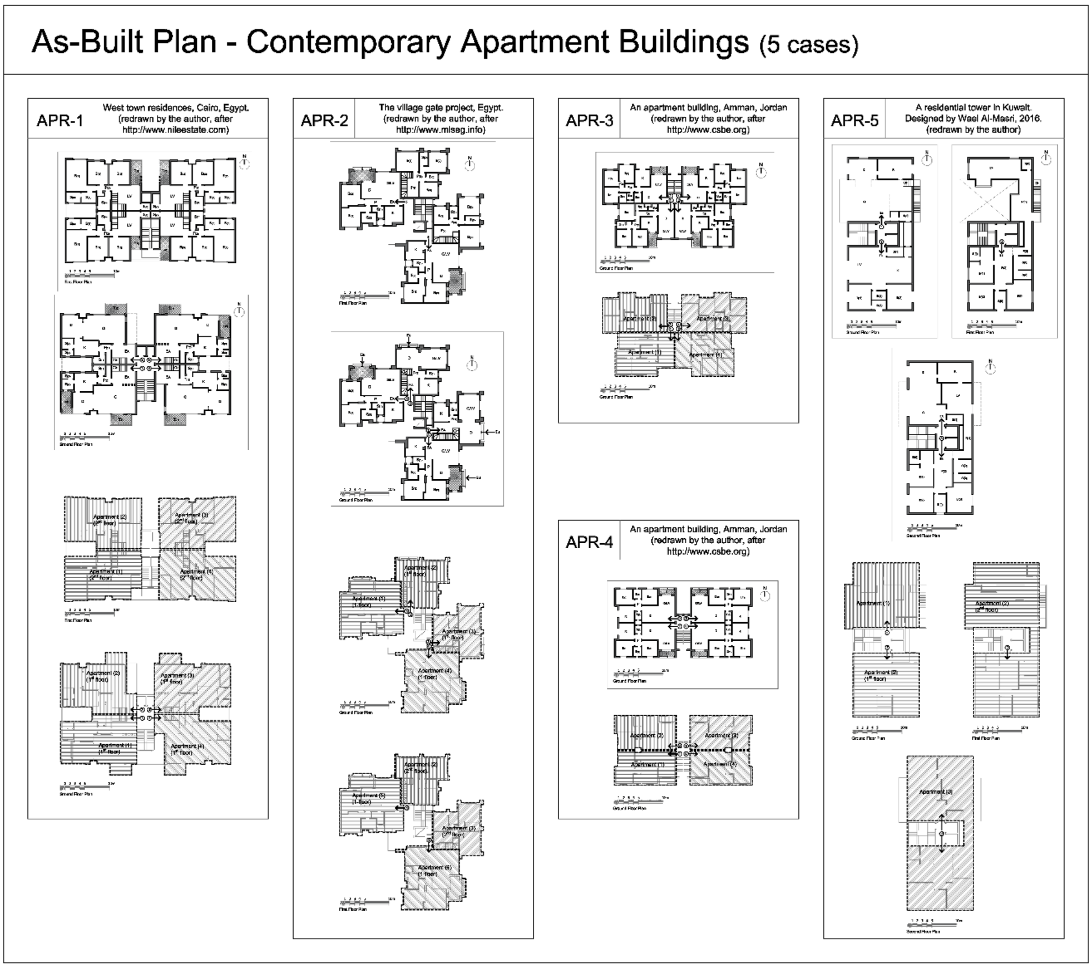


Figure 4.64: As-built architectural drawings for the selected contemporary apartment buildings in MENA region

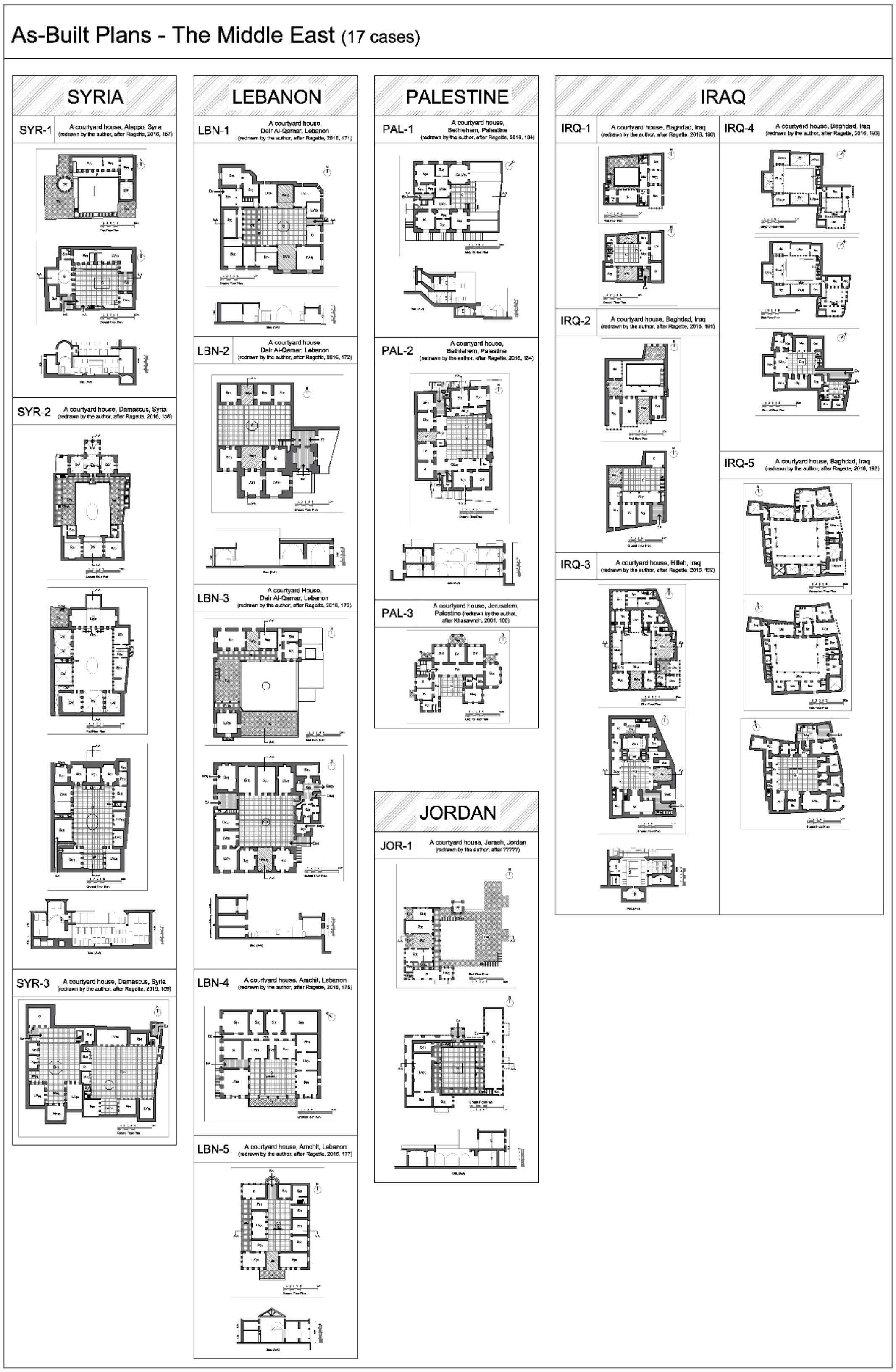


Figure 4.65: As-built architectural drawings for the selected vernacular houses in the Middle East

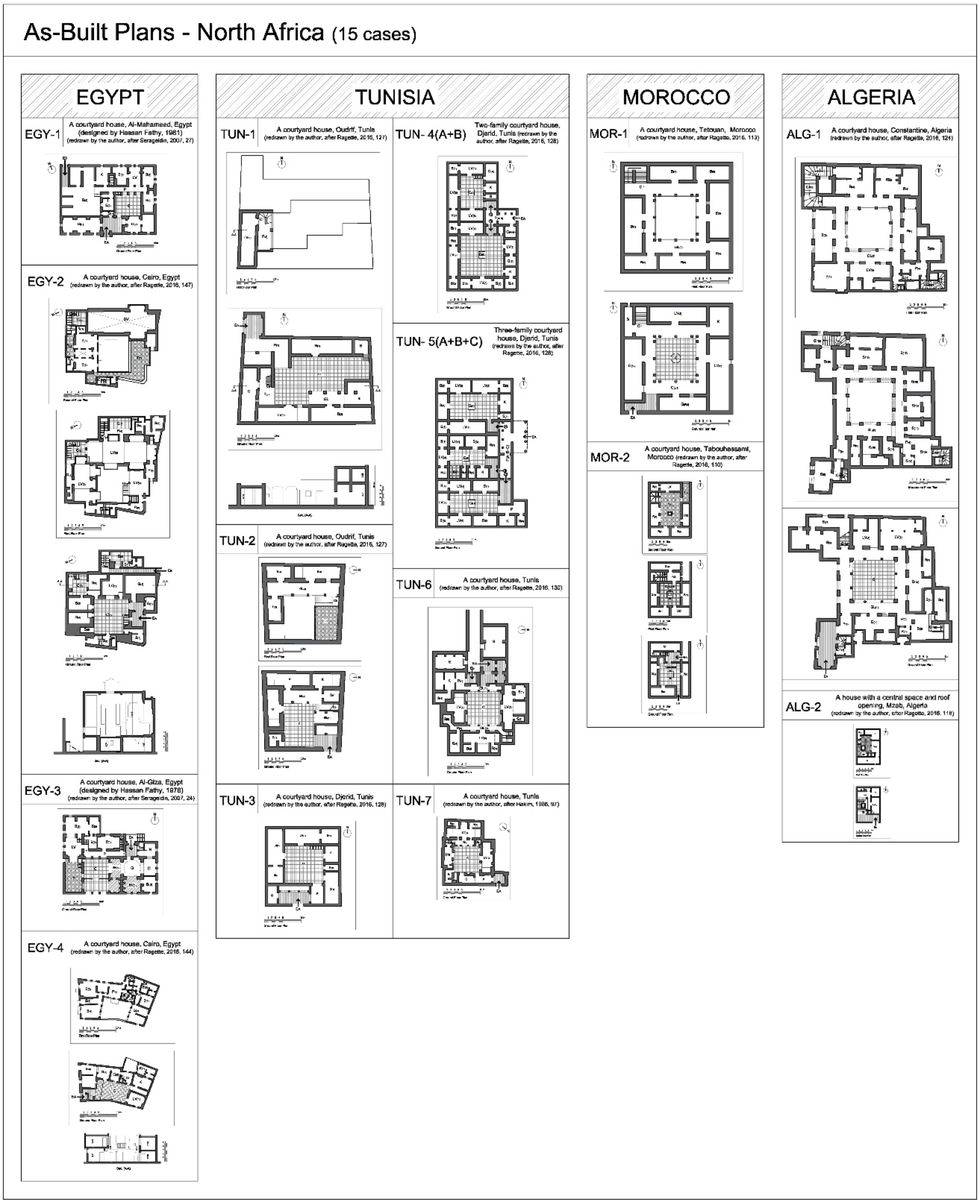


Figure 4.66: As-built architectural drawings for the selected vernacular houses in North Africa

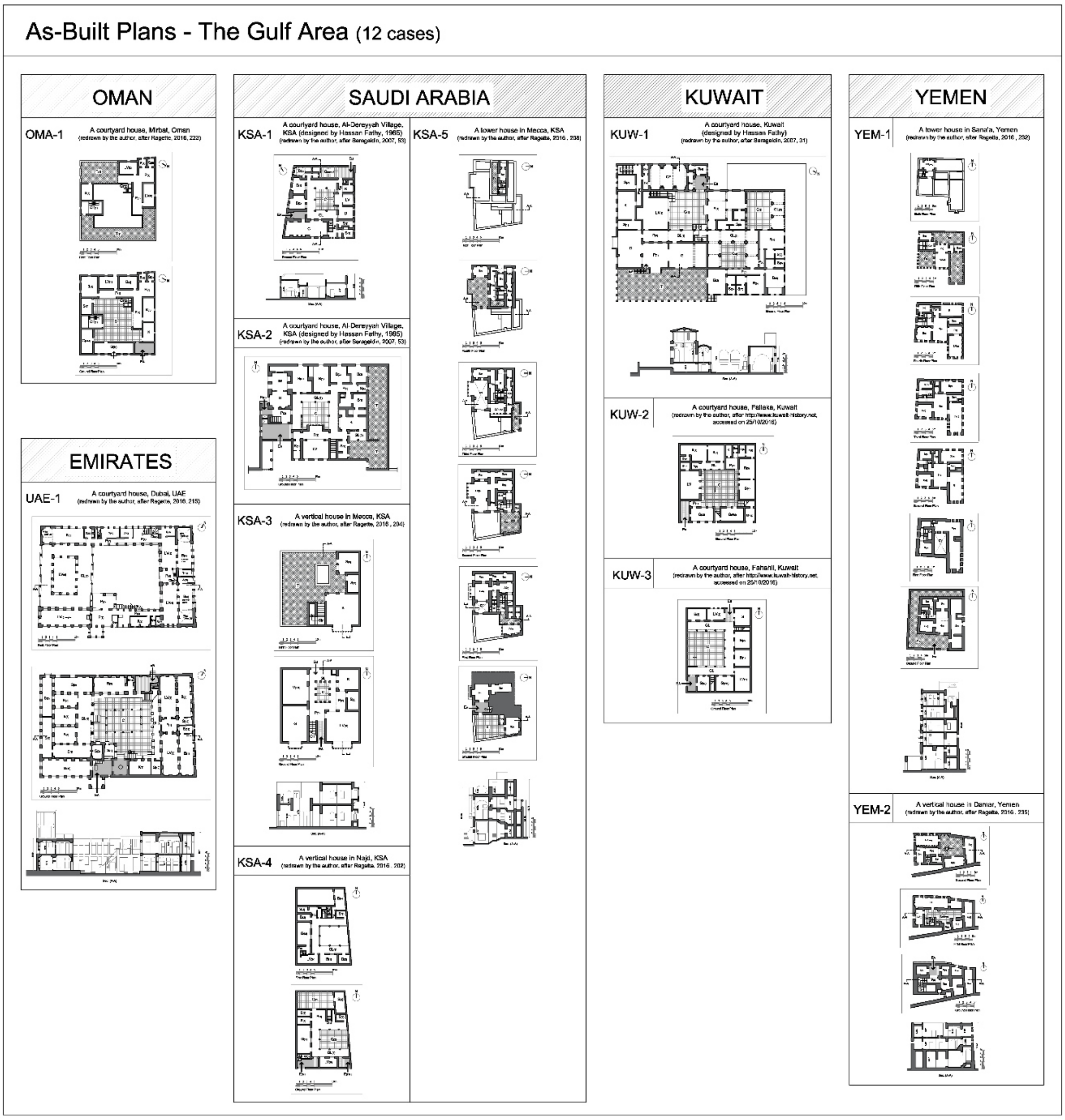


Figure 4.67: As-built architectural drawings for the selected vernacular houses in the Gulf Area

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.

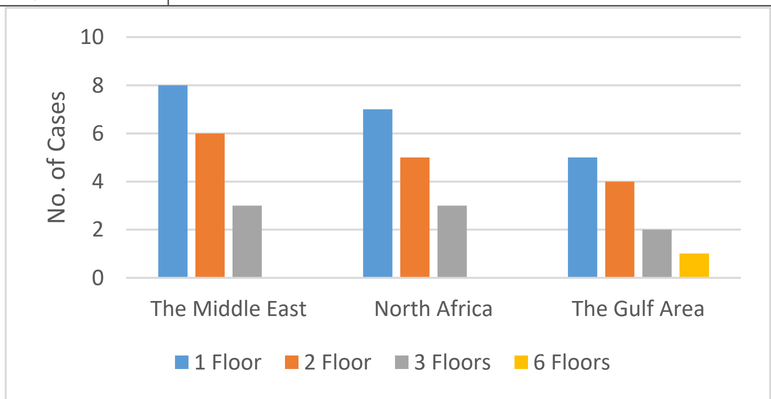
Spaces in most traditional houses are dynamic through using different techniques, such as changes in levels, and various degrees of openness (Ragette 2003). Other features include: (a) reception rooms for male and female guests, which are located adjacent to the main entry hall; (b) *iwan*, which is 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 (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).

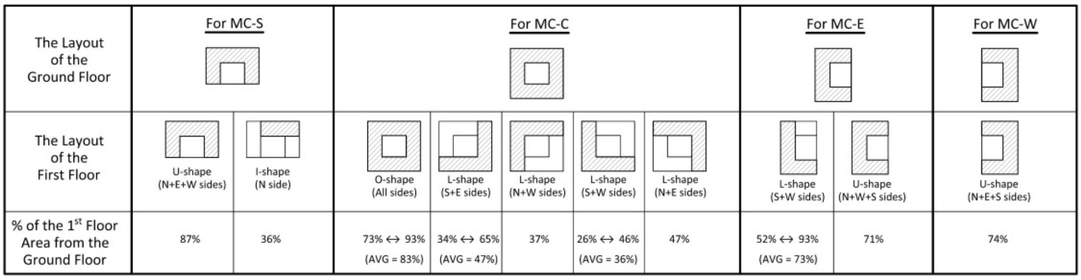


Figure 4.69: Diagrams showing the layout of the first level in two-floor houses

- 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

Movement Patterns for Guests
(a) Main Entrance → Courtyard → Guest Room (Public – Semi-Public)
(b) Main Entrance → Entry Hall → Guest Room (Public – Semi-Public – Semi-Private)
(c) Main Entrance → Entry Hall → Courtyard → Guest Room (Public – Semi-Public – Semi-Private – Semi-Public)
(d) Main Entrance → Gallery → Guest Room (Public – Semi-Public)
(e) Guest Entrance → Guest Room (Public – Semi-Public)

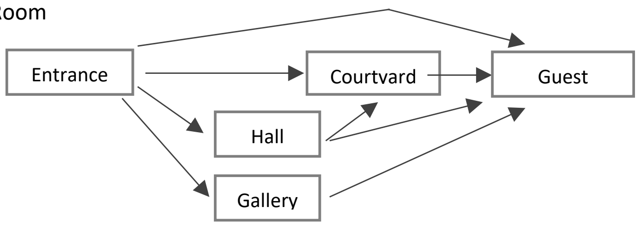
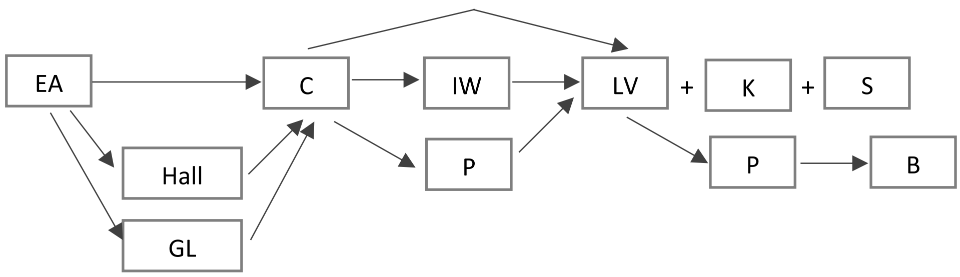


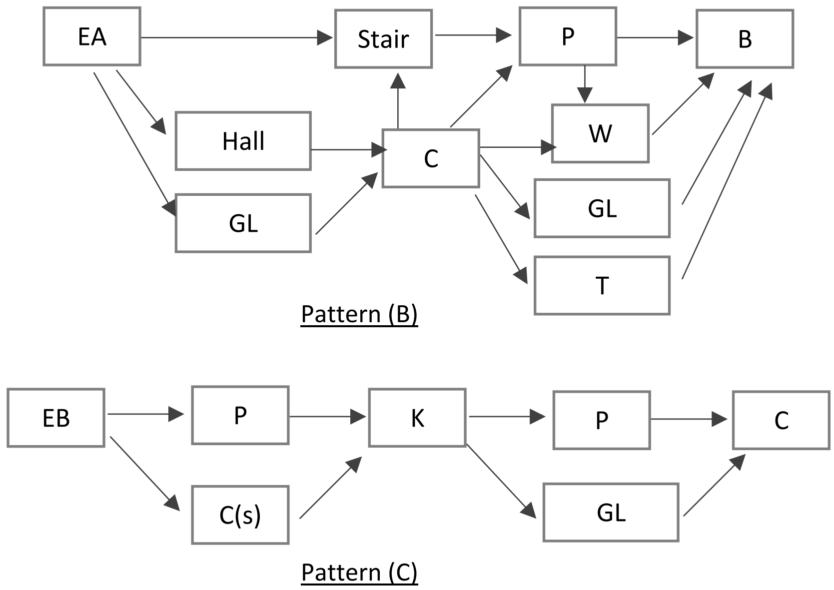
Table 4.40: Hierarchy of spaces and movement patterns for family members in traditional houses

Movement Pattern for Family Members	
(a)	Main Entrance → Courtyard → Iwan → Living Room Public – Semi-Public – Semi-Private – Private
(b)	Main Entrance → Stair → Corridor → Bedrooms Public – Semi-Public – Semi-Private – Intimate
(c)	Main Entrance → Entry Hall → Courtyard → Iwan → Living Rooms, Kitchen, Services Public – Semi-Public – Semi-Private – Private
(d)	Main Entrance → Entry Hall → Courtyard → Stair → Terrace → Gallery → Bedrooms Public – Semi-Public – Semi-Private – Private – Intimate
(e)	Main Entrance → Entry Hall → Courtyard → Corridor → Family Courtyard → Iwan → Bedrooms Public – Semi-Public – Semi-Private – Private – Private – Intimate
(f)	Main Entrance → Entry Hall → Courtyard → Gallery → Bedrooms Public – Semi-Public – Semi-Private – Private – Intimate
(g)	Main Entrance → Entry Hall → Courtyard → Iwan → Bedrooms Public – Semi-Public – Semi-Private – Private – Intimate
(h)	Main Entrance → Entry Hall → Courtyard → Living Rooms Public – Semi-Public – Semi-Private – Private
(i)	Main Entrance → Entry Hall → Courtyard → Living Rooms → Corridor → Bedrooms Public – Semi-Public – Semi-Private – Private – Intimate
(j)	Main Entrance → Gallery → Courtyard → Gallery → Living Rooms, Services Public – Semi-Public – Semi-Private – Private
(k)	Main Entrance → Gallery → Courtyard → Gallery → Stair → Terrace → Gallery → Iwan → Bedrooms Public – Semi-Public – Semi-Private –Semi-Private – Private – Intimate
(l)	Service Entrance → Corridor → Kitchen → Corridor → Courtyard Semi-Public – Semi-Private – Private – Semi-Private – Private
(m)	Service Entrance → Service Courtyard → Kitchen → Courtyard Semi-Public – Semi-Private – Private – Semi-Private
(n)	Service Entrance → Service Courtyard → Kitchen → Gallery → Courtyard Semi-Public – Semi-Private – Private – Semi-Private



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



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[1]

Region	% of Public Spaces	% of Semi-public Spaces	% of Semi-Private Spaces	% of Private Spaces	% of Intimate Spaces
The Middle East (ME)					
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	**2.7 %**	**9.8 %**	**41.6 %**	**28.9 %**	**17 %**
North Africa (NA)					
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	**4.0 %**	**10.2 %**	**26.7 %**	**40.7 %**	**17.1 %**
The Gulf Area (GA)					
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	**3.4 %**	**10.8 %**	**25.7 %**	**45.6 %**	**14.5 %**
AVG (Study Area)	**3.4 %**	**10.3 %**	**31.7 %**	**38.4 %**	**16.2 %**

[1] 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)[2]. 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).

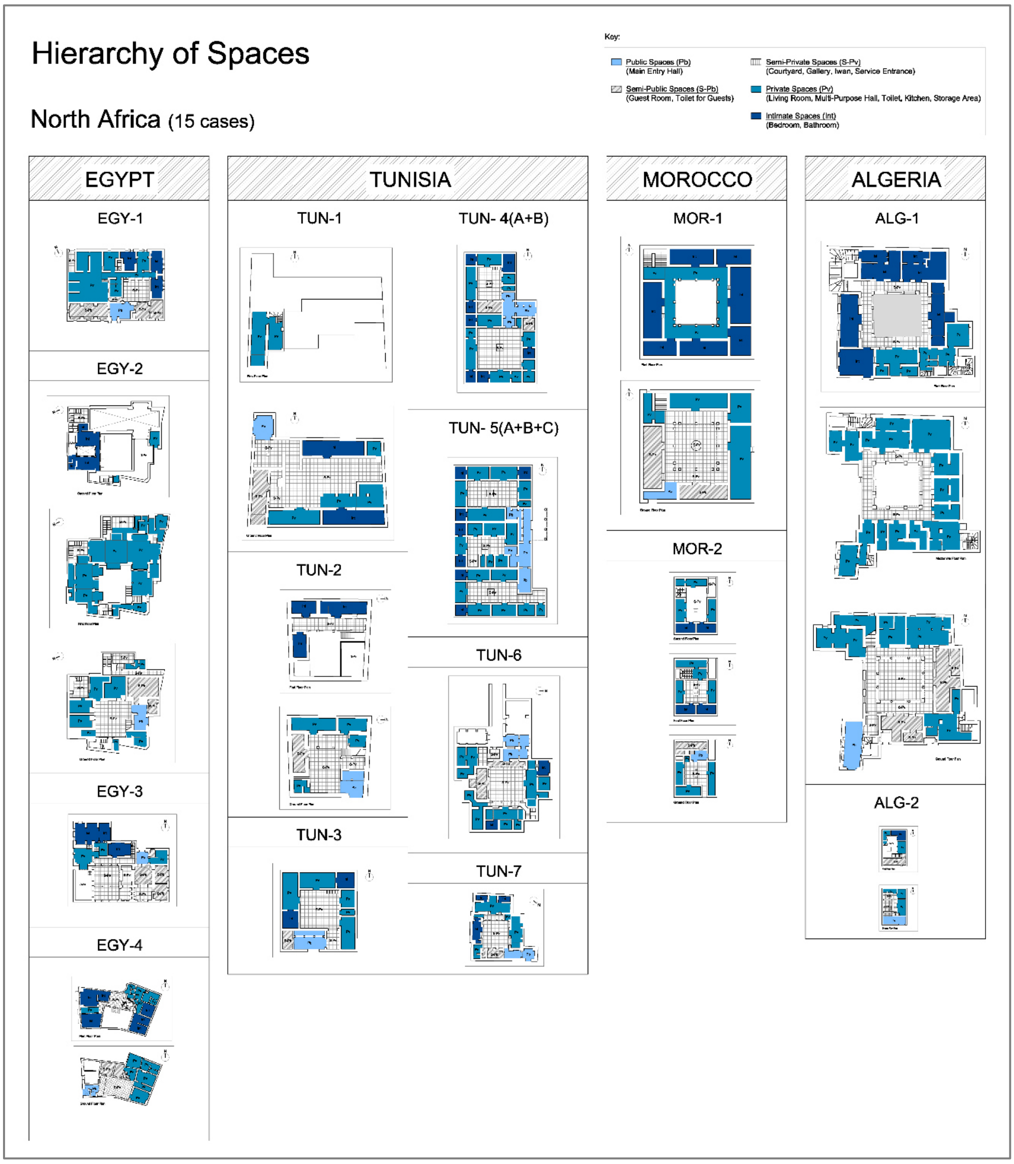


Figure 4.70: Diagrams showing hierarchy of spaces for traditional courtyard houses located in North Africa

[2] 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).

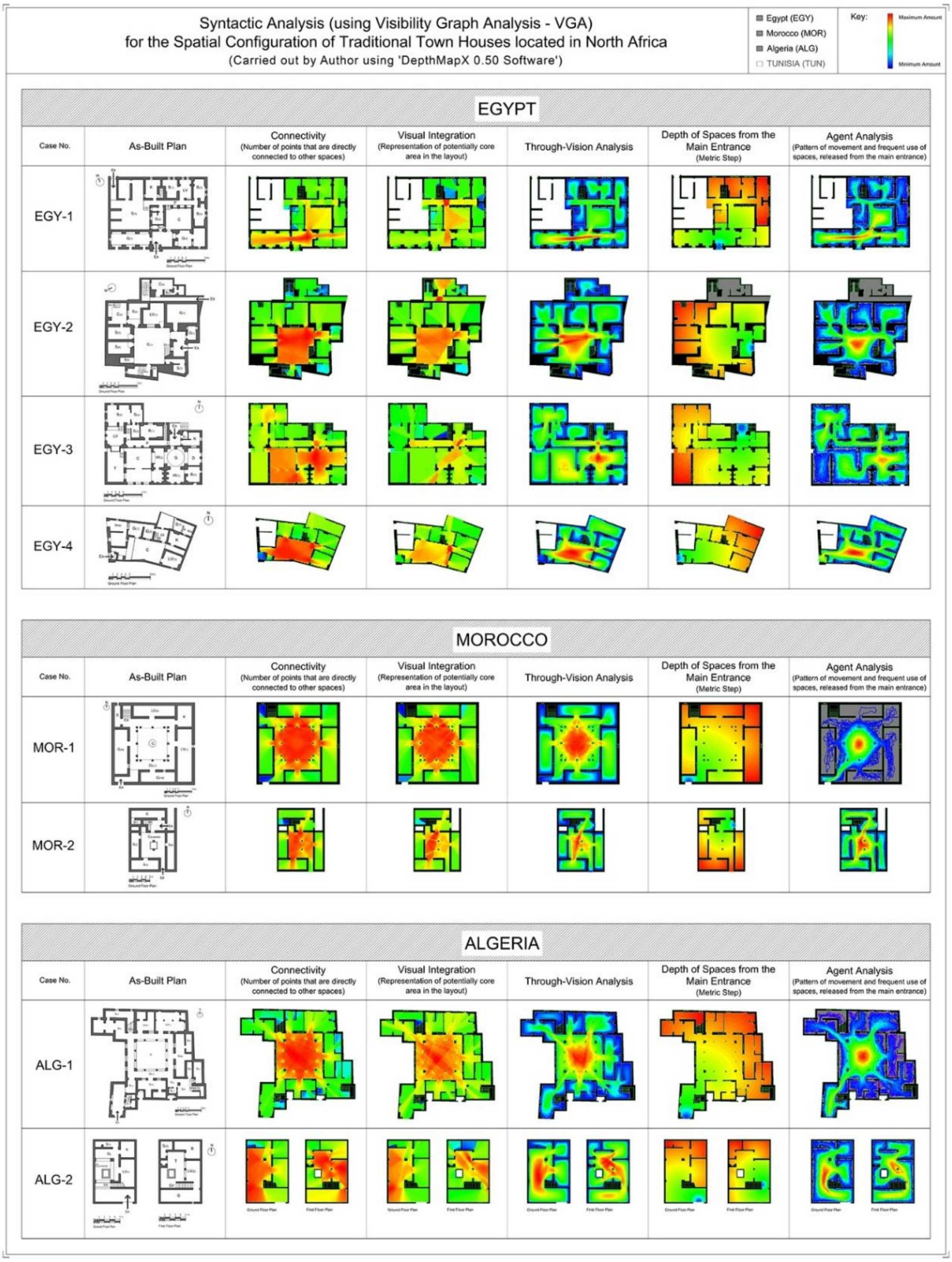


Figure 4.71: 'Visibility graph analysis' for traditional courtyard houses located in North Africa, produced by '*DepthmapX 0.50*' software

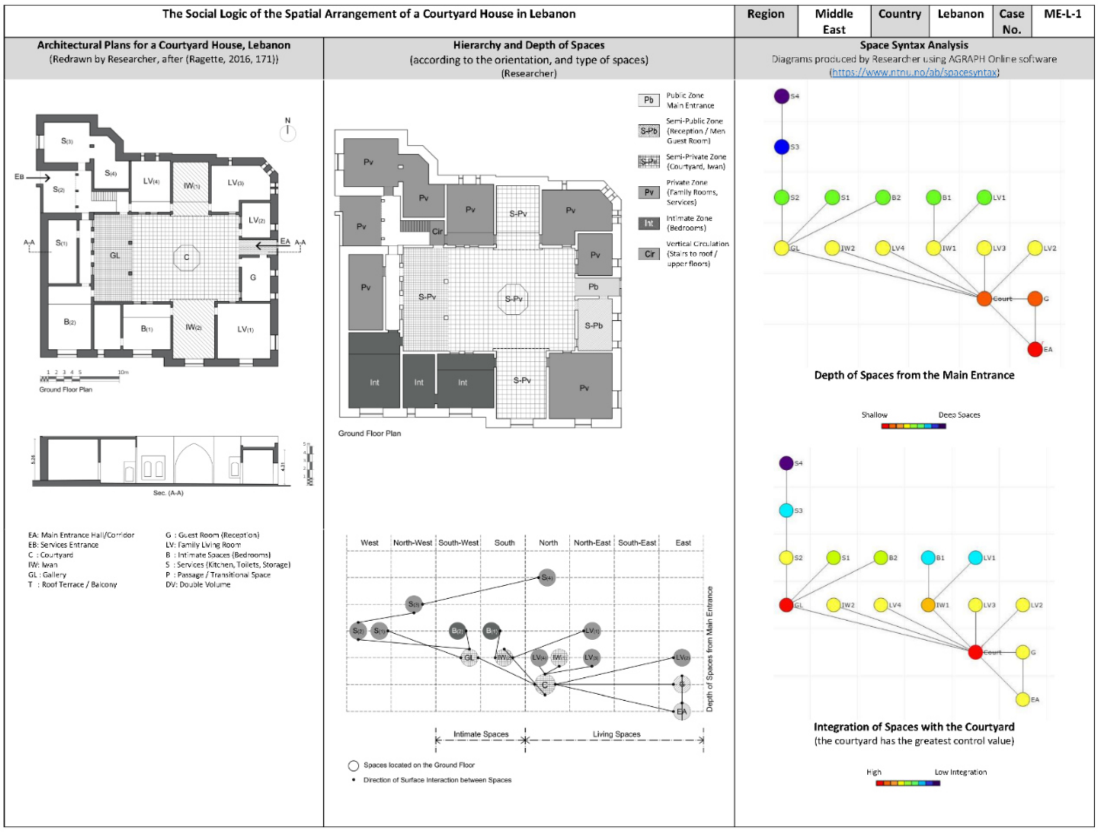


Figure 4.72: Sample of space syntax diagrams for a courtyard house located in Syria

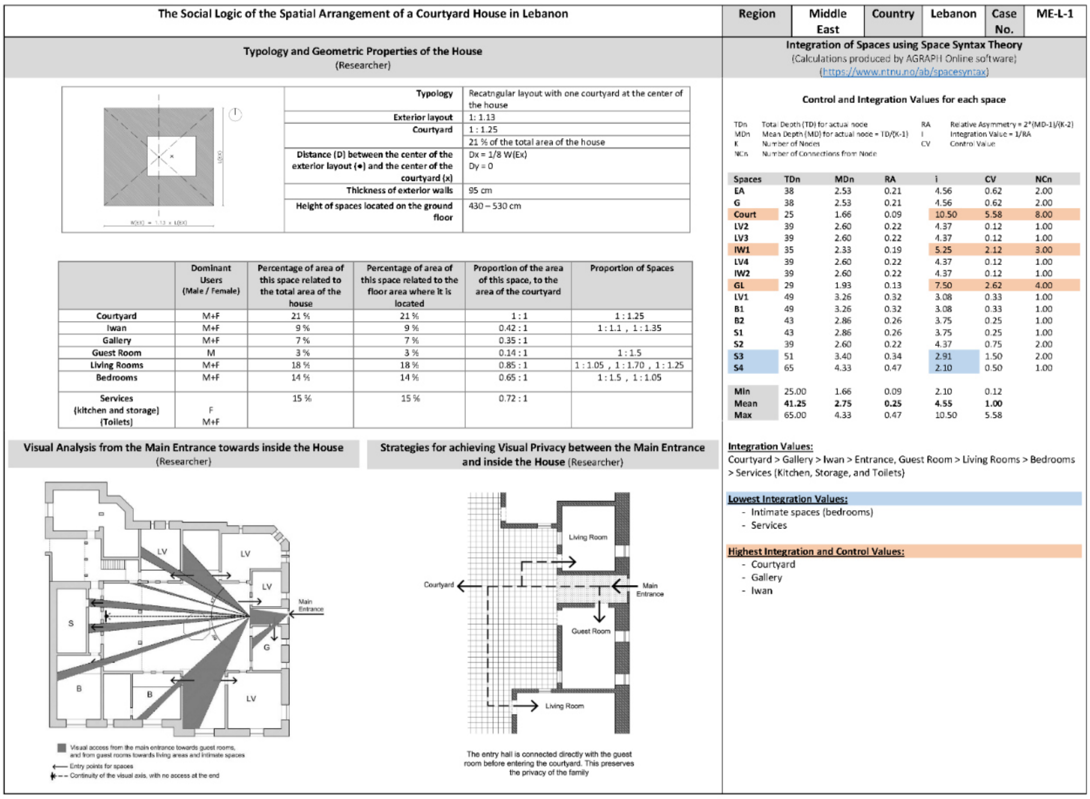


Figure 4.73: Sample of space syntax and geometric calculations for a courtyard house located in Syria

Table 4.42: Spaces that have the highest integration values in traditional houses

Region	Spaces that have the Highest Integration Value (*) (with identifying spaces that are connected with it)
The Middle East (ME)	
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
North Africa (NA)	
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
The Gulf Area (GA)	
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 (*)
The Middle East (ME)	
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
North Africa (NA)	
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
The Gulf Area (GA)	
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 (*)
The Middle East (ME)	
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
North Africa (NA)	
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
The Gulf Area (GA)	
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
The Middle East (ME)					
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	**11.88 %**	**4.94 %**	**18.22 %**	**15.8** %	**7.32 %**
North Africa (NA)					
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	**12.25 %**	**9.30 %**	**15.98 %**	**11.2 %**	**8.03 %**
The Gulf Area (GA)					
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	**11.00 %**	**-**	**13.82 %**	**16.0 %**	**7.40 %**
AVG (Study Area)	**11.71 %**	**7.12 %**	**16.00 %**	**14.33 %**	**7.58 %**
	Total Area of Social Spaces = 49.16 %				

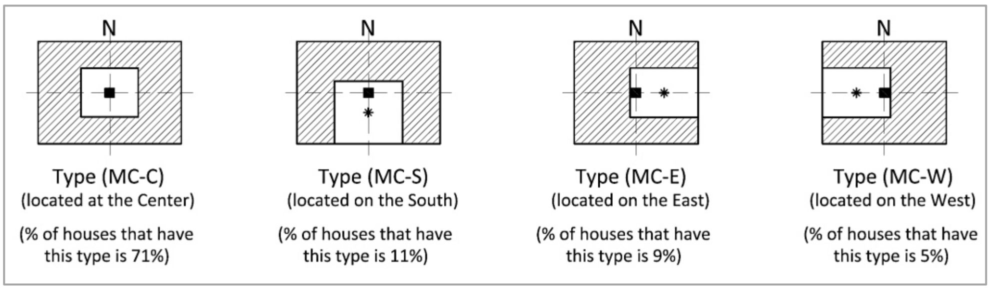


Figure 4.74: Diagrams showing location of the courtyard in vernacular houses

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).

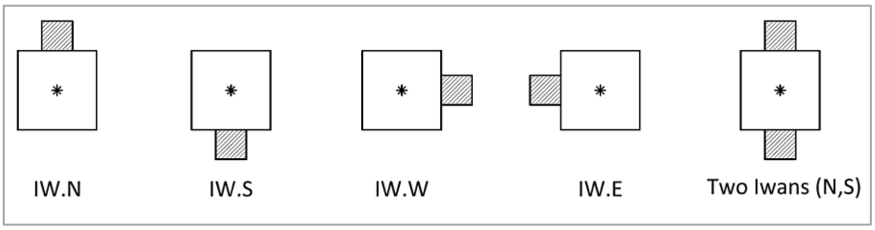


Figure 4.75: Diagrams showing location of *iwan* in vernacular houses

- **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		*Iwan*		Living Room		Guest Room	
	Proportion	Orientation	Proportion	Orientation	Proportion	Orientation	Proportion	Orientation
The Middle East (ME)								
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, 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, NW, W	1 : 2.35	S, W, SW, NE	1 : 1.92	S, E, SE
AVG	**1 : 1.23**		**1 : 1.40**		**1 : 1.79**		**1 : 2.09**	
North Africa (NA)								
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, 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	**1 : 1.27**		**1 : 1.16**		**1 : 2.20**		**1 : 3.40**	
The Gulf Area (GA)								
KSA	1 : 1.22	CEN., N, E, 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	**1 : 1.21**				**1 : 1.64**		**1 : 2.62**	
AVG (Study Area)	**1 : 1.24**		**1 : 1.28**		**1 : 1.88**		**1 : 2.70**	

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)
The Middle East (ME)						
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	**18.22 %**	**1 : 1.23**		**1.5 %**	**1 : 1.05**	
North Africa (NA)						
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	**15.98 %**	**1 : 1.27**		**1.8 %**	**1 : 1.17**	
The Gulf Area (GA)						
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	**13.82 %**	**1 : 1.21**		**7.5 %**	**1 : 1.77**	
AVG (Study Area)	**16 %**	**1 : 1.24**		**3.6 %**	**1 : 1.33**	

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
The Middle East (ME)			
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	**17.7 %**	**17.68 %**	**64.62 %**
North Africa (NA)			
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	**12.35 %**	**16.08 %**	**71.85 %**
The Gulf Area (GA)			
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	**13.62 %**	**12.5 %**	**78.88 %**
AVG (Study Area)	**14.56 %**	**13.66 %**	**71.78 %**

Table 4.49: Height of ceiling

Region	Height of Ceiling (cm)
The Middle East	433
North Africa	412
The Gulf Area	423
AVG (Study Area)	**423**

- **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
The Middle East (ME)						
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	**2.2 %**		**1.5 %**		**6.3 %**	
North Africa (NA)						
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	**5.3 %**		**1.7 %**		**9.1 %**	
The Gulf Area (GA)						
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	**2.8 %**		**2.1 %**		**15.2 %**	
AVG (Study Area)	**3.43 %**		**1.77 %**		**10.2 %**	

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

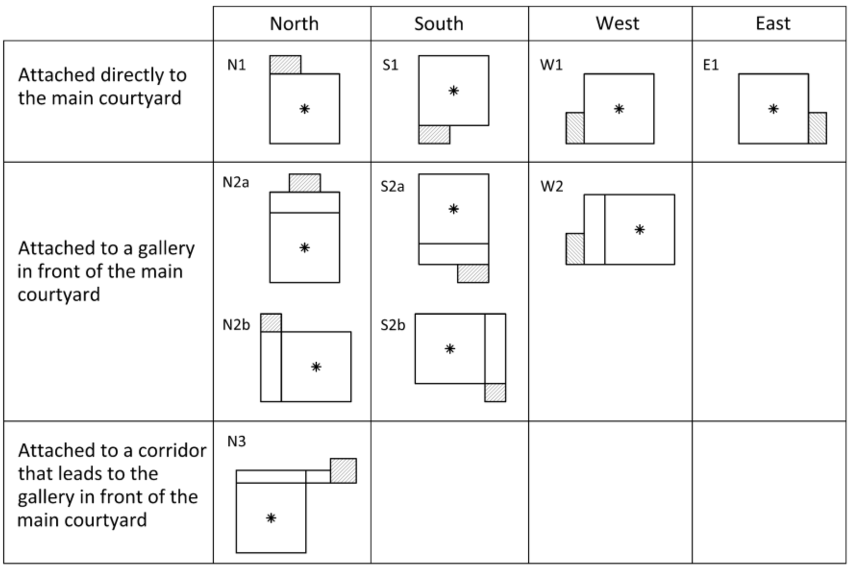


Figure 4.76: Diagrams showing location of the main entry hall in vernacular houses

Table 4.51: Arrangement of functions in vertical houses

Region	Functions located on the Ground Floor	Functions located on Upper Floors
The Middle East (ME)		
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
North Africa (NA)		
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
The Gulf Area (GA)		
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.

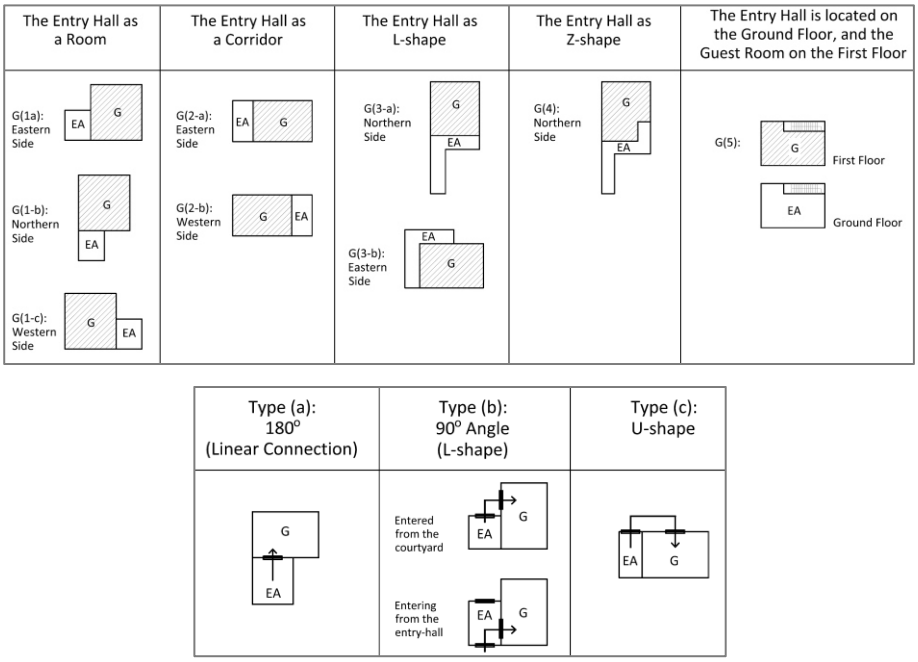


Figure 4.77: Diagrams showing movement patterns and location of guest rooms in relation to the main entry hall in vernacular houses

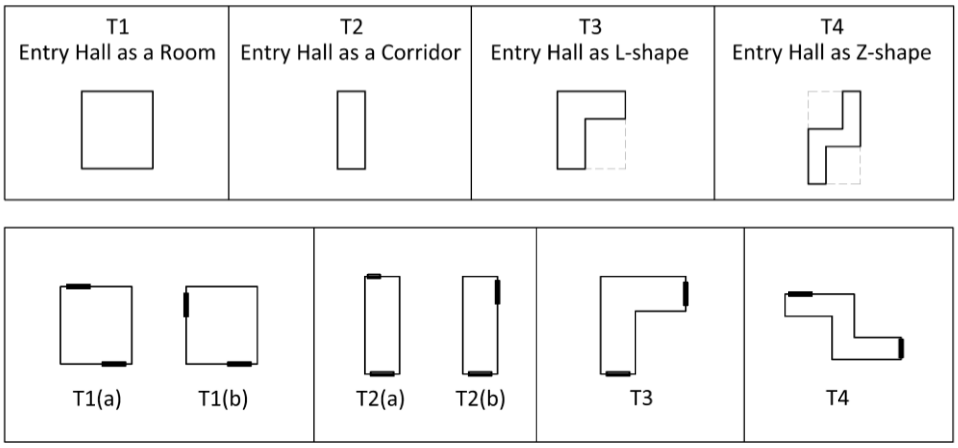


Figure 4.78: Diagrams showing location of openings for the main entry hall in vernacular houses

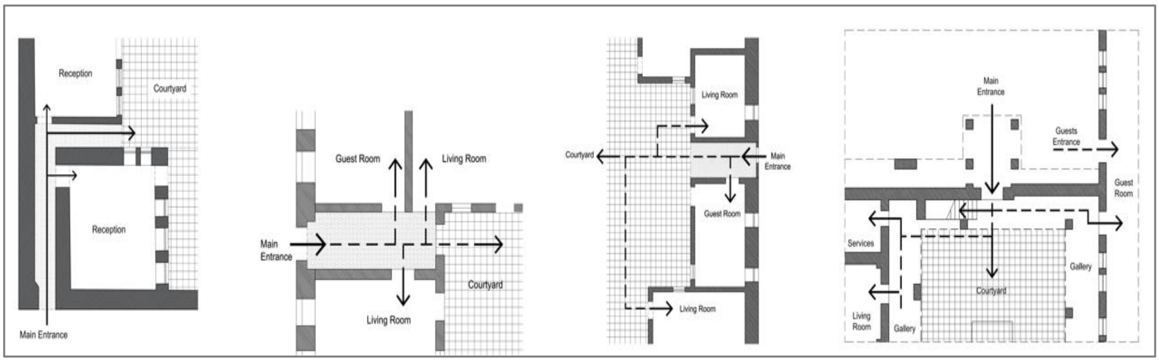


Figure 4.79: Diagrams showing the direct access from the main entry hall to guest room in vernacular houses

Figure 4.80: Diagrams showing the movement access from *iwan* to bedrooms and living rooms

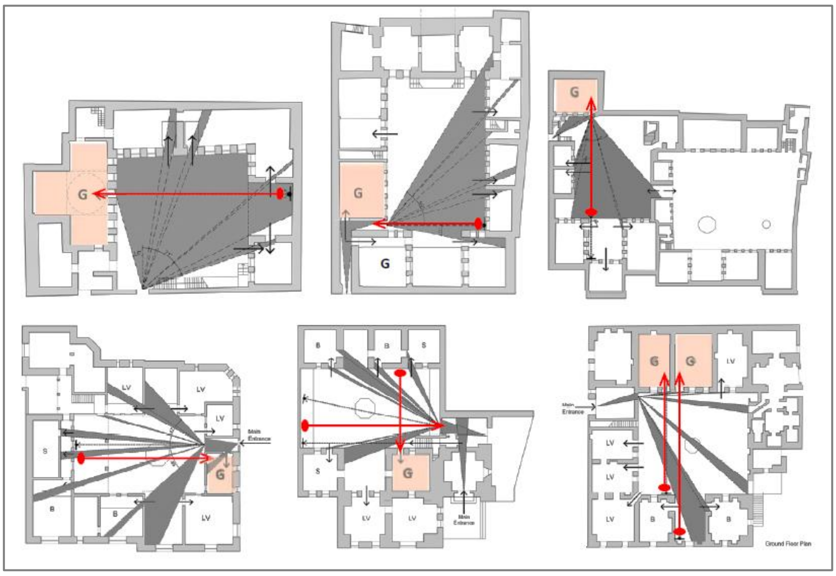


Figure 4.81: Visual fields from doors of guest rooms toward private spaces

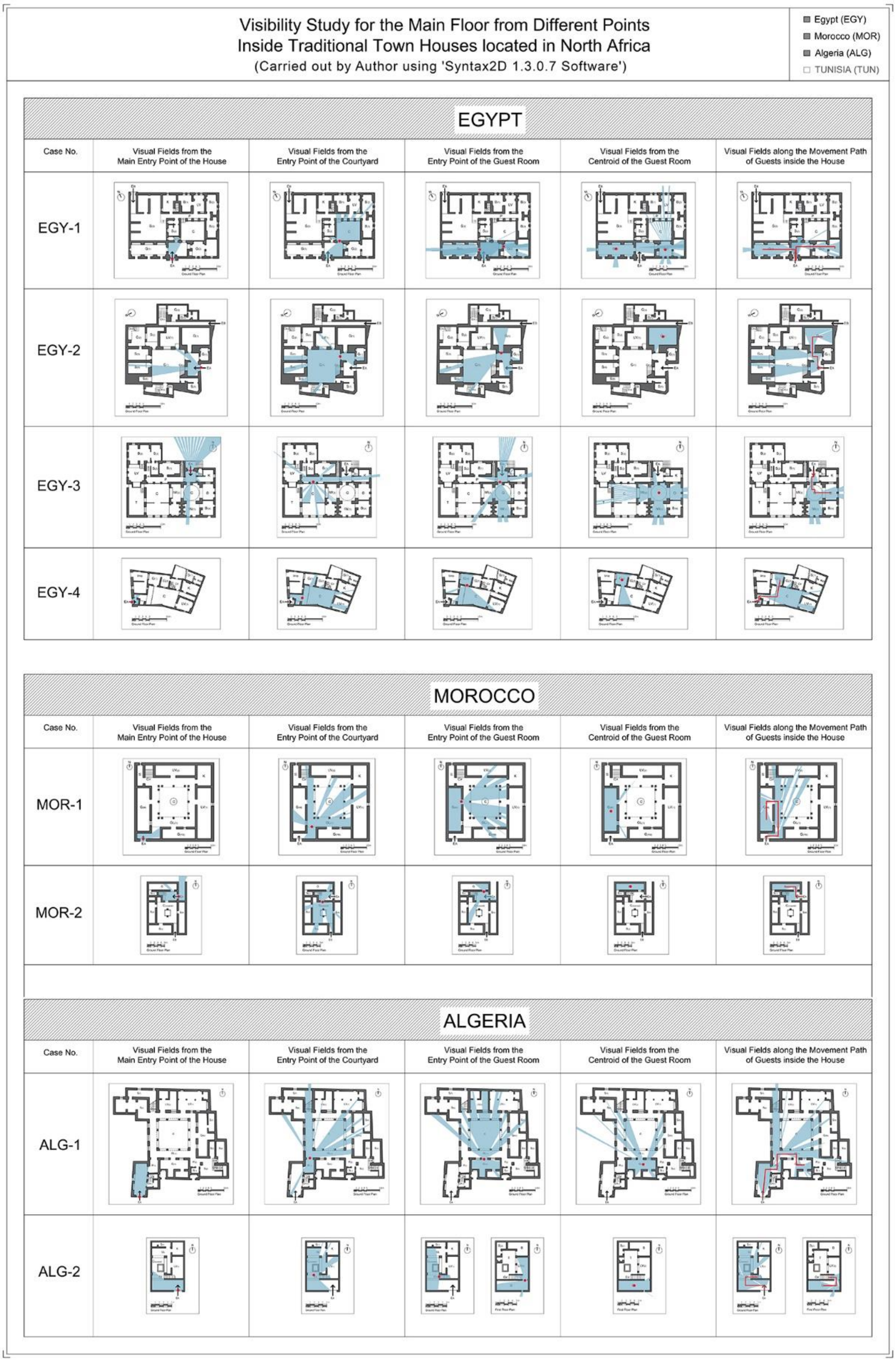


Figure 4.82: *Isovist* analysis for traditional courtyard houses located in North Africa, produced by '*Syntax2D 1.3.0.7*' software

- **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

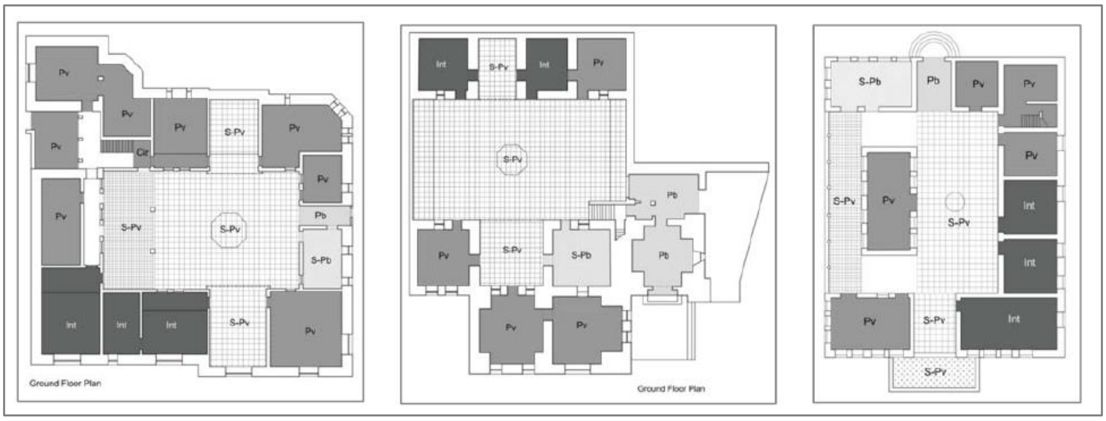


Figure 4.84: Horizontal separation between living rooms and bedrooms through courtyards in single-floor houses

Table 4.52: Thickness of exterior walls and shared surfaces between adjacent houses

Region	Thickness of Exterior Walls (cm)
The Middle East (ME)	
Syria	82
Lebanon	83
Jordan	50
Palestine	76
Iraq	70
AVG	**72**
North Africa (NA)	
Egypt	60
Tunisia	66
Morocco	75
Algeria	55
AVG	**64**
The Gulf Area (GA)	
KSA	48
UAE	65
Oman	40
Kuwait	37
Yemen	75
AVG	**53**
AVG (Study Area)	**63**

- **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
The Middle East (ME)			
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
North Africa (NA)			
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
The Gulf Area (GA)			
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
The Middle East (ME)	
Syria	27.5 %
Lebanon	21.0 %
Jordan	14.3 %
Palestine	15.5 %
Iraq	10.3 %
AVG	**17.7 %**
North Africa (NA)	
Egypt	11.4 %
Tunisia	22.8 %
Morocco	7.9 %
Algeria	7.3 %
AVG	**12.35 %**
The Gulf Area (GA)	
KSA	10.5 %
UAE	13.6 %
Oman	20.3 %
Kuwait	19.0 %
Yemen	4.7 %
AVG	**13.62 %**
AVG (Study Area)	**14.56 %**

- **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 → EA C → P → EA C → GL → EA C → Cir → P → EA C → P → S → EB C → S → EB	→ Outside Context
Terraces	T → IW → GL → Cir → GL → EA T → GL → Cir → EA T → LV → Cir → C → EA T → P → Cir → C → P → EA T → Cir → C → EA	→ Outside Context
Iwan	IW → C, GL, T IW → LV, S IW → B	
Gallery	GL → EA GL → C, IW, Cir, P GL → LV, S GL → 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

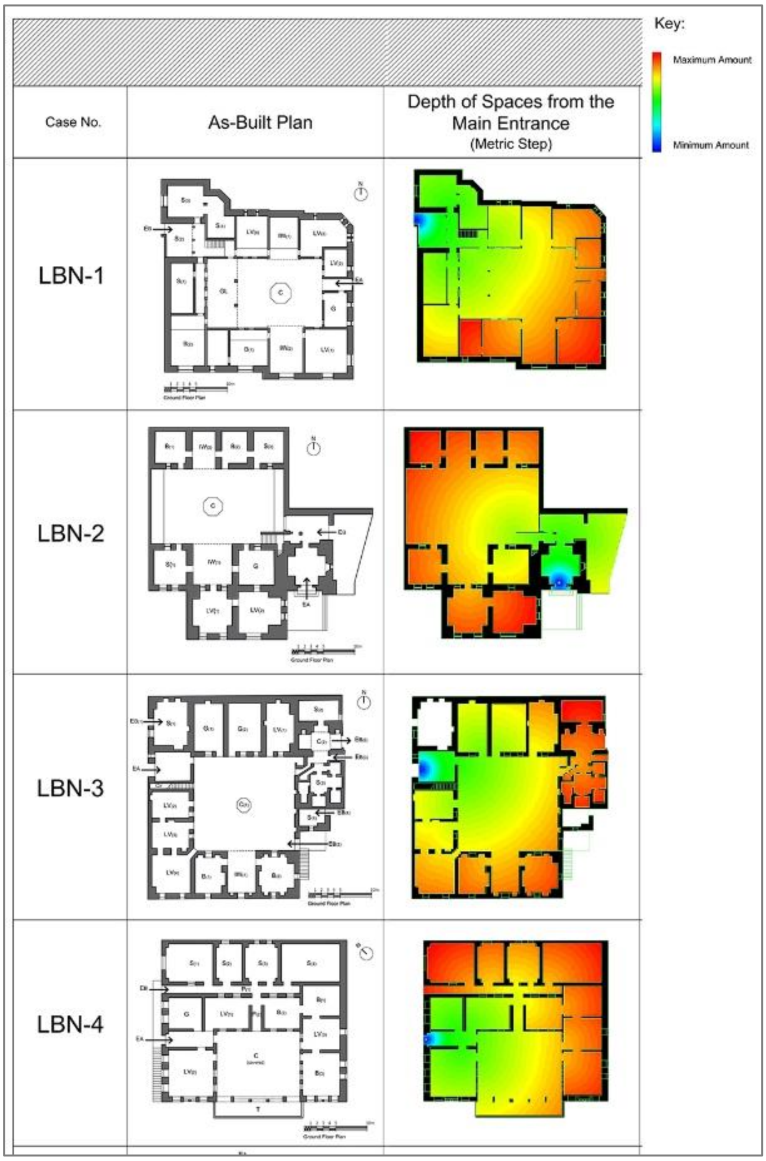


Figure 4.85: Depth of spaces in four traditional courtyard houses located in Lebanon, produced by '*DepthmapX 0.50*' software

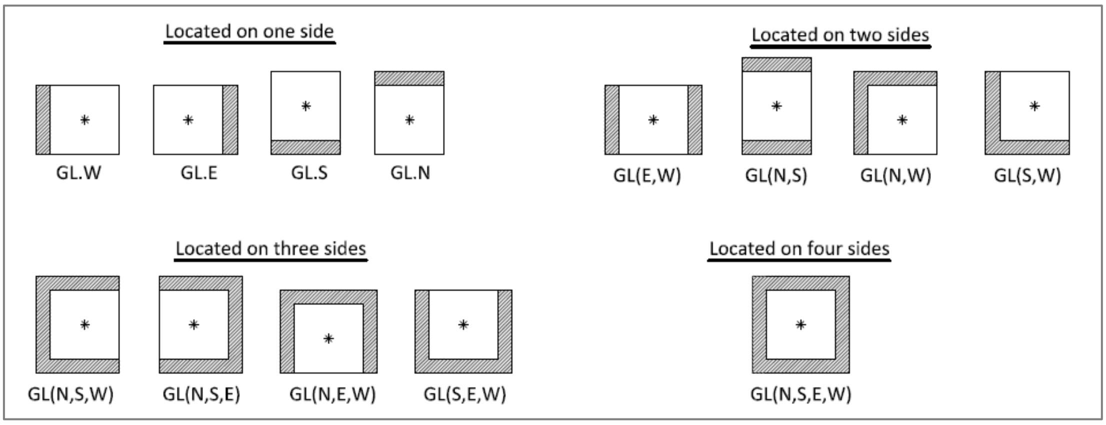


Figure 4.86: Diagrams showing location of galleries (semi-open spaces) in relation to the courtyard

- **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).

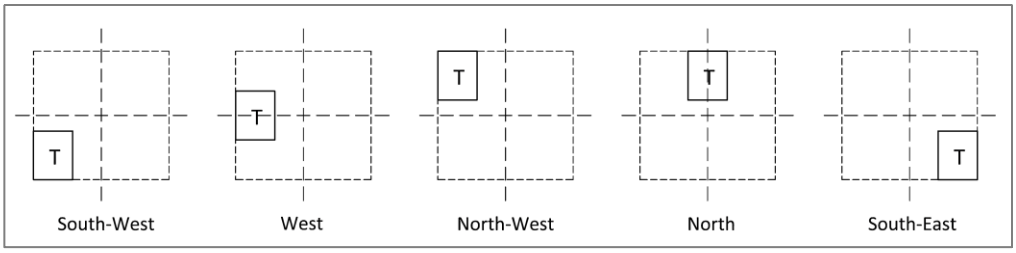


Figure 4.87: Location of terraces in relation to the layout of the ground floor

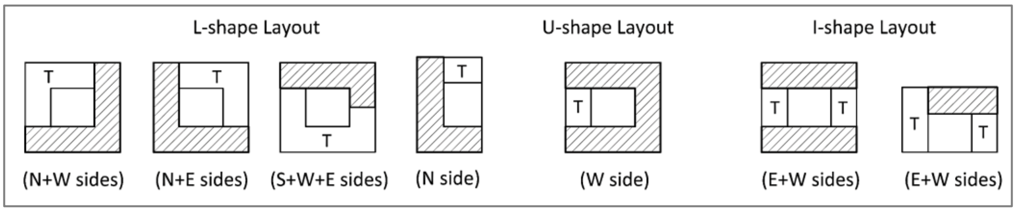


Figure 4.88: Location of terraces in relation to the layout of upper floors

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	*Iwan*	Gallery
The Middle East (ME)				
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	**17.7 %**	**15.8** %	**4.9** %	**12.7** %
North Africa (NA)				
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	**12.35 %**	**11.2 %**	**9.3 %**	**15.2 %**
The Gulf Area (GA)				
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	**13.62 %**	**16.0 %**	**-**	**12.5 %**
AVG (Study Area)	**14.56 %**	**14.33 %**	**7.10 %**	**13.47 %**

- **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
The Middle East (ME)	
Syria	7.5 %
Lebanon	15.5 %
Jordan	7.5 %
Palestine	10.0 %
Iraq	12.8 %
AVG	**10.7 %**
North Africa (NA)	
Egypt	16.4 %
Tunisia	15.2 %
Morocco	22.8 %
Algeria	26.4 %
AVG	**20.2 %**
The Gulf Area (GA)	
KSA	15.3 %
UAE	19.9 %
Oman	8.9 %
Kuwait	9.2 %
Yemen	30.1 %
AVG	**16.7 %**
AVG (Study Area)	**15.87 %**

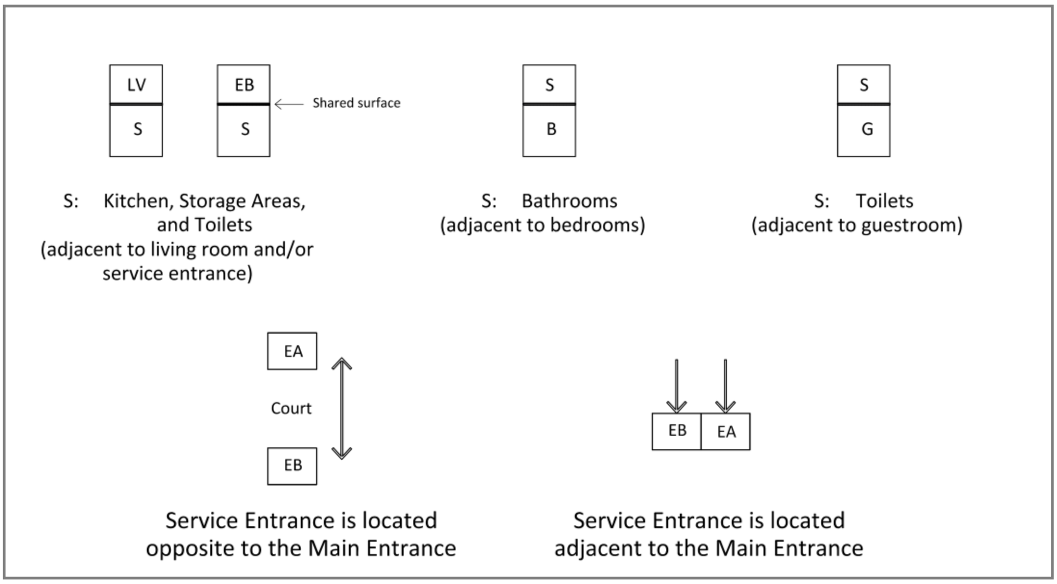


Figure 4.89: Location of services and service entrance in relation to other spaces

- **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).

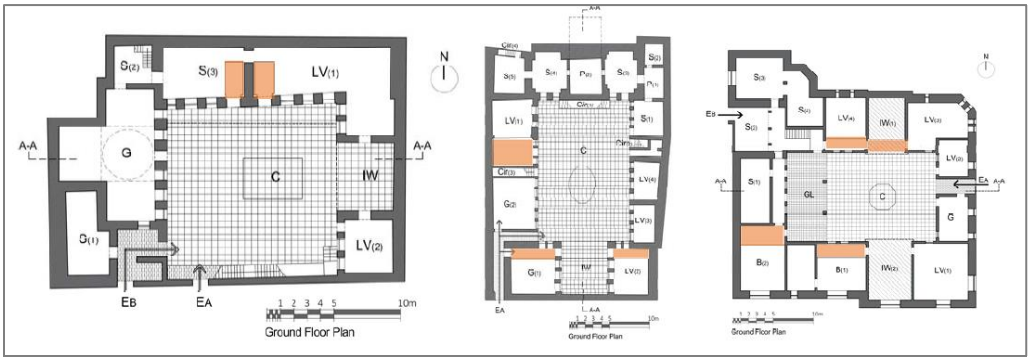


Figure 4.90: Sunken area separating living zones and services from the outside

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); Morroco (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^2)	Open Spaces		Public Spaces		Total Area of Houses (m^2)	Total Area of Covered Spaces (m^2)	Private Courtyards	
		Total Area (m^2)	%	Total Area (m^2)	% (relative to the Total Area of the Cluster)			Total Area (m^2)	% (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

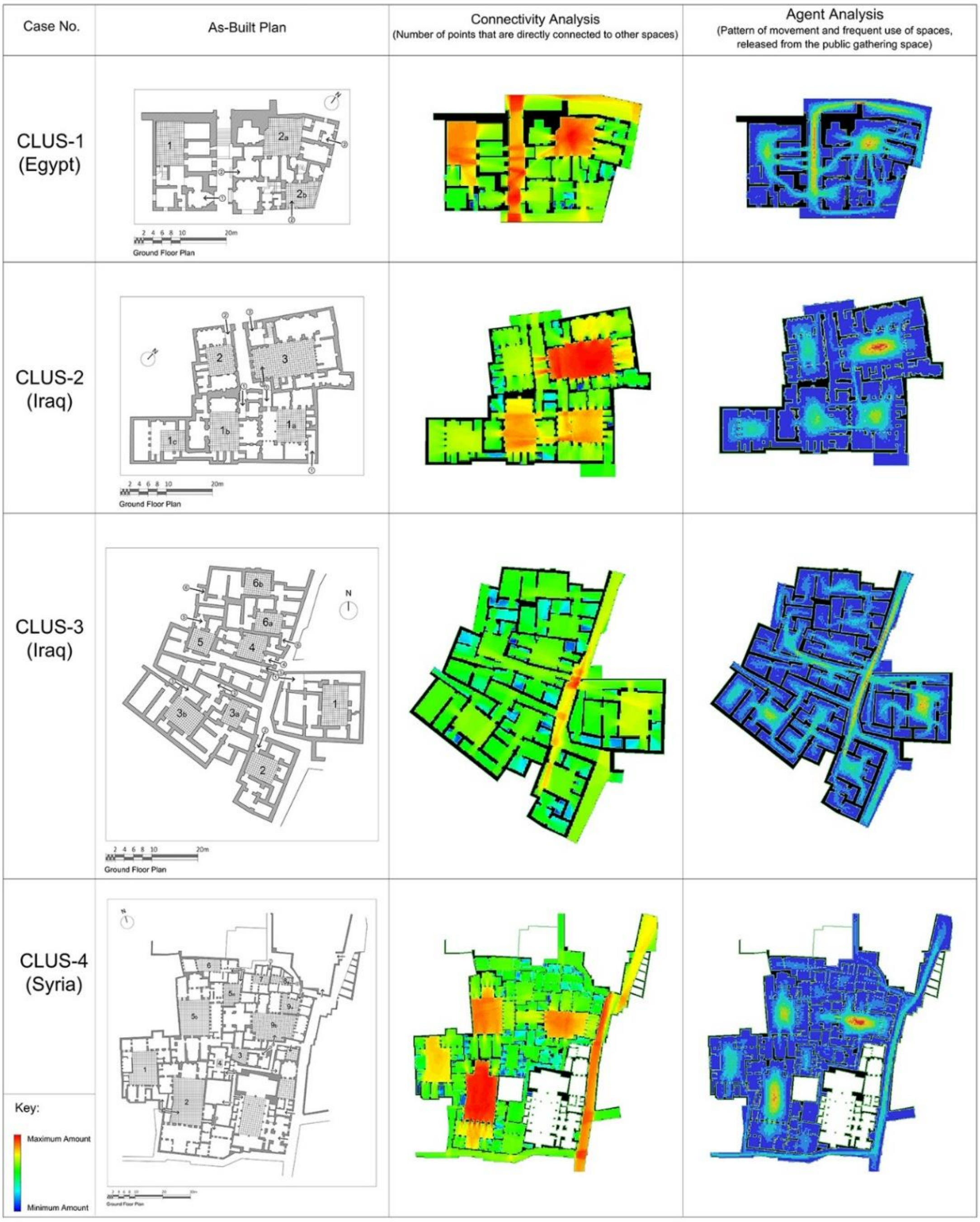


Figure 4.94: Connectivity and agent analyses for traditional neighbourhoods located in MENA region, produced by '*DepthmapX 0.50*' software

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.

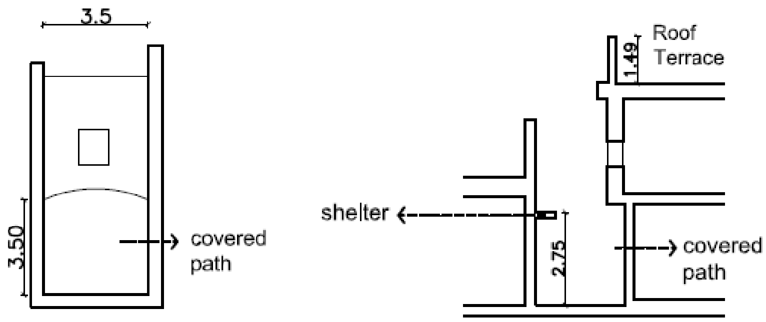


Figure 4.95: Sections showing the use of covered pathways and shelters in open spaces

- **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 towads 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

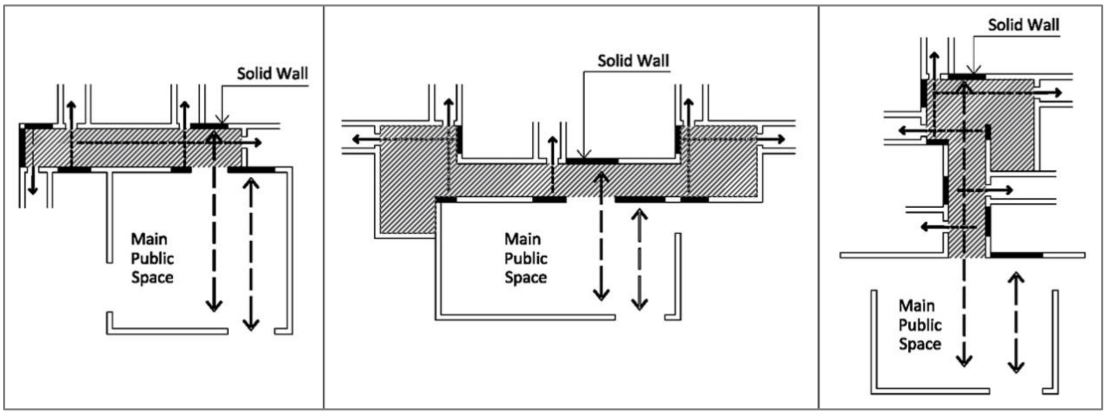


Figure 4.97: Strategies for achieving visual privacy in traditional neighbourhoods

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

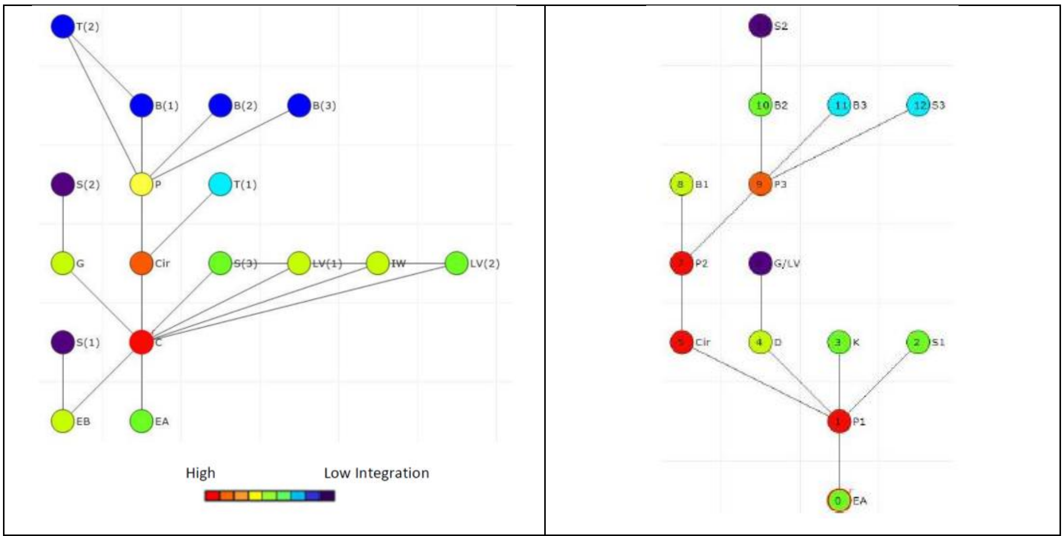
The other four social indicators; (8) Olfactory Privacy, (9) Spirituality, (11) Views to the Exterior, and (12) Availability of Services, have not been addressed in the spatial analysis of neighbourhoods, due to the lack of information about the context and the surrounding. Yet, advantages and impacts 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/neighbourhhods 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).



A Traditional Courtyard House	A Contemporary Apartment

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	**Vertical Circulation** > Entrance, Living Area > Corridors > **Guest Room** > Kitchen > Dining Room > **Bedrooms** > Terraces > **Services (Toilets)**	**Courtyard** > Vertical Circulation > Entrance, **Guest Room** > Living Rooms, *Iwan* > **Bedrooms** > **Services (Kitchen, Storage, and Toilets)**
AP-2 (a)	**Entrance, Corridors** > **Guest Room** > Kitchen > **Bedrooms** > Dining Room > Services (Toilets) > **Terrace**	**Courtyard** > Vertical Circulation, Service > Entrance > Living Rooms, *Iwan* > , **Guest Room** > **Bedrooms** > Services (Kitchen, Storage, and Toilets) > **Terraces**
AP-2 (b)	**Vertical Circulation** > Corridors > Dining Room > **Bedroom** (1) > Entrance > Kitchen > **Bedrooms** (2, 3) > **Guest Room** > **Services (Toilets)**	**Courtyard** > Main Entrance and Service Entrance > Gallery and *Iwan* > Living Rooms > **Guest Room** > **Bedrooms** > Services (Kitchen, Storage, and Toilets) > **Terraces**
AP-3	**Corridors** > Dining Room > Services, Kitchen > **Bedroom** (1) > **Guest Room**, **Bedrooms** (2, 3) > Entrance > Services (Toilets) > **Terrace**	**Corridor** > Courtyard > Living Room > Entrance > **Bedrooms** > Services (Kitchen, Storage, and Toilets) > **Guest Room**
AP-4	**Corridors** > Dining Room > Entrance > Services, Kitchen, **Bedrooms** > **Guest Room, Terrace**	**Gallery** > Vertical Circulation > Courtyard > Living Rooms, *Iwan* > **Guest Room** > **Bedrooms**, Terraces > **Services (Kitchen, Storage, and Toilets)**

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.

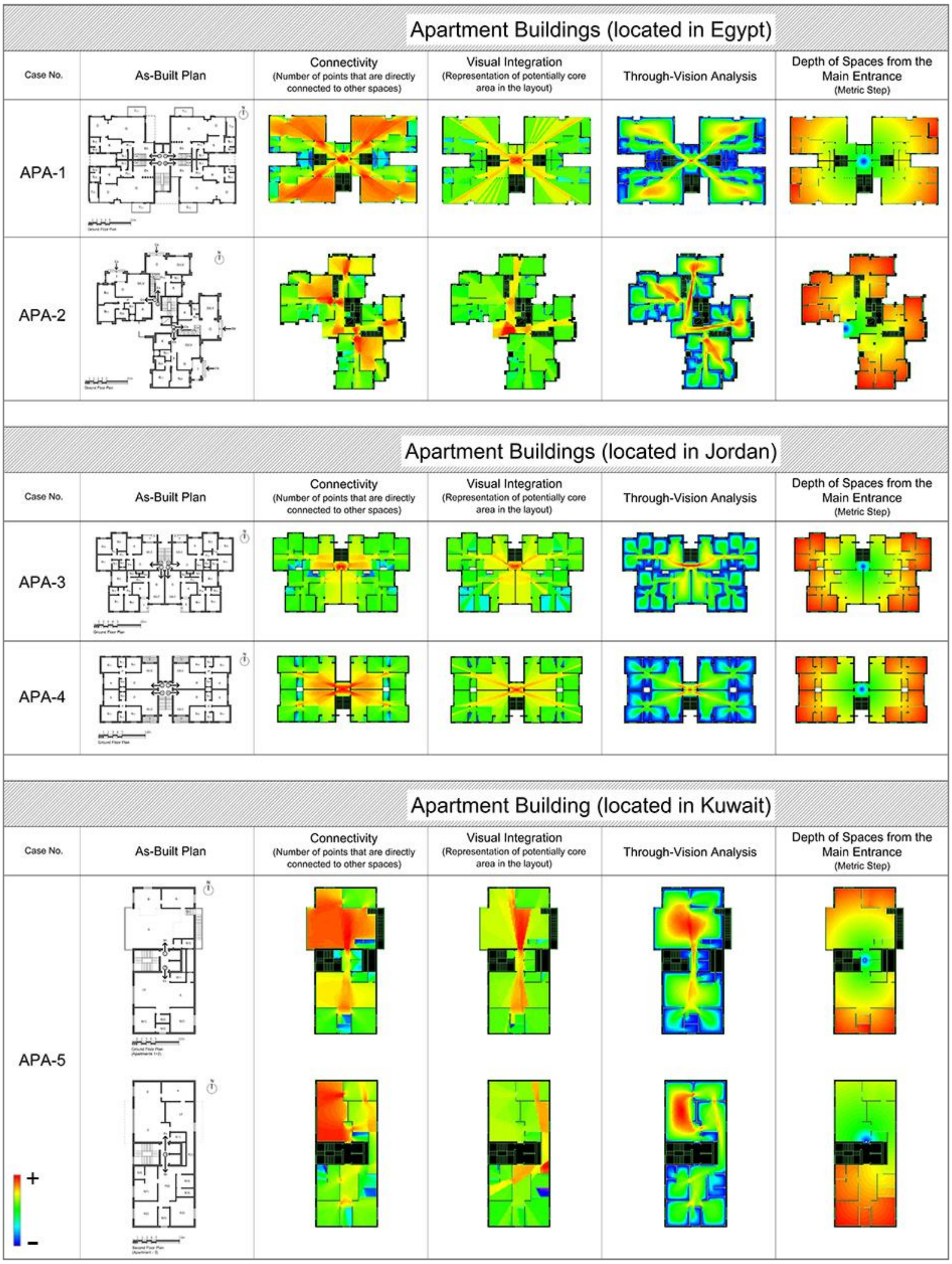


Figure 4.102: Connectivity and visual integration analyses for contemporary apartment buildings located in MENA region, produced by '*DepthmapX 0.50*' software

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	*Iwans* (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 %
AVG (Contemporary Apartments)		**19 %**	**3 %**	**0 %**	**0 %**	**22 %**
AVG (Traditional Houses)		**13 %**	**8 %**	**25 %**	**5 %**	**51 %**

- *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.

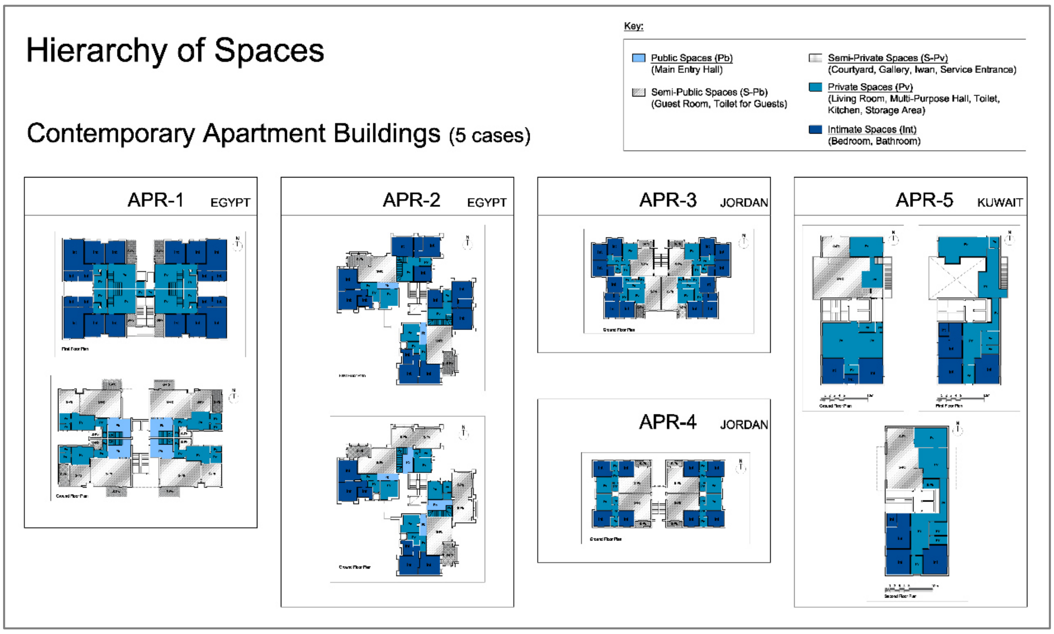


Figure 4.103: Hierarchy of spaces in contemporary apartment buildings

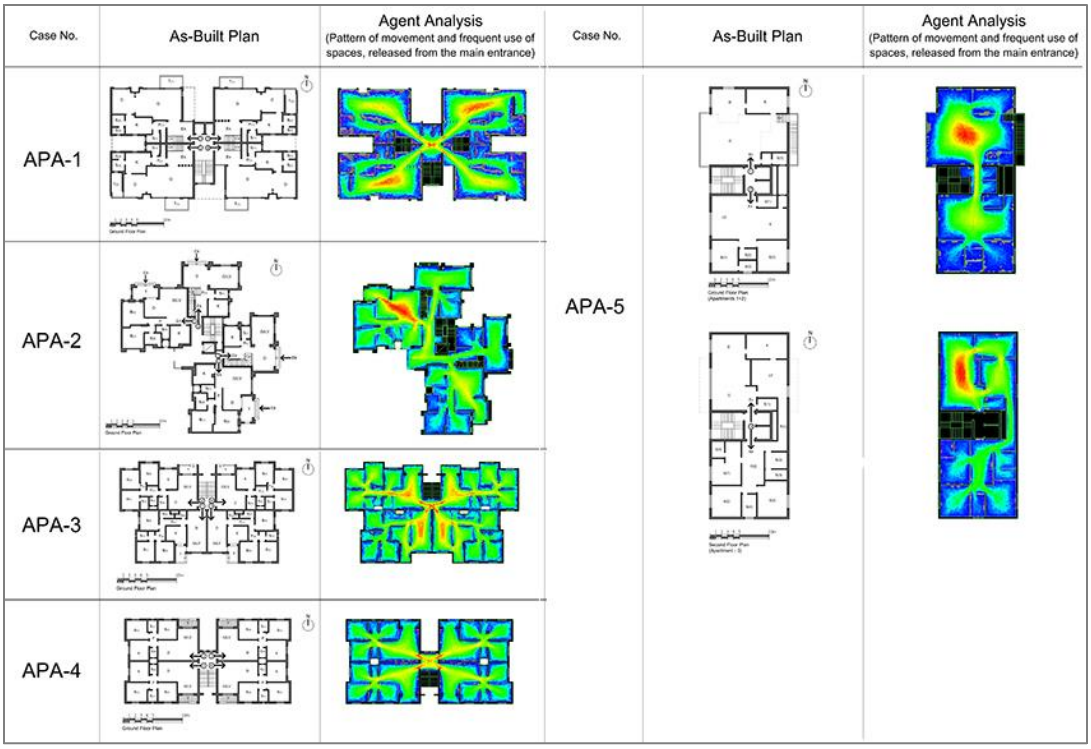


Figure 4.104: Agent analysis and patterns of movement in contemporary apartment buildings

Table 4.63: Movement patterns for guests and family members in contemporary houses

Contemporary Apartment Buildings	
AP-1	Movement Pattern for Guests: (a) Entrance → Entry Hall → Guest room → Dining Room → Terrace **Public – Semi-Public** Movement Pattern for Family Members: (b) Entrance → Entry Hall → Corridor → Kitchen → Service **Public – Semi-Public – ~~Semi-Private~~ – Private** (c) Entrance → Entry Hall → Stair → Living Room → Corridor → Bedrooms **Public – Semi-Public – Semi-Private – Private – Intimate**
AP-2 (a)	Movement Pattern for Guests: (a) Entrance → Entry Hall → Guest Room → Dining Room → Terrace **Public – Semi-Public** Movement Pattern for Family Members: (b) Entrance → Entry Hall → Kitchen **Public – Semi-Public – ~~Semi-Private~~ – Private** (c) Entrance → Entry Hall → Corridor → Bedrooms **Public – Semi-Public – ~~Semi-Private~~ – ~~Private~~ – Intimate**
AP-2 (b)	Movement Pattern for Guests: (a) Entrance → Entry Hall → Corridor → Dining Room → Guest Room **Public – Semi-Public** Movement Pattern for Family Members: (b) Entrance → Entry Hall → Corridor → Services and Kitchen **Public – Semi-Public – ~~Semi-Private~~ – Private** (c) Entrance → Entry Hall → Stair → Corridor → Bedrooms **Public – Semi-Public – Semi-Private – Private – Intimate**
AP-3	Movement Pattern for Guests: (a) Entrance → Dining Room → Guest Room → Terrace **Public – Semi-Public** Movement Pattern for Family Members: (b) Entrance → Dining Room → Kitchen and Services → Corridor → Bedrooms **Public – Semi-Public – ~~Semi-Private~~ – Private – Intimate**
AP-4	Movement Pattern for Guests: (a) Entrance → Guest Room → Terrace **Public – Semi-Public** Movement Pattern for Family Members: (b) Entrance → Dining Room → Corridor → Bedrooms **Public – Semi-Public – ~~Semi-Private~~ – Private – Intimate**

- *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.

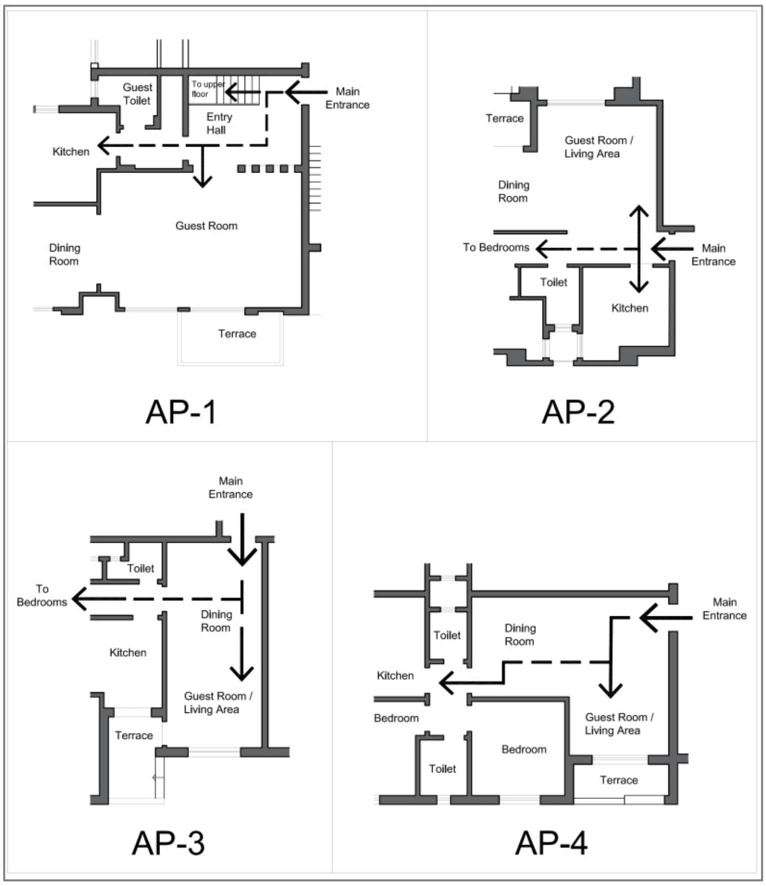


Figure 4.105: Visual connections between public, semi-public, and private spaces in contemporary apartments

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).

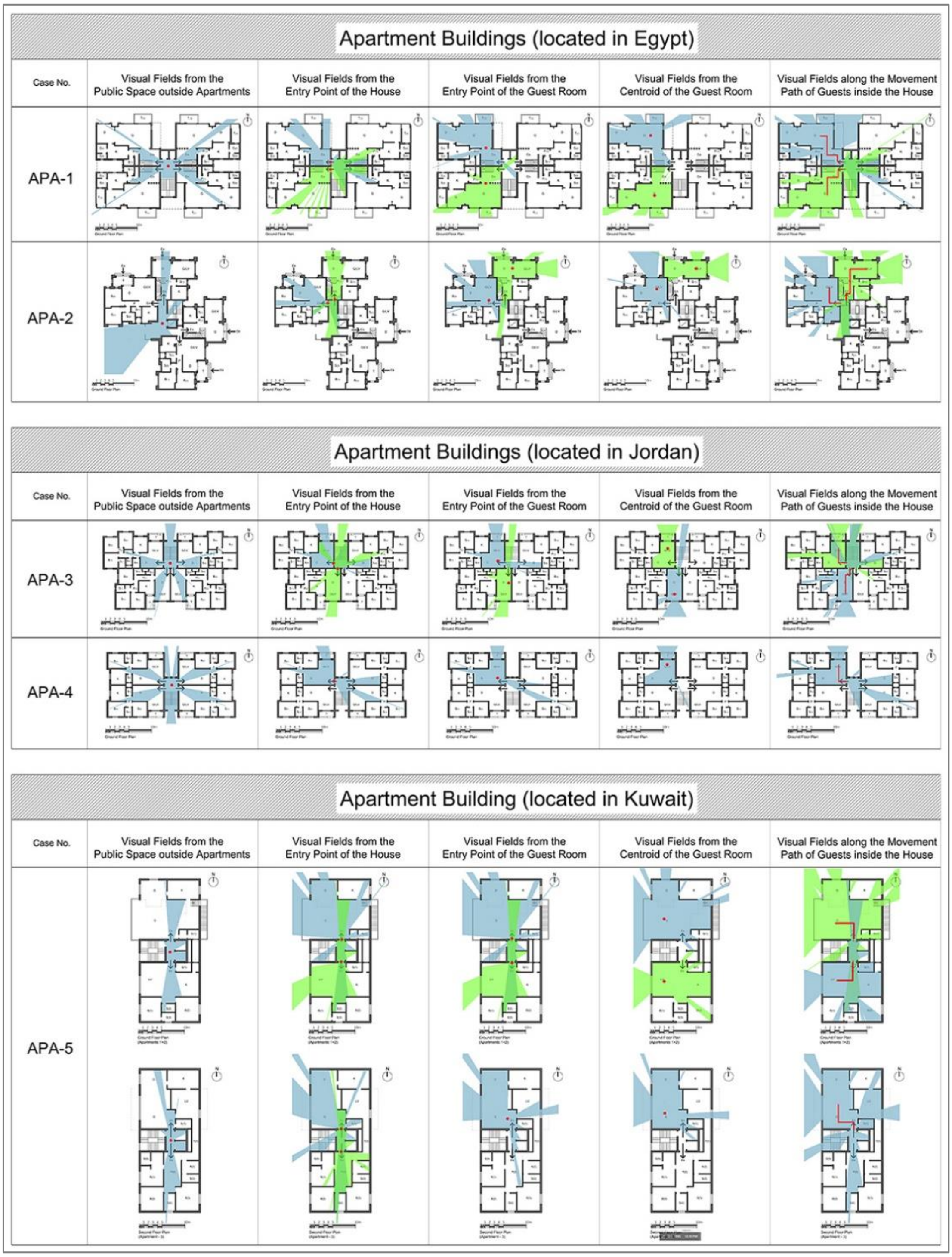


Figure 4.106: *Isovist* analysis for contemporary apartments, produced by '*Syntax2D 1.3.0.7*' software

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 comutational design tool that integrates the design breif, preferences of residends, requirements of high-rise buildings, and spatial toplogies that have the potential to achieve the different social indicatrs.

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 scaler 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.

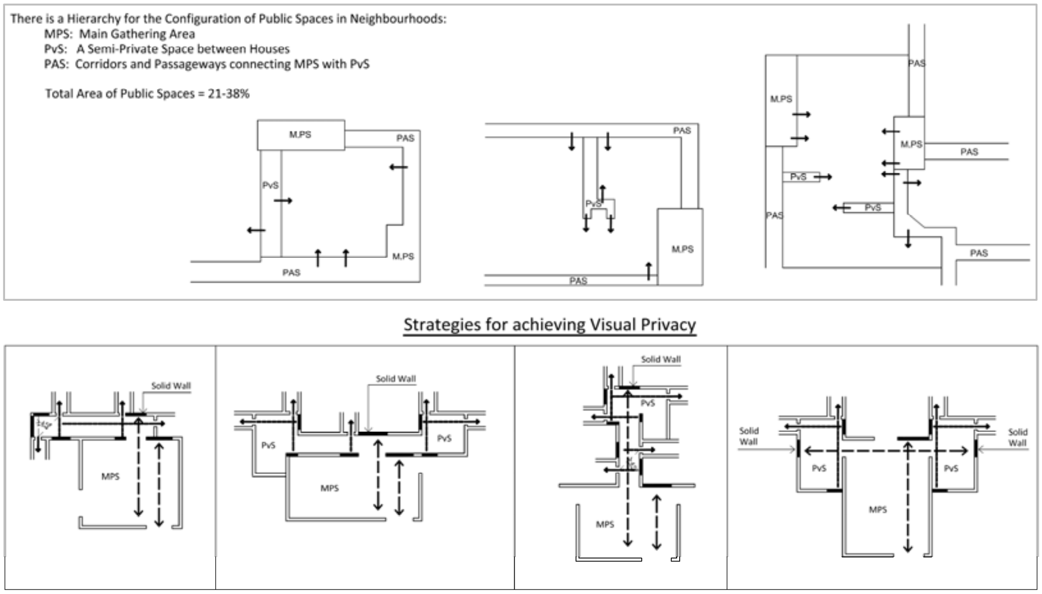


Figure 5.1: Prototypes of public spaces and arrangement of entrances in traditional neighbourhoods

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.

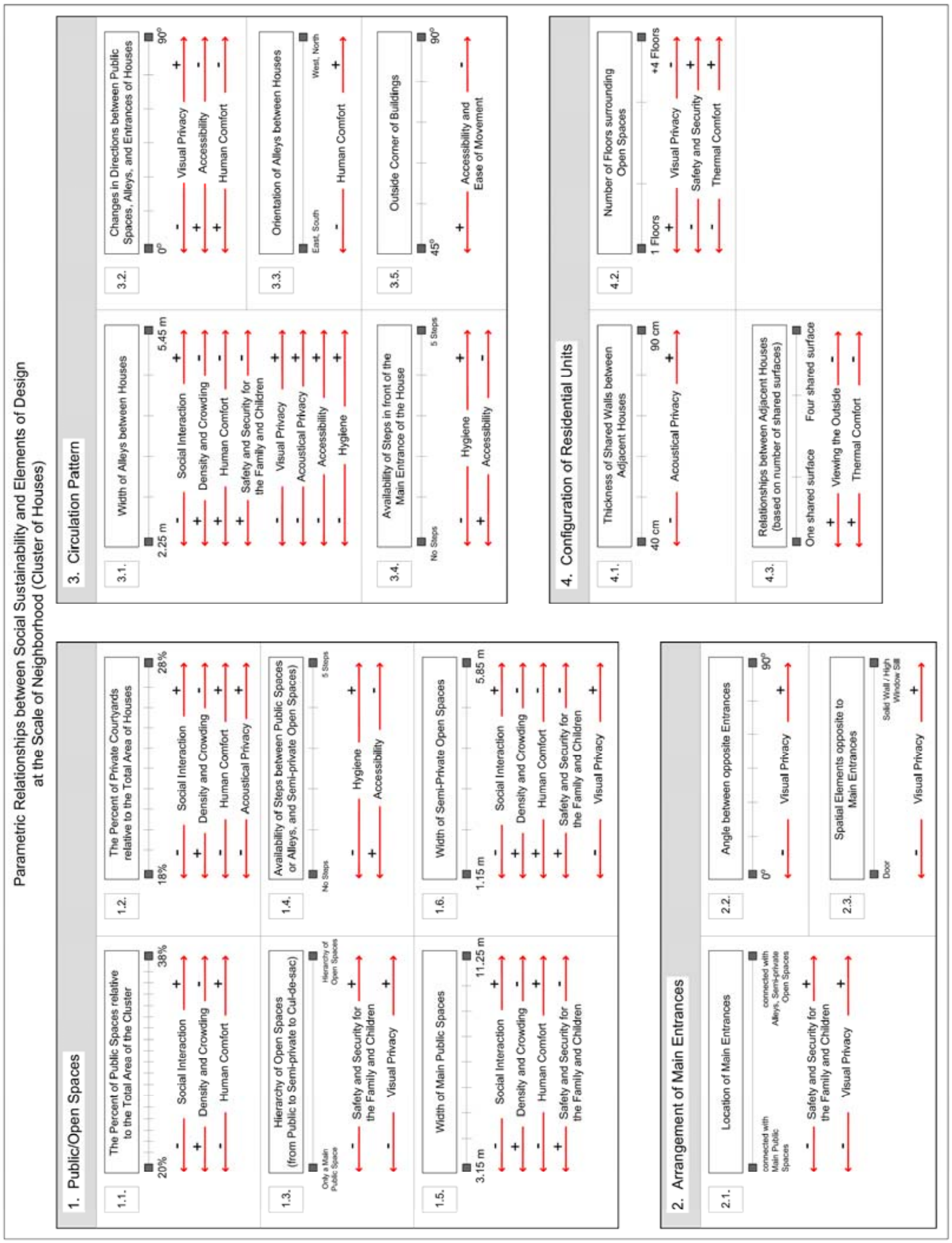


Figure 5.2: Parametric relationships between aspects of social sustainability and elements of design at the scale of neighbourhoods

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
Total number of parametric rules	73

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.

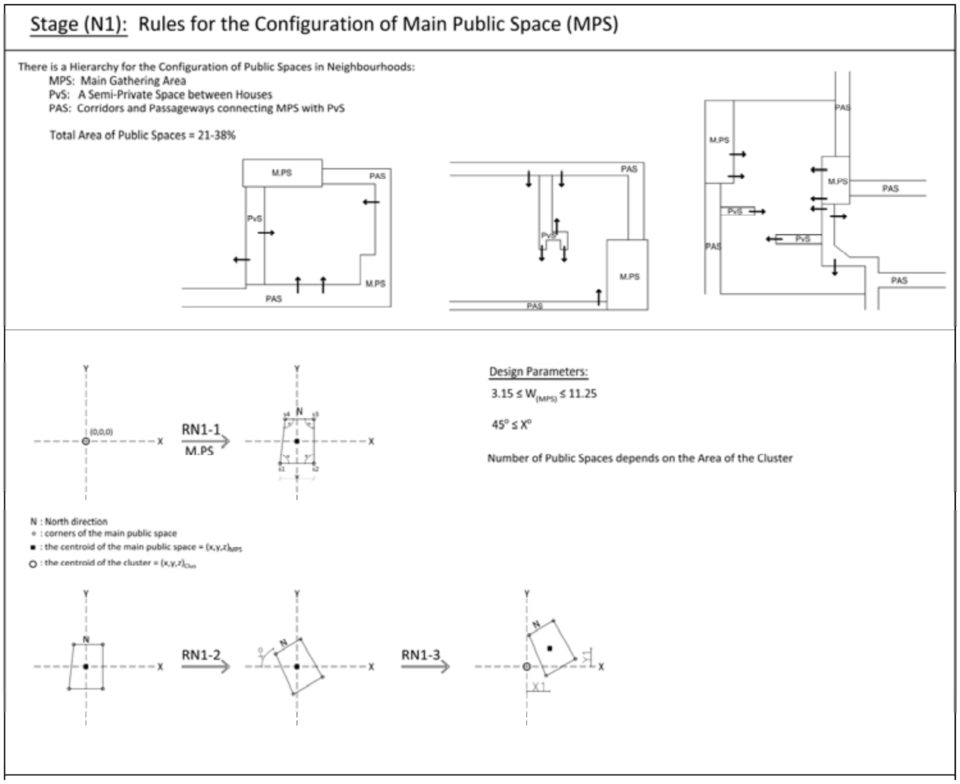


Figure 5.3: Parametric rules for the configuration of main public spaces in a neighbourhoods

The same process is used for the configuration of semi-private open spaces between residential units. These rules are illustrated in (Figure 5.4).

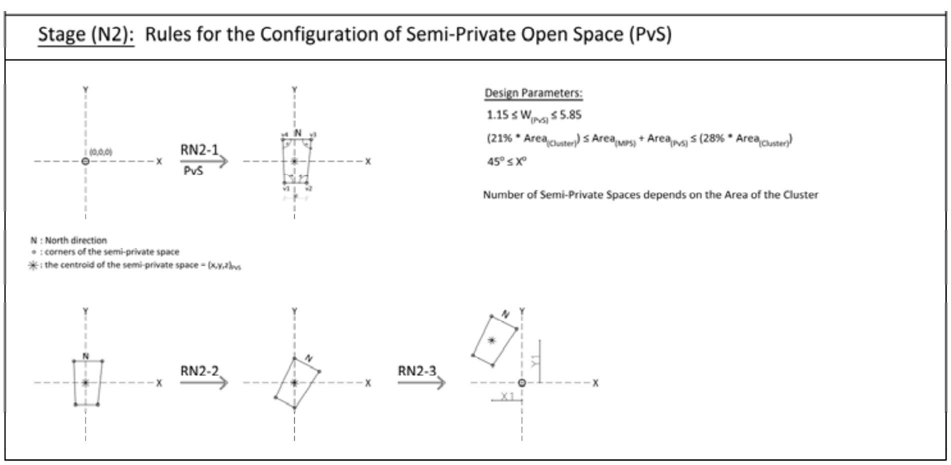


Figure 5.4: Parametric rules for the configuration of semi-private open spaces between residential units

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).

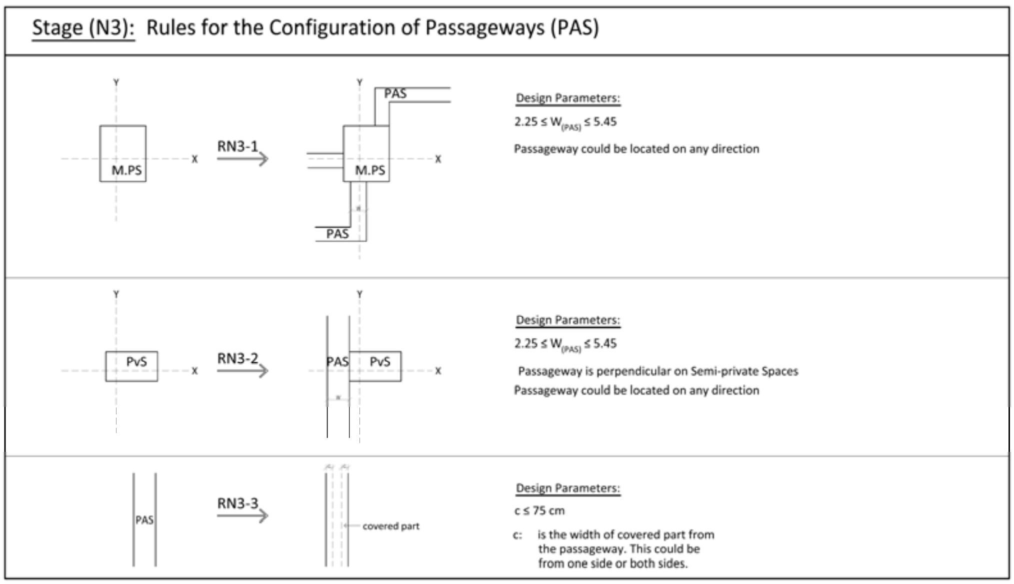


Figure 5.5: Parametric rules for the configuration of passageways in neighbourhoods

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

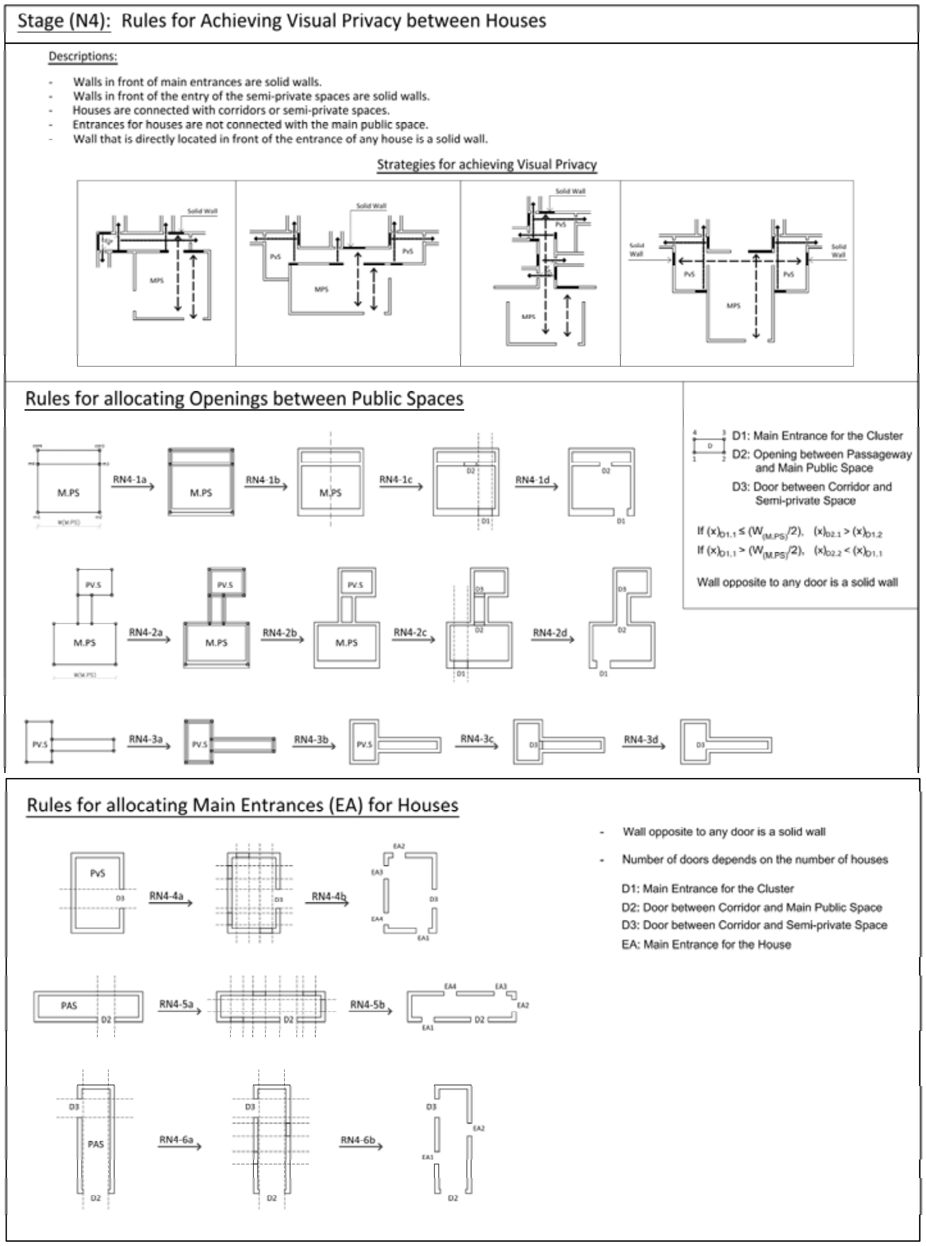


Figure 5.6: Parametric rules for achieving visual privacy between houses

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).

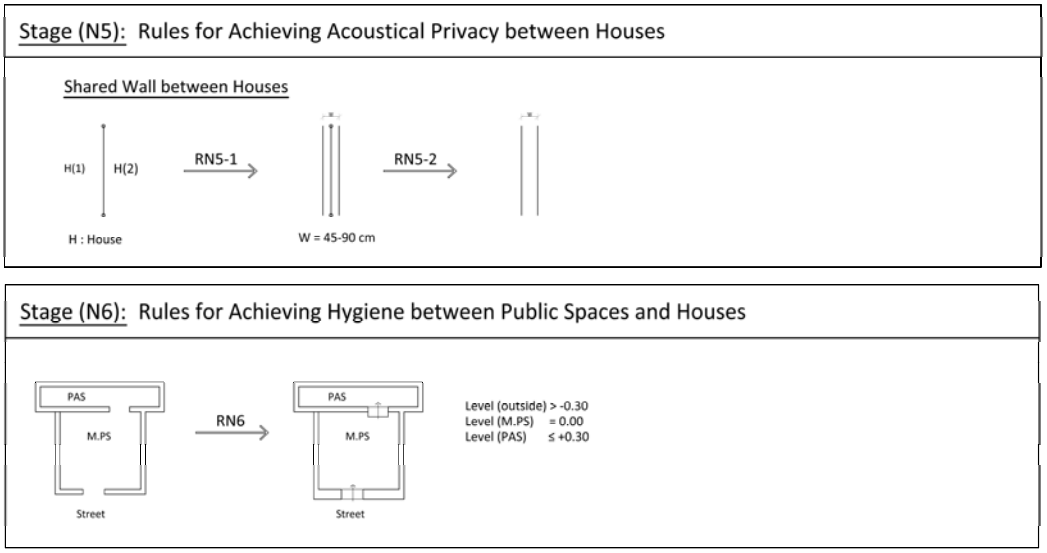


Figure 5.7: Sets of parametric rules for achieving acoustical privacy and hygiene in traditional neighbourhoods

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.

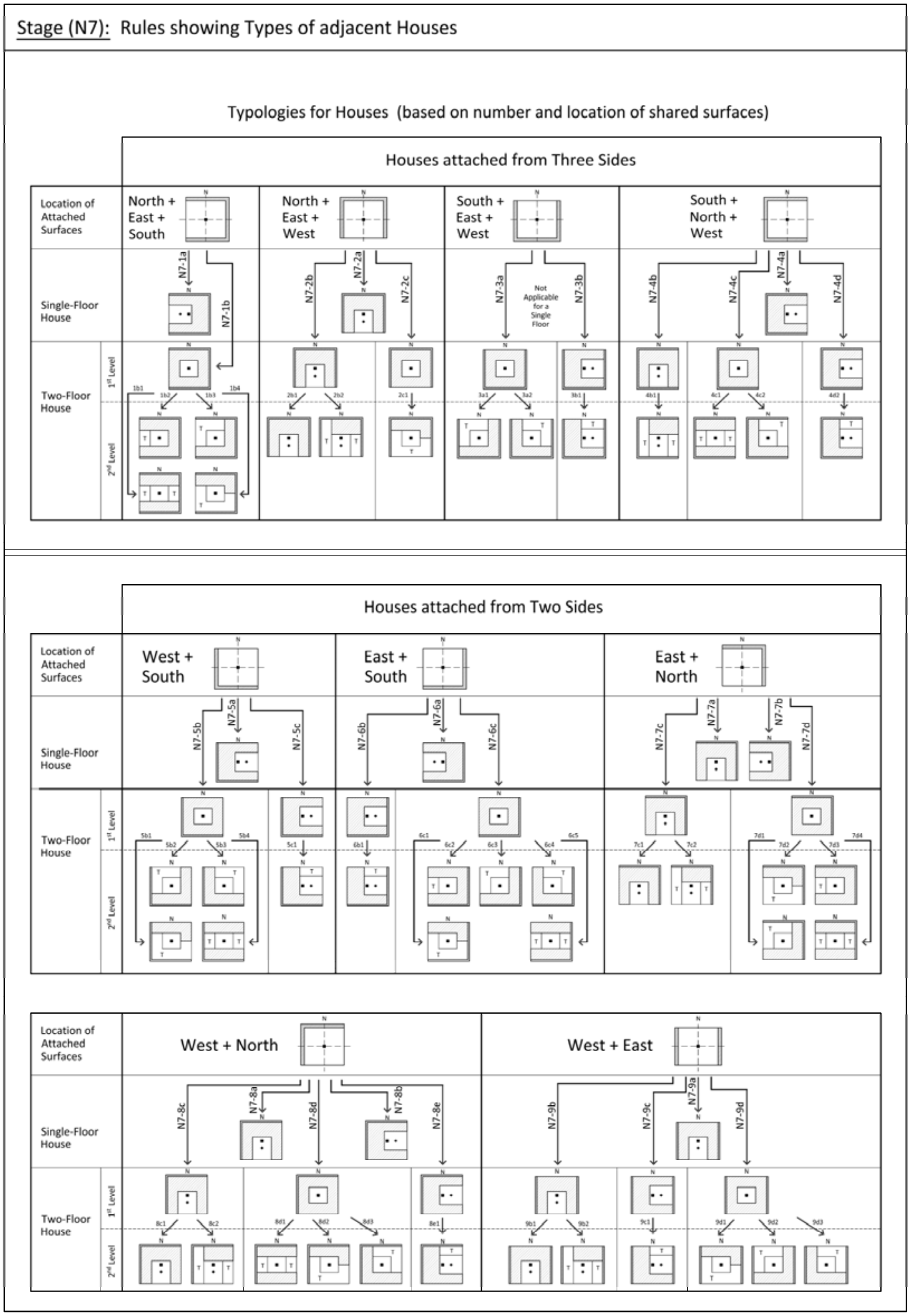


Figure 5.8: Sets of parametric rules for the configuration of adjacent houses in traditional neighbourhoods (part 1)

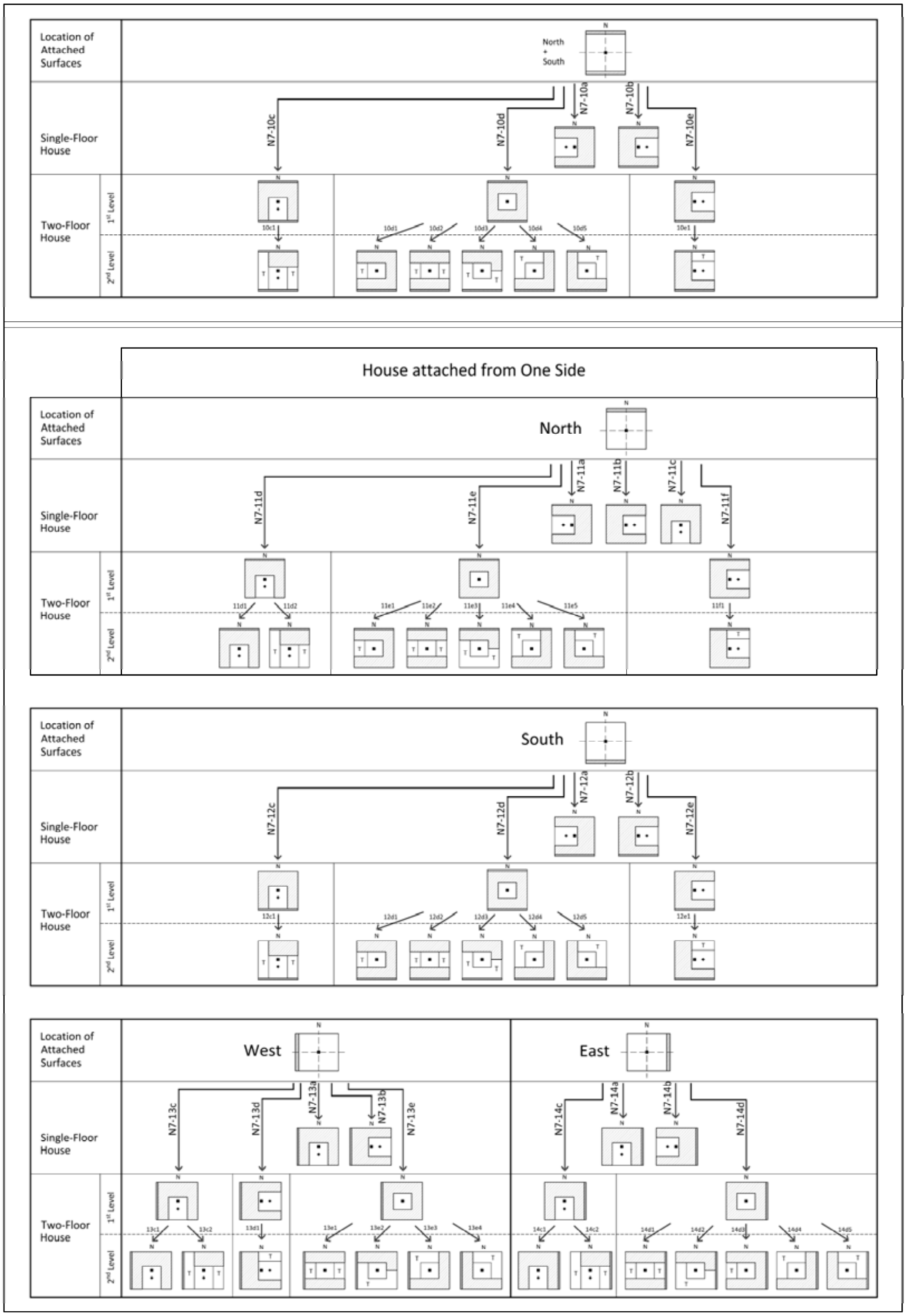


Figure 5.9: Sets of parametric rules for the configuration of adjacent houses in traditional neighbourhoods (part 2)

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% X $Area_{(House)}$) ≤ Area(MC) ≤ (29.8% X $Area_{(House)}$)
Iwan (IW)	<u>ONE Iwan (IW-N) is located on the Northern side of the courtyard</u> $1.18 \leq \frac{W(IW.N)}{L(IW.N)} \leq 1.97$ $0.44 \leq \frac{W(IW.N)}{W(MC)} \leq 0.80$ L(IW.N) = L(R.N), where (R.N) are rooms located on the Northern side of the courtyard <u>ONE Iwan (IW-S) is located on the Southern side of the courtyard</u> $1.00 \leq \frac{W(IW.S)}{L(IW.S)} \leq 1.51$ $0.21 \leq \frac{W(IW.S)}{W(MC)} \leq 0.65$ <u>ONE Iwan (IW-E) is located on the Eastern side of the courtyard</u> $1.18 \leq \frac{W(IW.E)}{L(IW.E)} \leq 1.60$ $0.42 \leq \frac{W(IW.E)}{W(MC)} \leq 0.66$ L(IW.E) = W(R.E), where (R.E) are rooms located on the Eastern side of the courtyard <u>ONE Iwan (IW-W) is located on the Western side of the courtyard</u> $1.33 \leq \frac{W(IW.W)}{L(IW.W)} \leq 1.80$ $0.44 \leq \frac{W(IW.W)}{W(MC)} \leq 0.48$

	<u>TWO Iwans (IW.N, IW.S) are located on the Northern & Southern sides of the courtyard</u> $1.52 \leq \frac{W(IW.N)}{L(IW.N)} \leq 2.14$ $1.04 \leq \frac{W(IW.S)}{L(IW.S)} \leq 1.42$ $0.18 \leq \frac{W(IW.N)}{W(MC)} \leq 0.63$ $0.30 \leq \frac{W(IW.S)}{W(MC)} \leq 0.65$ L(IW.N) = L(R.N), where (R.N) are rooms located on the Northern side of the courtyard
Gallery (GL)	<u>Gallery (GL.W) is located on the Western side of the courtyard</u> L(GL.W) = L(MC) 1.10 ≤ W(GL.W) ≤ 4.80 m (0.15 X W(MC)) ≤ W(GL.W) ≤ (0.43 X W(MC)) <u>Gallery (GL.E) is located on the Eastern side of the courtyard</u> L(GL.E) = L(MC) 1.40 ≤ W(GL.E) ≤ 3.10 m (0.10 X W(MC)) ≤ W(GL.W) ≤ (0.47 X W(MC)) <u>Gallery (GL.N) is located on the Northern side of the courtyard</u> L(GL.N) = W(MC) 1.15 ≤ W(GL.N) ≤ 3.65 m (0.13 X L(MC)) ≤ W(GL.N) ≤ (0.53 X L(MC)) <u>Gallery (GL.S) is located on the Southern side of the courtyard</u> L(GL.S) = W(MC) 1.50 ≤ W(GL.S) ≤ 3.60 m (0.17 X L(MC)) ≤ W(GL.S) ≤ (0.47 X L(MC))
The main entry hall (EA)	<u>EA (Type 1): Entry Hall as a Room</u> (2.2% X $Area_{(House)}$) ≤ (W(EA) X L(EA)) ≤ (5.3% X $Area_{(House)}$) 2.25 ≤ W(EA) ≤ 3.60 m L(EA) = length of adjacent room <u>EA (Type 2): Entry Hall as a Corridor</u> (1.4% X $Area_{(House)}$) ≤ (W(EA) X L(EA)) ≤ (3.8% X $Area_{(House)}$) 1.35 ≤ W(EA) ≤ 1.90 m L(EA) = length of adjacent room

	EA (Type 3): Entry Hall as L-shape $(W(EA) \times L(EA)) \leq (3.5\% \times Area_{(House)})$ $1.35 \leq W(a) \leq 1.90$ m, where (a) is the width of the corridor L(EA), W(EA) = width & length of adjacent rooms EA (Type 4): Entry Hall as Z-shape $(W(EA) \times L(EA)) \leq (5.3\% \times Area_{(House)})$ $1.35 \leq W(a) \leq 1.90$ m, where (a) is the width of the corridor L(EA), W(EA) = width and length of adjacent rooms
Guest room (G)	$(4.5\% \times Area_{(House)}) \leq (W(G) \times L(G)) \leq (13.1\% \times Area_{(House)})$ $1.17 \leq \frac{W(G)}{L(G)} \leq 3.86$
Living space (LV)	$(4\% \times Area_{(House)}) \leq (W(LV) \times L(LV)) \leq (12\% \times Area_{(House)})$ $(7\% \times Area_{(House)}) \leq \sum Area_{(All\ Living\ Rooms)} \leq (21\% \times Area_{(House)})$ $1.17 \leq \frac{W(LV)}{L(LV)} \leq 3.25$
Bedroom (B)	$(4\% \times Area_{(House)}) \leq (W(B) \times L(B)) \leq (7\% \times Area_{(House)})$ $(12\% \times Area_{(House)}) \leq \sum Area_{(All\ Bedrooms)} \leq (28\% \times Area_{(House)})$ $1.00 \leq \frac{W(B)}{L(B)} \leq 2.00$
Service entrance (EB)	EB (Type 1): Service Entrance as a Hall $2.25 \leq W(EB) \leq 3.60$ m L(EB) = length of adjacent room EB (Type 2): Service Entrance as a Corridor $1.35 \leq W(EB) \leq 1.90$ m L(EB) = length of adjacent room
Services (S)	$(11\% \times Area_{(House)}) \leq \sum Area_{(Services)} \leq (20\% \times Area_{(House)})$ The width of services depends on the width of rooms surrounding the main courtyard.
Terraces (T)	$(11\% \times Area_{(House)}) \leq \sum Area_{(Terraces)} \leq (16\% \times Area_{(House)})$

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)	<u>The main courtyard (MC) could be located:</u> - At the centre of the layout (Type MC-C). - On the Southern side of the layout (Type MC-S). - On the Eastern side of the layout (Type MC-E). - On the Western side of the layout (Type MC-W).
Iwan (IW)	- <u>Options for the Location of (IW.N), which is located on the Northern side of the courtyard:</u> $(X,Y)_{IW.N} = (X,Y)_{MC} + (\frac{L(MC)}{2}) + (\frac{L(IW.N)}{2})$ $(X,Y)_{IW1} = (X,Y)_{C4}$, where (IW1) and (C4) are corners of *iwan* and courtyard - <u>Options for the Location of (IW.S), which is located on the Southern side of the courtyard:</u> $(X,Y)_{IW.S} = (X,Y)_{MC} - ((\frac{L(MC)}{2}) + (\frac{L(IW.S)}{2}))$ $(X,Y)_{IW4} = (X,Y)_{C1}$, where (IW4) and (C1) are corners of *iwan* and courtyard $(X,Y)_{IW.S} = (X,Y)_{MC} + (\frac{W(MC)}{2}) + (\frac{W(IW.S)}{2}) + d$, where: $0 \le d \le ((\frac{L(MC)}{2}) - (\frac{L(IW.S)}{2}))$ - <u>Options for the Location of (IW.E), which is located on the Eastern side of the courtyard:</u> $(X,Y)_{IW.E} = (X,Y)_{MC} + (\frac{W(MC)}{2}) + (\frac{W(IW.E)}{2})$ $(X,Y)_{IW4} = (X,Y)_{C3}$, where (IW4) and (C3) are corners of *iwan* and courtyard $(X,Y)_{IW.E} = (X,Y)_{MC} + (\frac{W(MC)}{2}) + (\frac{W(IW.E)}{2}) + d$, where: $0 \le d \le ((\frac{L(MC)}{2}) - (\frac{L(IW.E)}{2}))$ - <u>Options for the Location of IW.W:</u> $(X,Y)_{IW.W} = (X,Y)_{MC} – ((\frac{W(MC)}{2}) + (\frac{W(IW.W)}{2}))$ $(X,Y)_{IW3} = (X,Y)_{C4}$, where (IW3) and (C4) are corners of *iwan* and courtyard
Gallery (GL)	- Gallery is attached to the courtyard - <u>Gallery (GL.W) on the Western side of the courtyard</u> $(X,Y)_{GL3} = (X,Y)_{C4}$ $(X,Y)_{GL2} = (X,Y)_{C1}$ where (GL3), (GL2), (C4), and (C1) are corners of the *gallery* and the courtyard

	- Gallery (GL.E) is located on the Eastern side of the courtyard $(X,Y)_{GL1} = (X,Y)_{C2}$ $(X,Y)_{GL4} = (X,Y)_{C3}$ where (GL1), (GL4), (C2), and (C3) are corners of the *gallery* and the courtyard - Gallery (GL.N) is located on the Northern side of the courtyard $(X,Y)_{GL1} = (X,Y)_{C4}$ $(X,Y)_{GL2} = (X,Y)_{C3}$ where (GL1), (GL2), (C4), and (C3) are corners of the *gallery* and the courtyard - Gallery (GL.S) is located on the Southern side of the courtyard $(X,Y)_{GL4} = (X,Y)_{C1}$ $(X,Y)_{GL3} = (X,Y)_{C2}$ where (GL4), (GL3), (C1), and (C2) are corners of the *gallery* and the courtyard
The main entry hall (EA)	- EA is attached directly to the main courtyard. - EA is attached to a gallery in front of the main courtyard. - EA is attached to a corridor that leads to the gallery in front of the main courtyard.
Guest room (G)	- The guest room is attached to the main entry hall.
Living space (LV)	- Location of a living room depends on the location of semi-private spaces (IW, GL, and MC). - The living room is located opposite to bedrooms (for achieving acoustical privacy). - 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. - 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).
Bedroom (B)	- Location of bedrooms depends on the location of guest room and living room.
Vertical circulation (Cir)	- On the ground floor, stairs could be attached to the main entry hall (EA), the courtyard (MC), or a gallery (GL). - On upper floor(s), stairs are attached to the gallery (GL), terraces (T), or paths/transitional spaces (P). - There are three prototypes for the location of stairs in relation to courtyards (MC), galleries (GL), and main entry hall (EA): o Type (1): accessed directly from the entry hall (EA). o Type (2a): adjacent to the courtyard, and located at the opposite corner of the entry hall (diagonal relationships). o Type (2b): adjacent to the courtyard, and located at the opposite corner of the entry hall (linear relationships). o Type (3): adjacent to the courtyard/gallery, and accessed from the gallery.

Service entrance (EB)	- EB is connected with services and/or courtyard/gallery, and it has to open to the outside context. - Service entrance could be located opposite to, or adjacent to the main entrance (EA).
Services (S)	- Location of services depends on the overall layout of the house, and the location of the courtyard and other rooms. - Kitchen, storage areas, and toilets are adjacent to living room and/or service entrance. - Bathrooms are adjacent to bedrooms. - Toilets are adjacent to the guestroom.
Terraces (T)	- Options for the location of terraces in relation to the layout of the ground floor: South-West, West, North-West, North, South-East. - 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). - Terraces could be connected with bedrooms or living spaces.

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.

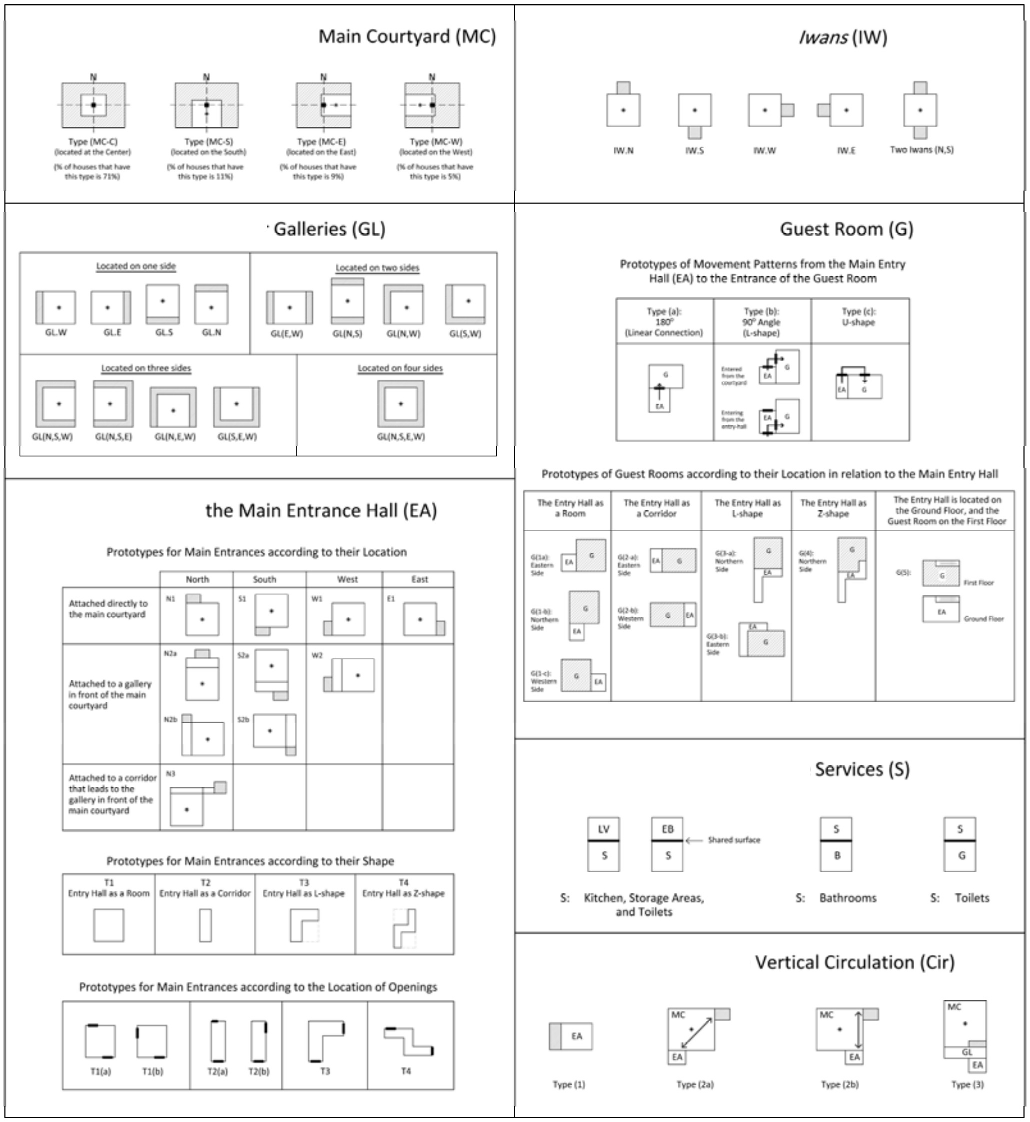


Figure 5.10: Diagrams showing design variations for the different elements in vernacular houses (part 1)

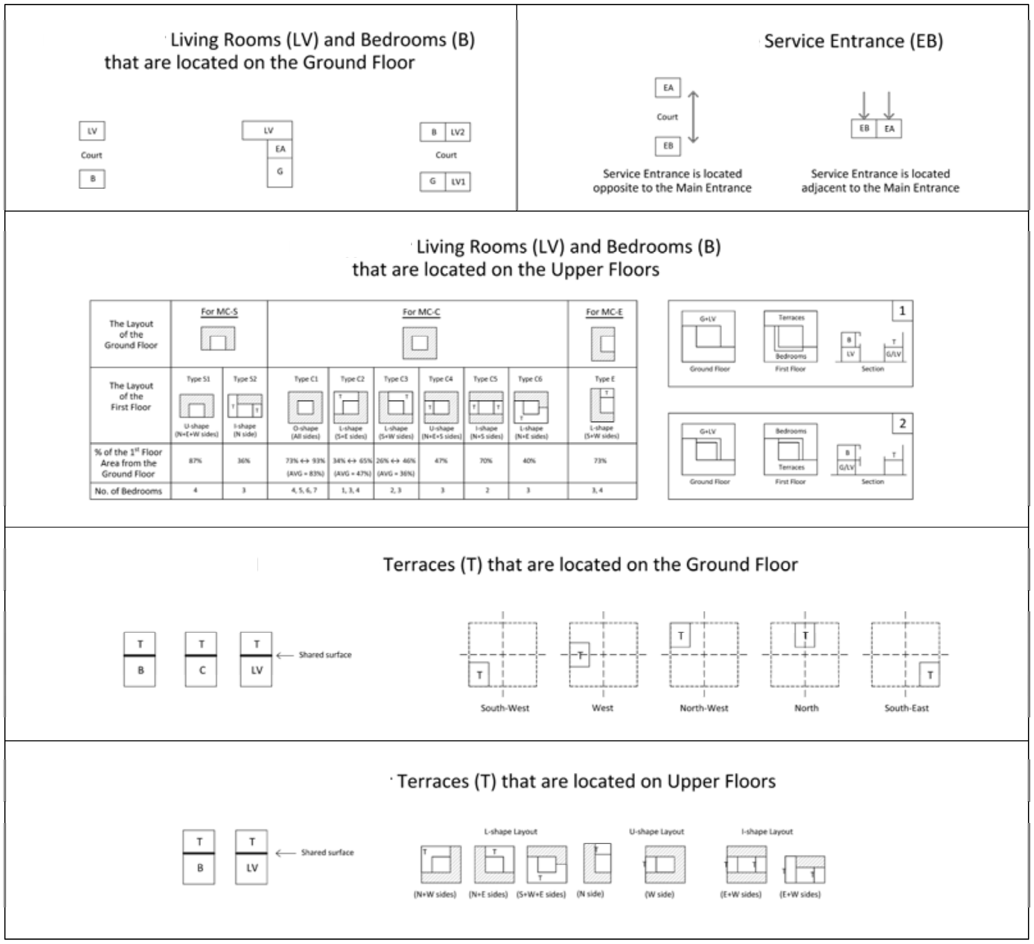


Figure 5.11: Diagrams showing design variations for the different elements in vernacular houses (part 2)

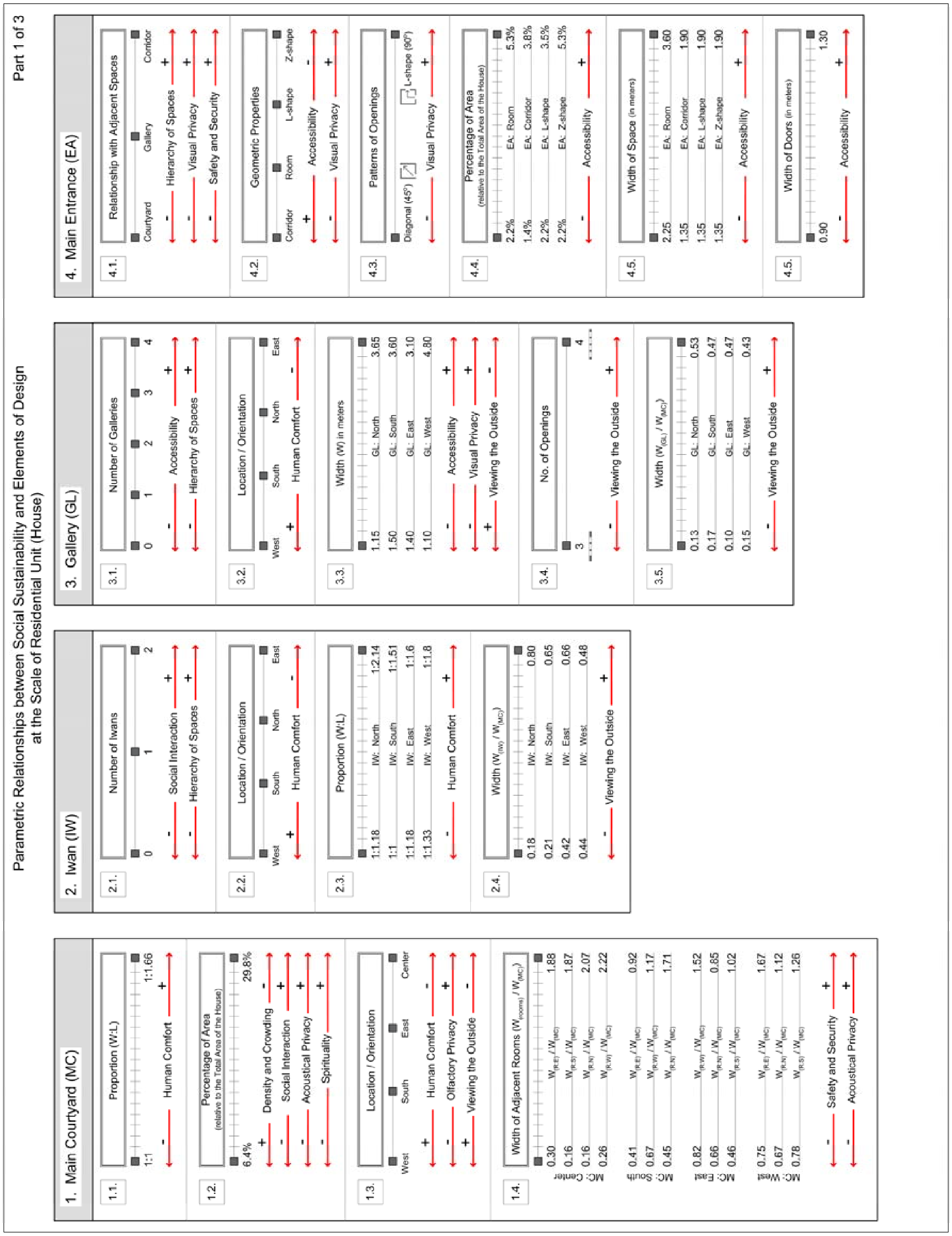


Figure 5.12: Parametric relationships between social sustainability and elements of design at the scale of residential units (part 1)

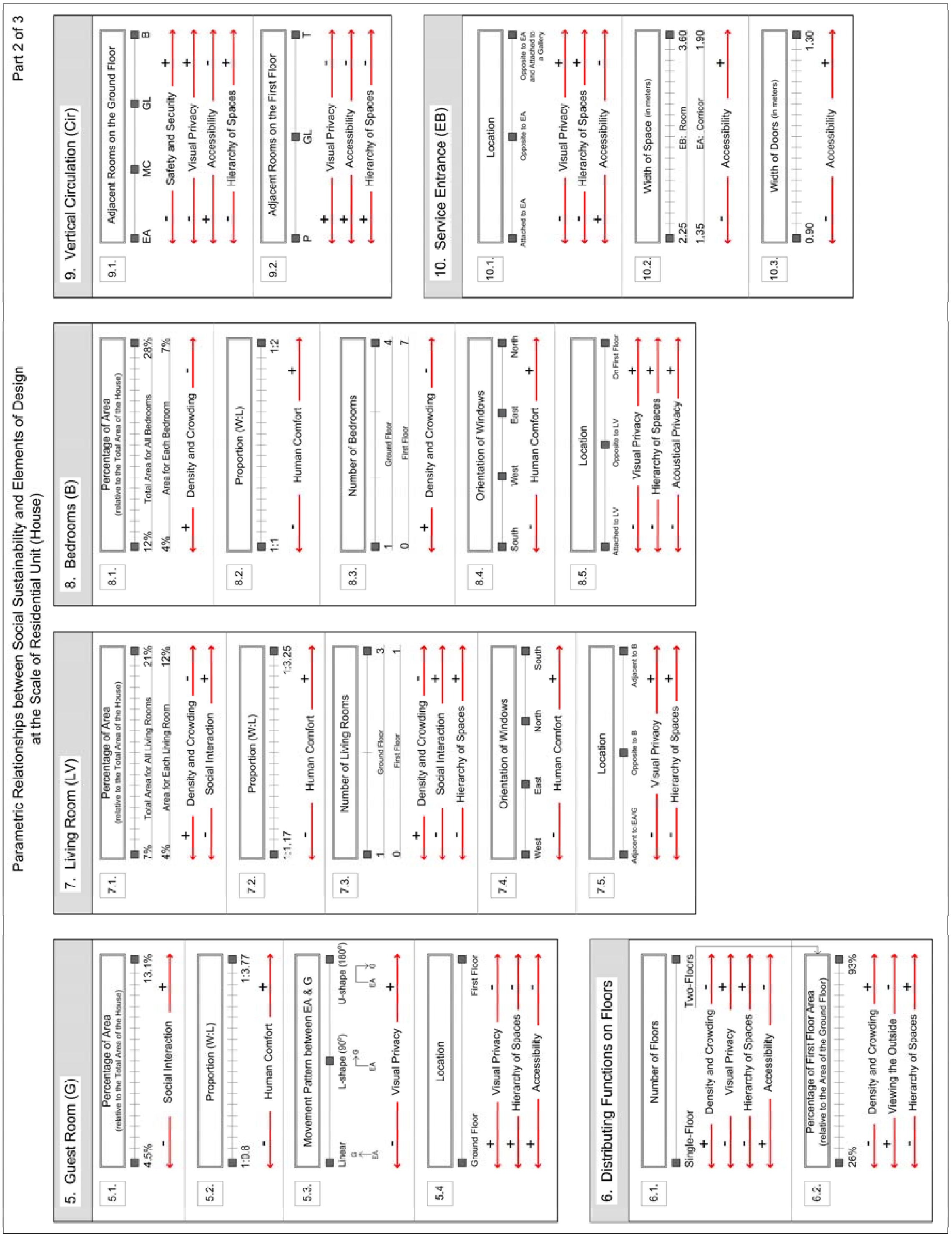


Figure 5.13: Parametric relationships between social sustainability and elements of design at the scale of residential units (part 2)

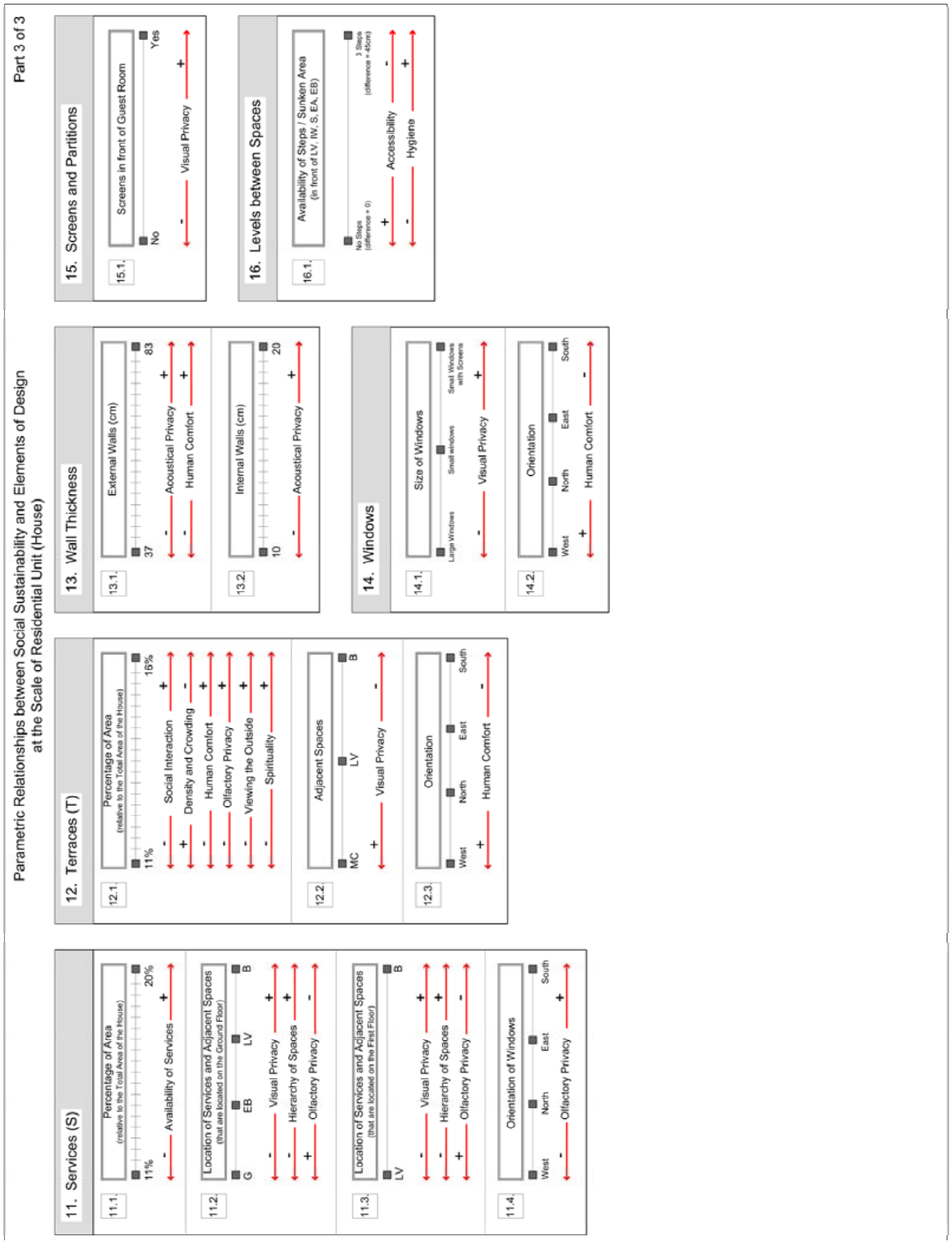


Figure 5.14: Parametric relationships between social sustainability and elements of design at the scale of residential units (part 3)

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).

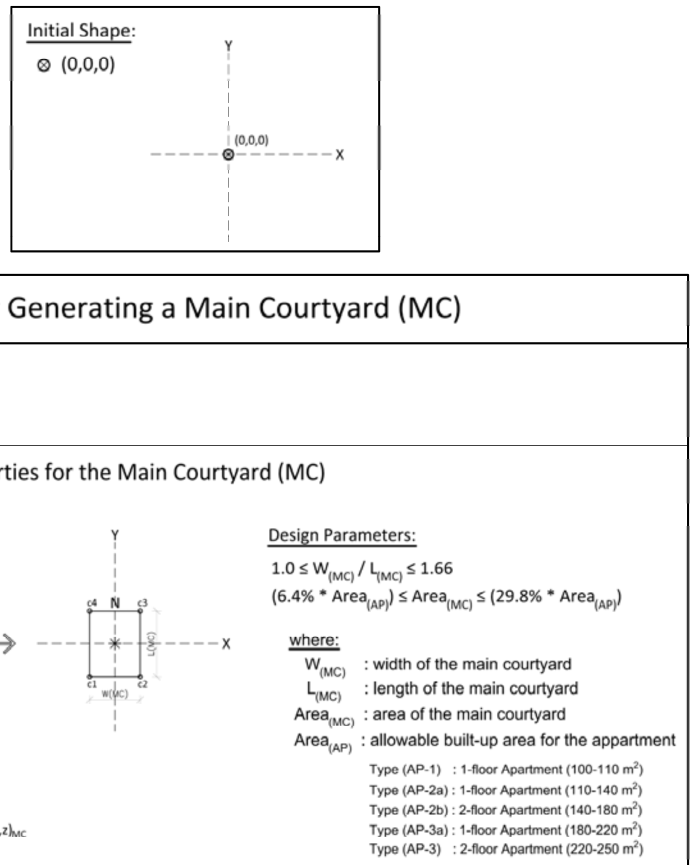
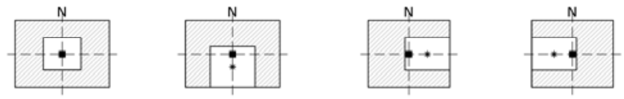


Figure 5.16: The initial shape, and the parametric rule (R1-01) for generating a main courtyard/hall in a traditional house in MENA region

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).

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



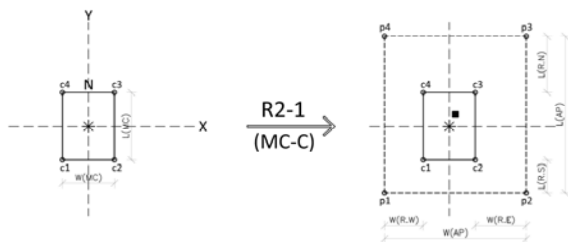
Type (MC-C) (located at the Center) (% of houses that have this type is 71%)

Type (MC-S) (located on the South) (% of houses that have this type is 11%)

Type (MC-E) (located on the East) (% of houses that have this type is 9%)

Type (MC-W) (located on the West) (% of houses that have this type is 5%)

Rule (2-01): Generating Schematic Layout for the Ground Floor that has a Main Courtyard located at the Center (Type MC-C)



■ : the centroid of the initial layout of the apartment $(x,y,z)_{AP}$

$W_{(R.W)}$: 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

Design Parameters:

$0.34 \le W_{(MC)} / W_{(AP)} \le 0.53$

$-2.33 \le x_{(MC)} - x_{(AP)} \le 4.11$ m (AVG = 0.07 m)

$-4.25 \le y_{(MC)} - y_{(AP)} \le 1.95$ m (AVG = -0.25 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:

$0.31 \le W_{(R.E)} / W_{(MC)} \le 1.17$ (AVG=0.68)

$0.26 \le W_{(R.W)} / W_{(MC)} \le 1.13$ (AVG=0.64)

$0.16 \le L_{(R.N)} / L_{(MC)} \le 1.51$ (AVG=0.55)

$0.16 \le L_{(R.S)} / L_{(MC)} \le 1.02$ (AVG=0.53)

For Apartments located in North-Africa:

$0.30 \le W_{(R.E)} / W_{(MC)} \le 1.38$ (AVG=0.60)

$0.27 \le W_{(R.W)} / W_{(MC)} \le 1.04$ (AVG=0.53)

$0.36 \le L_{(R.N)} / L_{(MC)} \le 1.49$ (AVG=0.74)

$0.35 \le L_{(R.S)} / L_{(MC)} \le 0.96$ (AVG=0.66)

For Apartments located in the Gulf Area:

$0.34 \le W_{(R.E)} / W_{(MC)} \le 1.88$ (AVG=0.94)

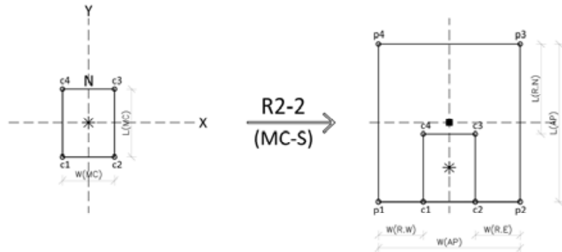
$0.32 \le W_{(R.W)} / W_{(MC)} \le 2.22$ (AVG=1.01)

$0.35 \le L_{(R.N)} / L_{(MC)} \le 2.07$ (AVG=1.00)

$0.28 \le L_{(R.S)} / L_{(MC)} \le 1.87$ (AVG=1.06)

Figure 5.17: Sets of parametric rules for generating the schematic layout of the ground floor in single-floor houses (part 1)

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:

$0.34 \leq W_{(MC)} / W_{(AP)} \leq 0.53$

$L_{(AP)} = L_{(MC)} + L_{(R.N)}$

$W_{(AP)} = W_{(MC)} + W_{(R.E)} + W_{(R.W)}$

$(x)_{(MC)} = (x)_{(AP)}$

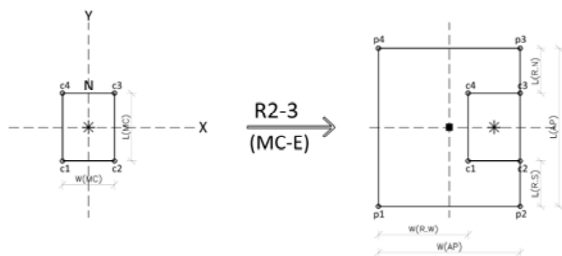
$0.41 \leq W_{(R.E)} / W_{(MC)} \leq 0.92$ (AVG=0.62)

$0.67 \leq W_{(R.W)} / W_{(MC)} \leq 1.17$ (AVG=0.78)

$0.45 \leq L_{(R.N)} / L_{(MC)} \leq 1.71$ (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:

$0.34 \leq W_{(MC)} / W_{(AP)} \leq 0.53$

$L_{(AP)} = L_{(MC)} + L_{(R.N)} + L_{(R.S)}$

$W_{(AP)} = W_{(MC)} + W_{(R.W)}$

$(y)_{(MC)} = (y)_{(AP)}$

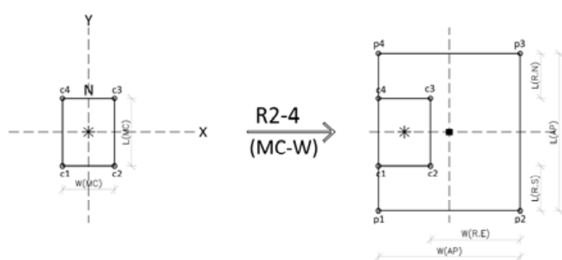
$W_{(R.E)} = 0.00$

$0.82 \leq W_{(R.W)} / W_{(MC)} \leq 1.52$ (AVG=1.07)

$0.66 \leq L_{(R.N)} / L_{(MC)} \leq 0.85$ (AVG=0.73)

$0.46 \leq L_{(R.S)} / L_{(MC)} \leq 1.02$ (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:

$0.34 \leq W_{(MC)} / W_{(AP)} \leq 0.53$

$L_{(AP)} = L_{(MC)} + L_{(R.S)} + L_{(R.N)}$

$W_{(AP)} = W_{(MC)} + W_{(R.E)}$

$(y)_{(MC)} = (y)_{(AP)}$

$0.75 \leq W_{(R.E)} / W_{(MC)} \leq 1.67$ (AVG=1.21)

$W_{(R.W)} = 0.00$

$0.67 \leq L_{(R.N)} / L_{(MC)} \leq 1.12$ (AVG=0.90)

$0.78 \leq L_{(R.S)} / L_{(MC)} \leq 1.26$ (AVG=1.02)

Figure 5.18: Sets of parametric rules for generating the schematic layout of the ground floor in single-floor houses (part 2)

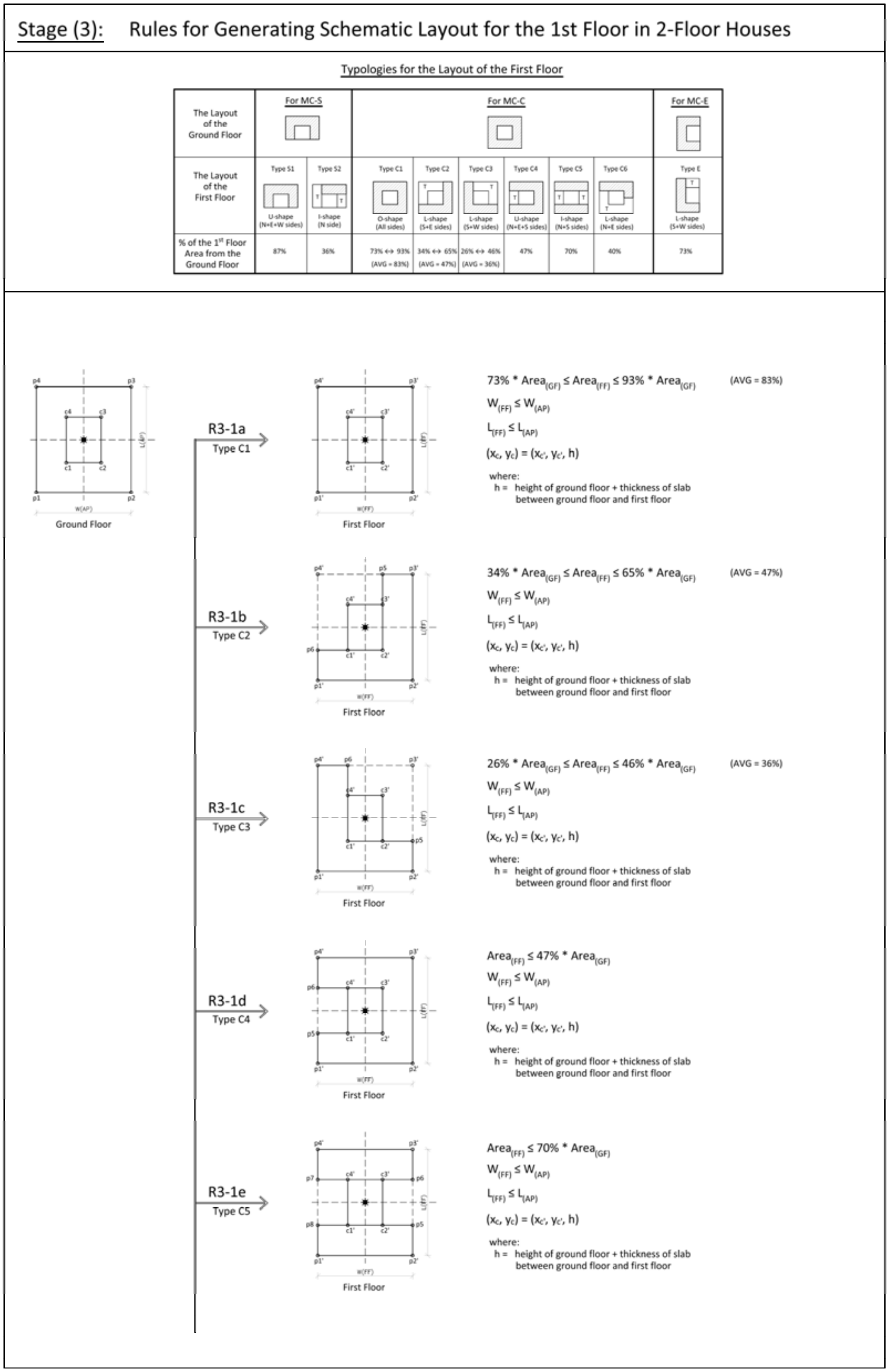


Figure 5.19: Sets of parametric rules for generating the schematic layout of the ground/first floors in two-floor houses (part 1)

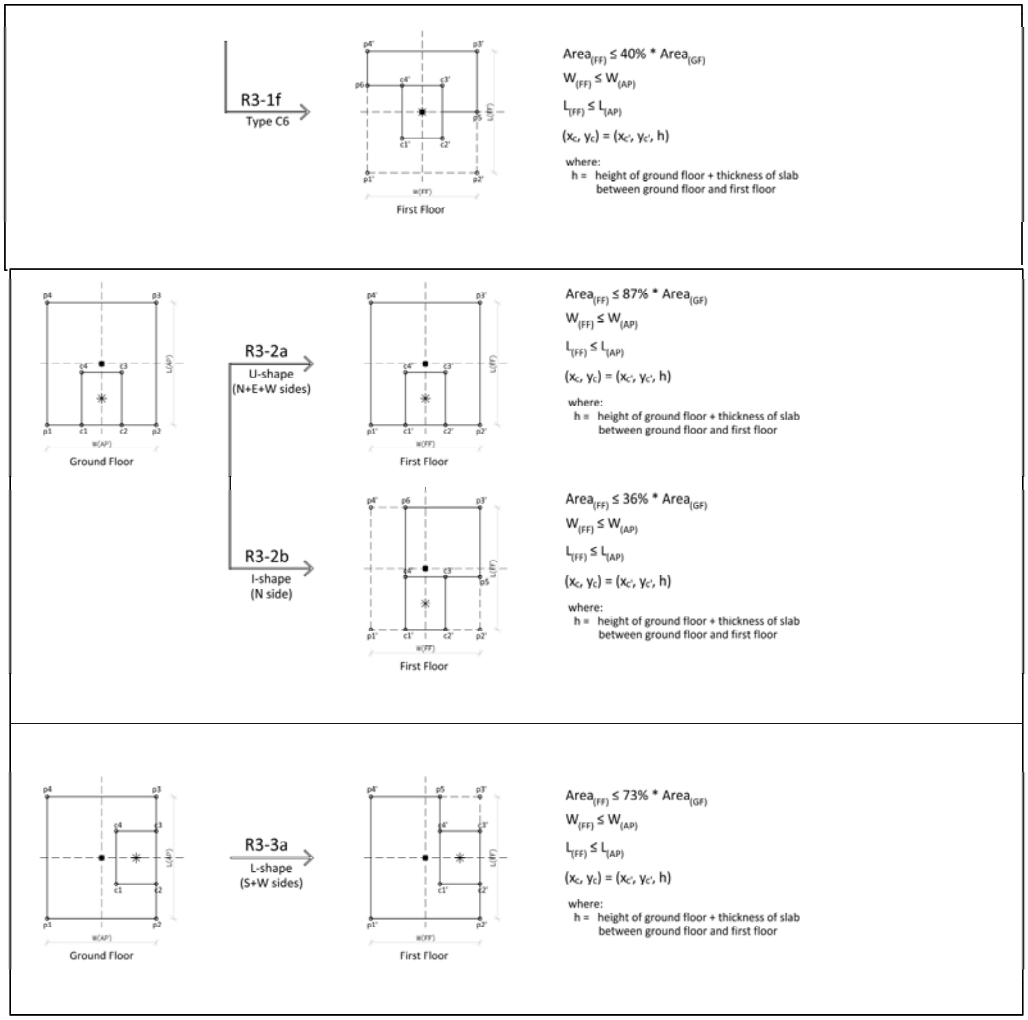


Figure 5.20: Sets of parametric rules for generating the schematic layout of the ground/first floors in two-floor houses (part 2)

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).

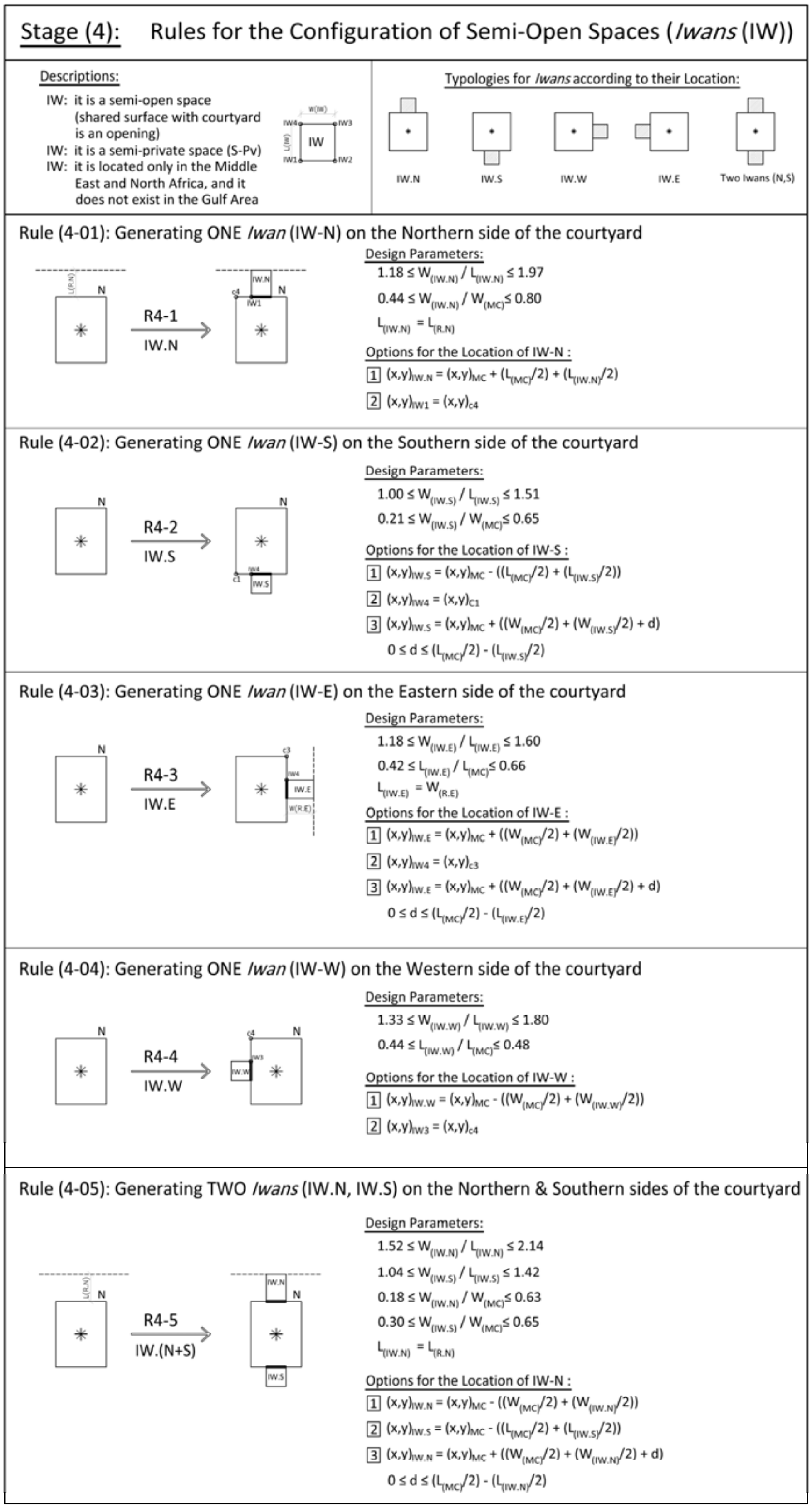


Figure 5.21: Sets of parametric rules for generating semi-open spaces (*iwans*)

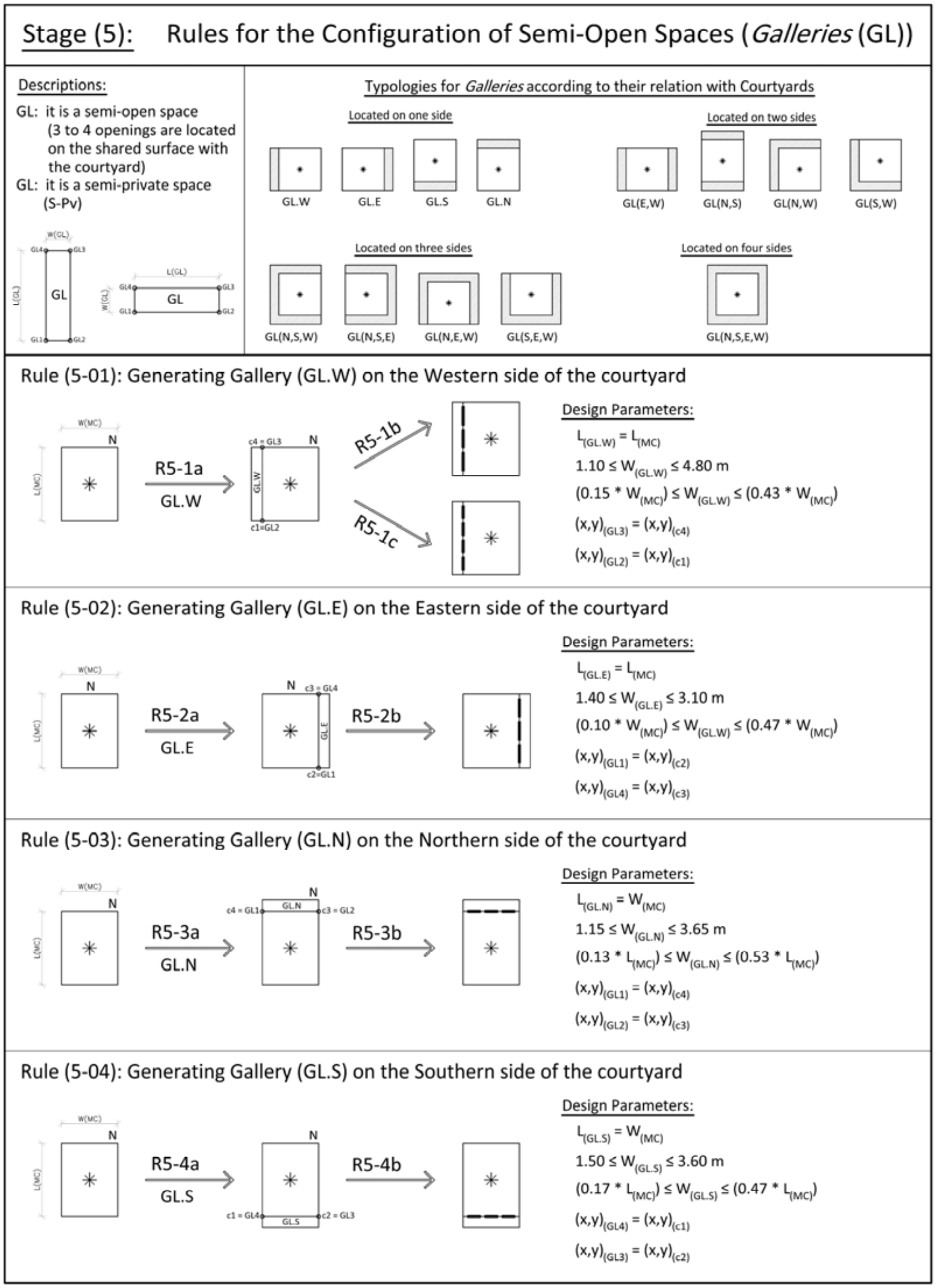


Figure 5.22: Sets of parametric rules for generating semi-open spaces (galleries)

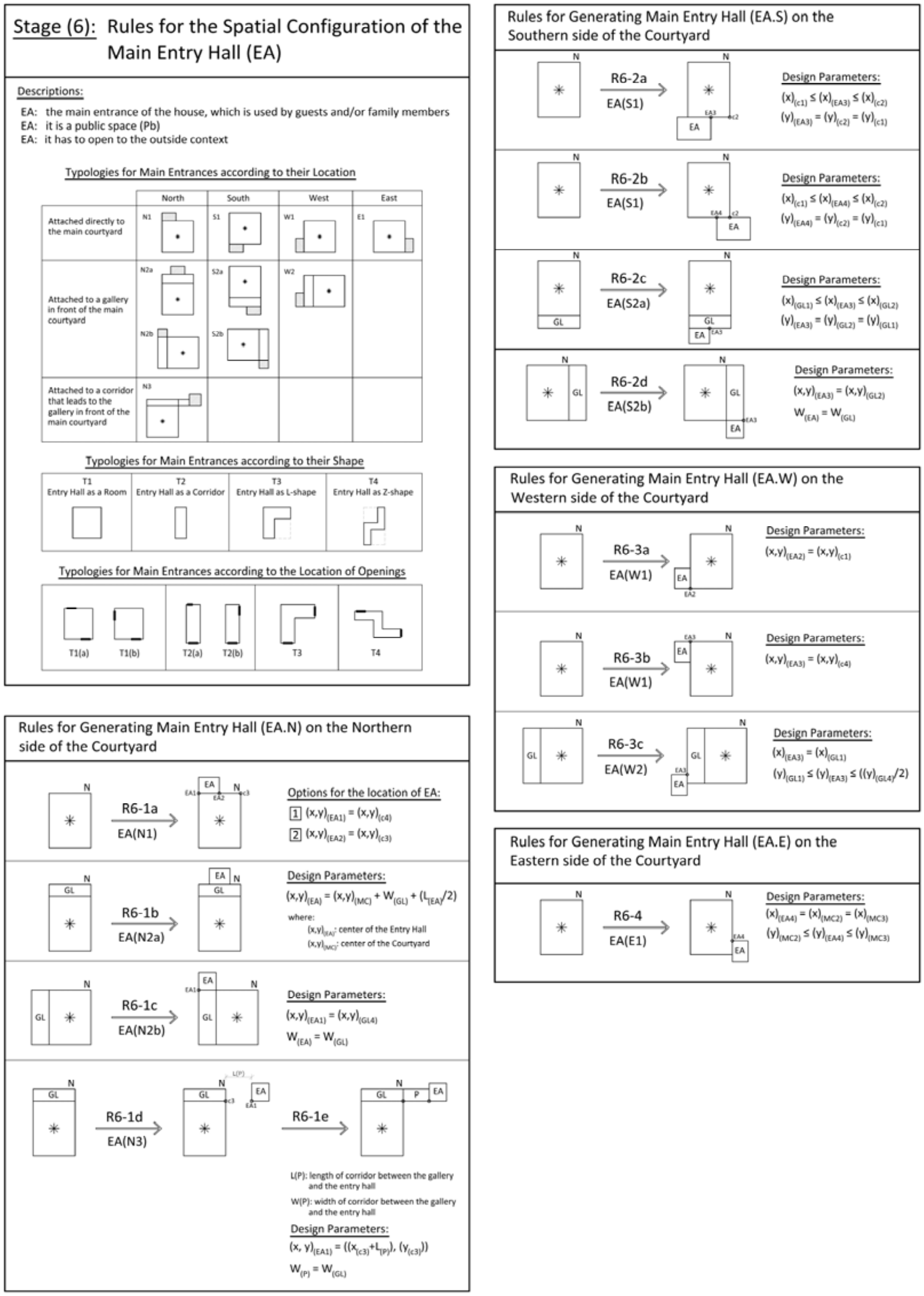


Figure 5.23: Sets of parametric rules for generating the main entry space for vernacular houses in MENA region (part 1)

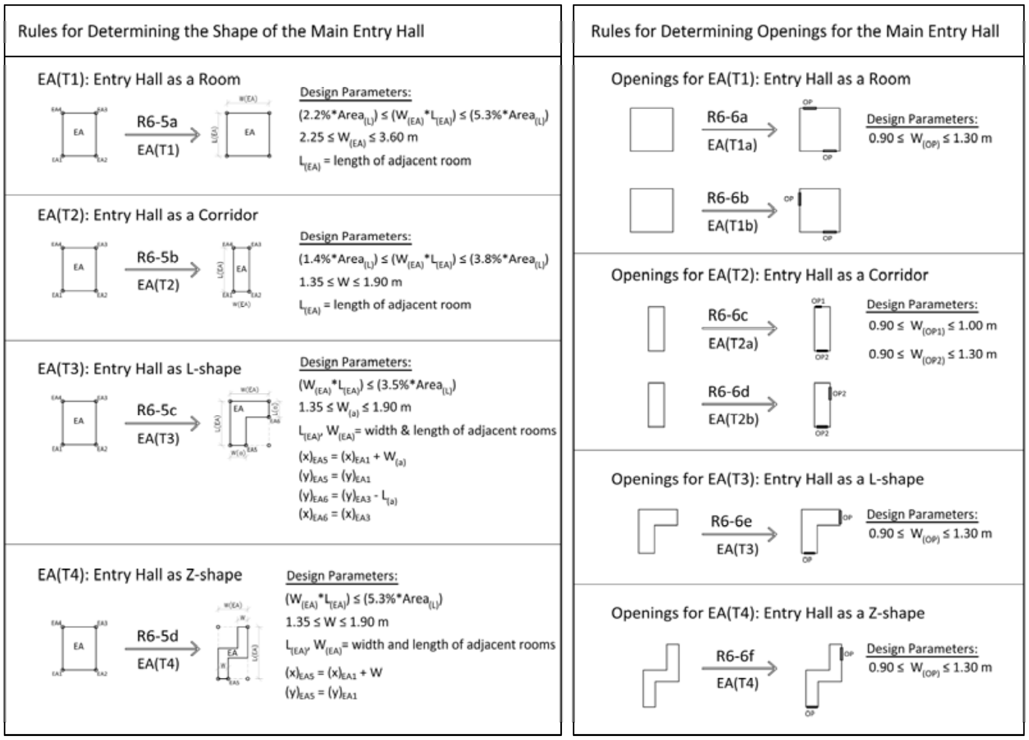


Figure 5.24: Sets of parametric rules for generating the main entry space for vernacular houses in MENA region (part 2)

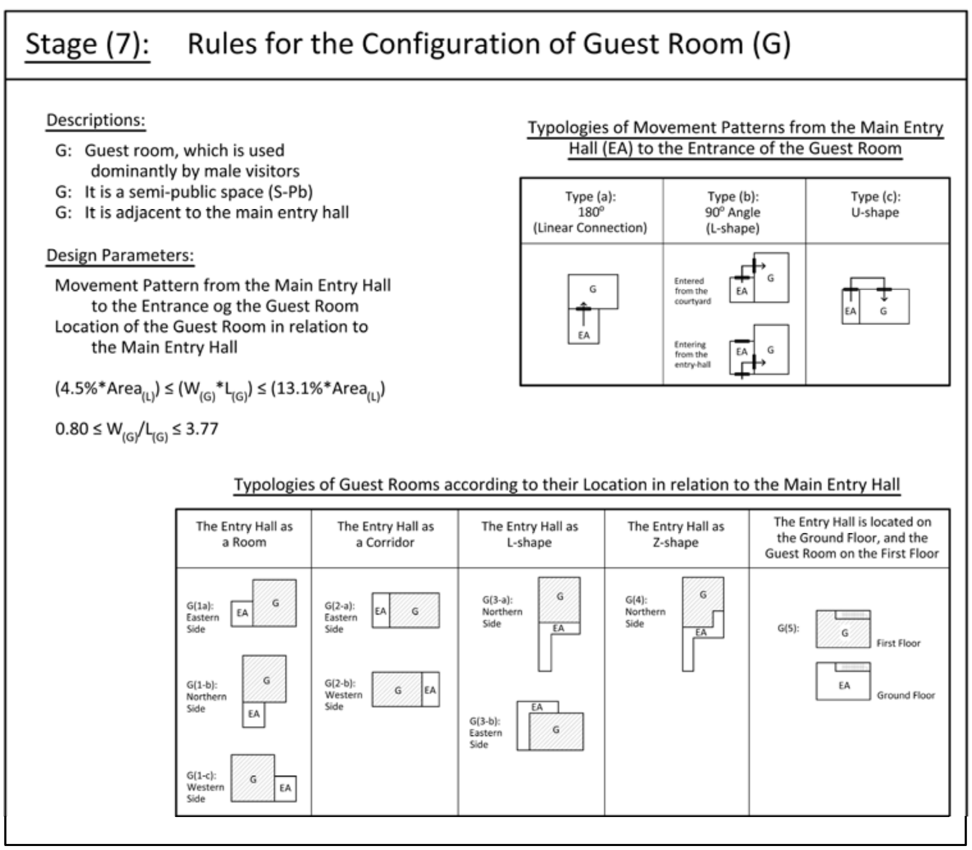


Figure 5.25: Sets of parametric rules for the configuration of a guest room (part 1)

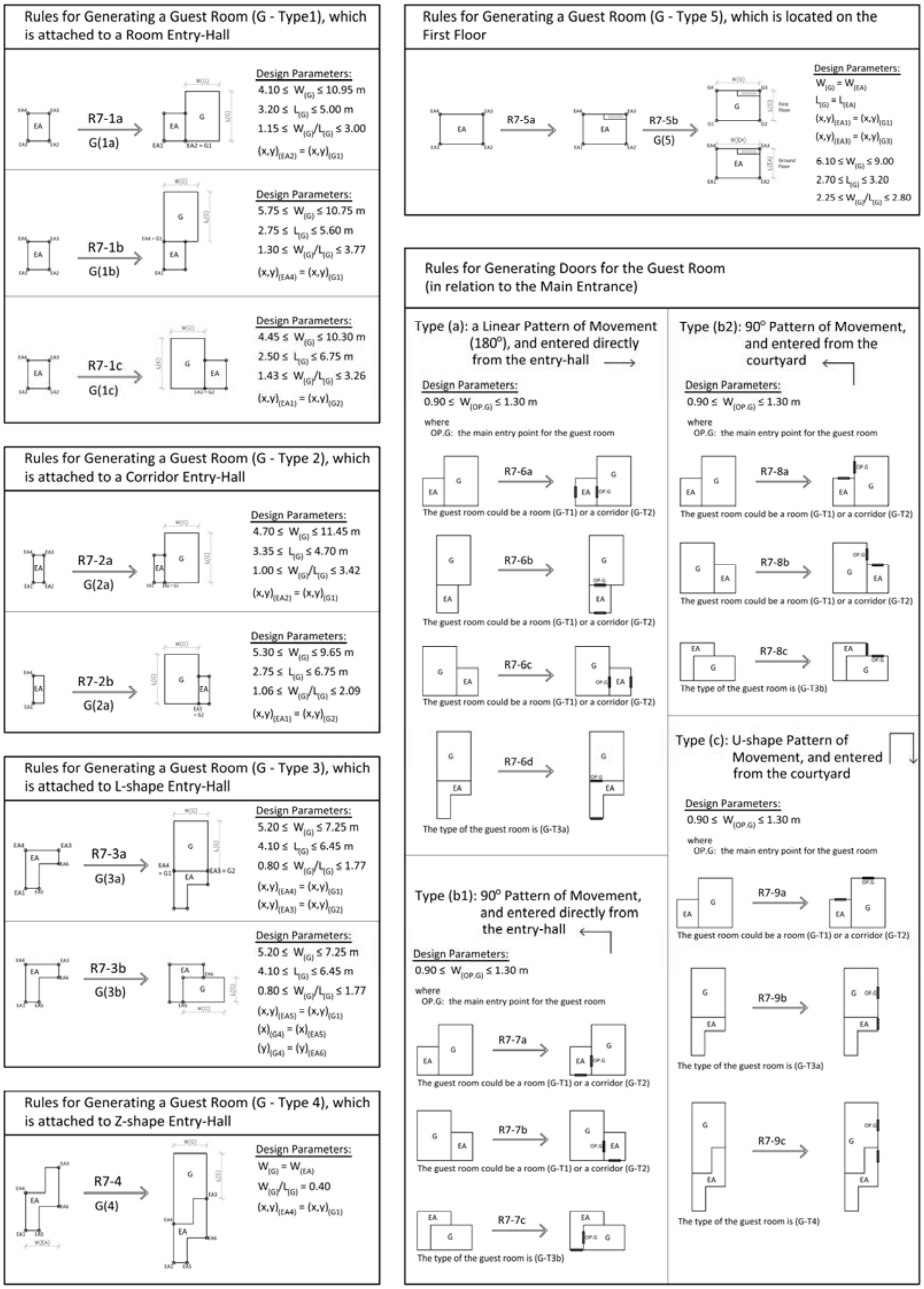


Figure 5.26: Sets of parametric rules for the configuration of a guest room (part 2)

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).

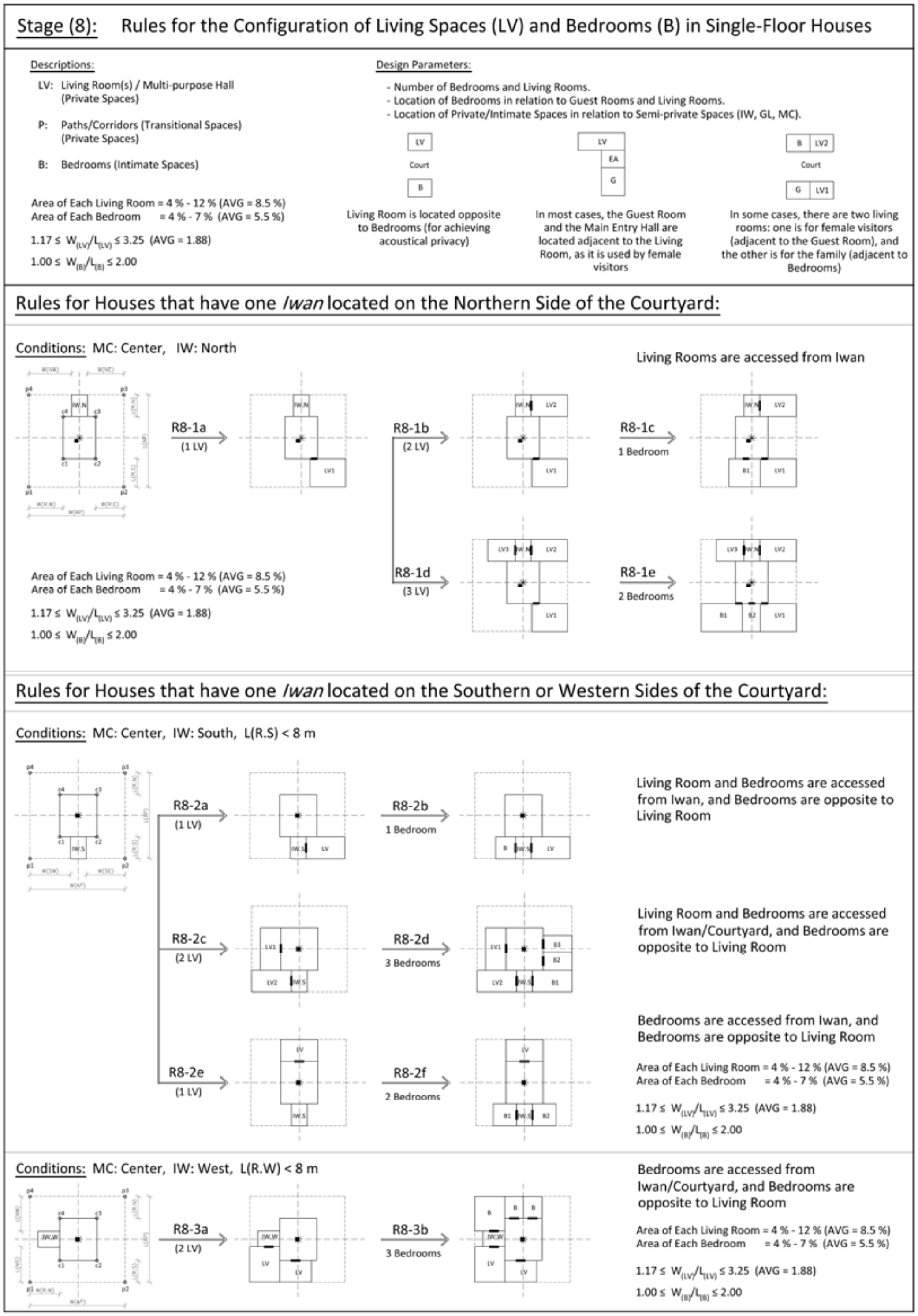


Figure 5.27: Sets of parametric rules for the configuration of living spaces and bedrooms in single-floor houses (part 1)

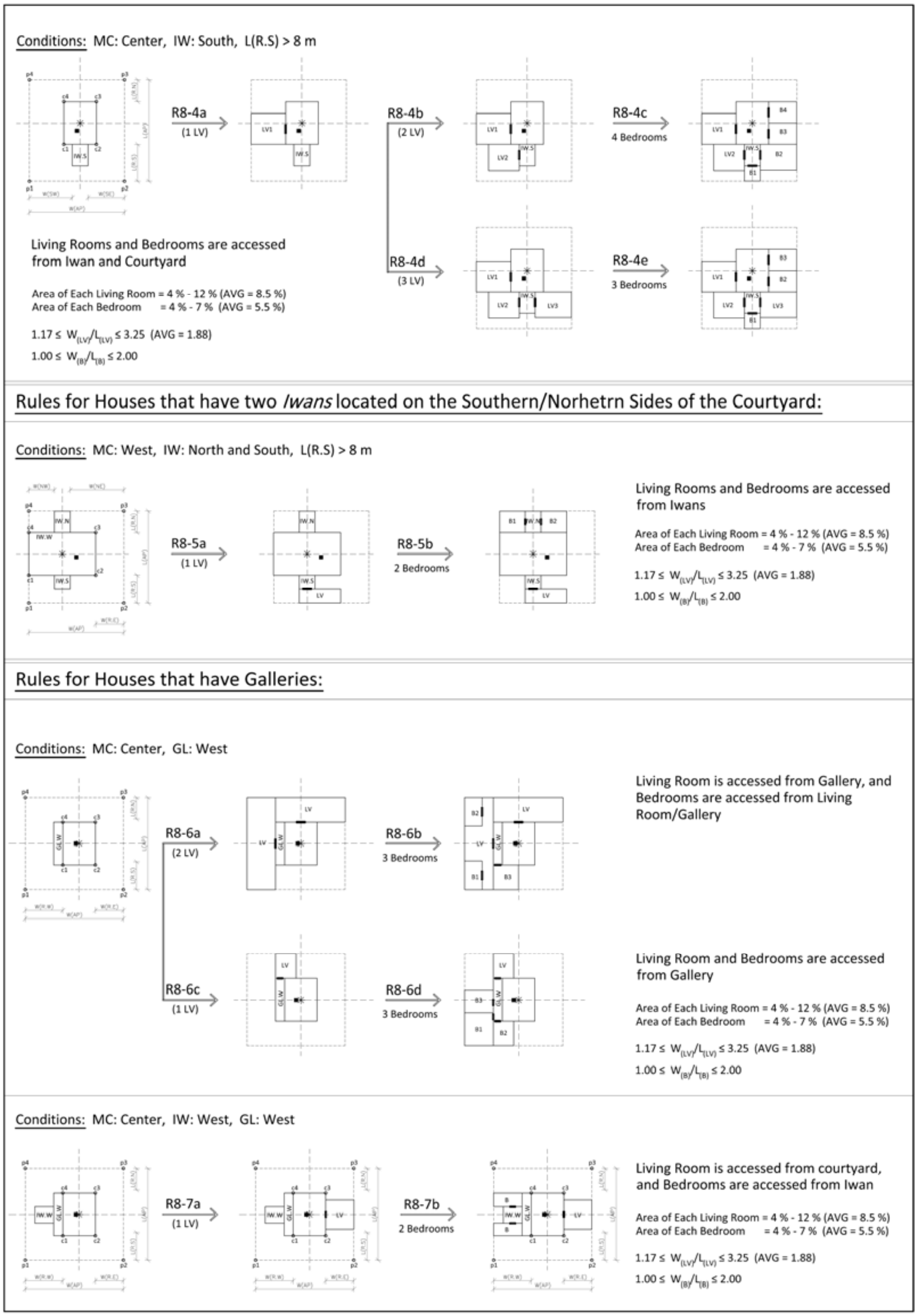


Figure 5.28: Sets of parametric rules for the configuration of living spaces and bedrooms in single-floor houses (part 2)

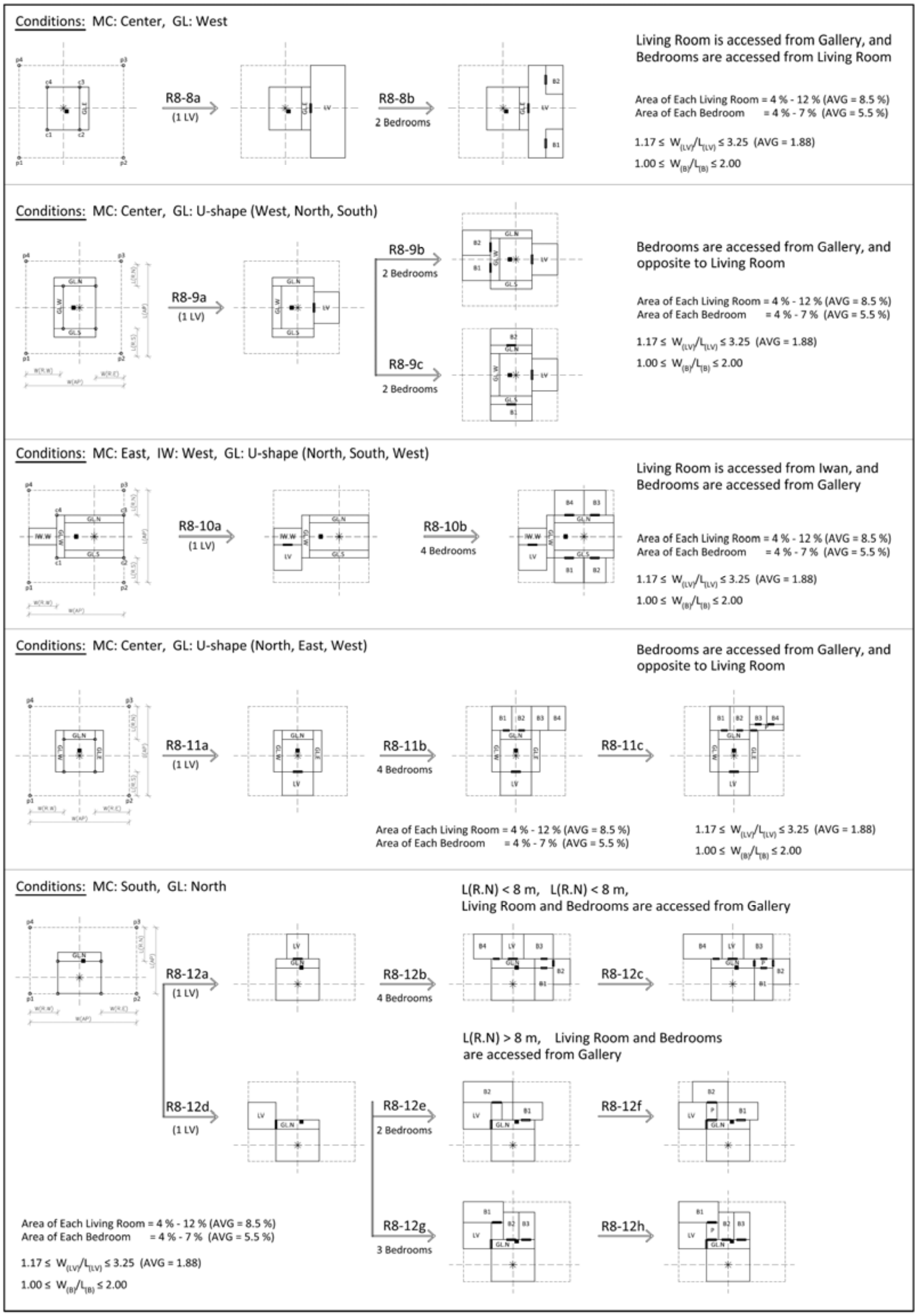


Figure 5.29: Sets of parametric rules for the configuration of living spaces and bedrooms in single-floor houses (part 3)

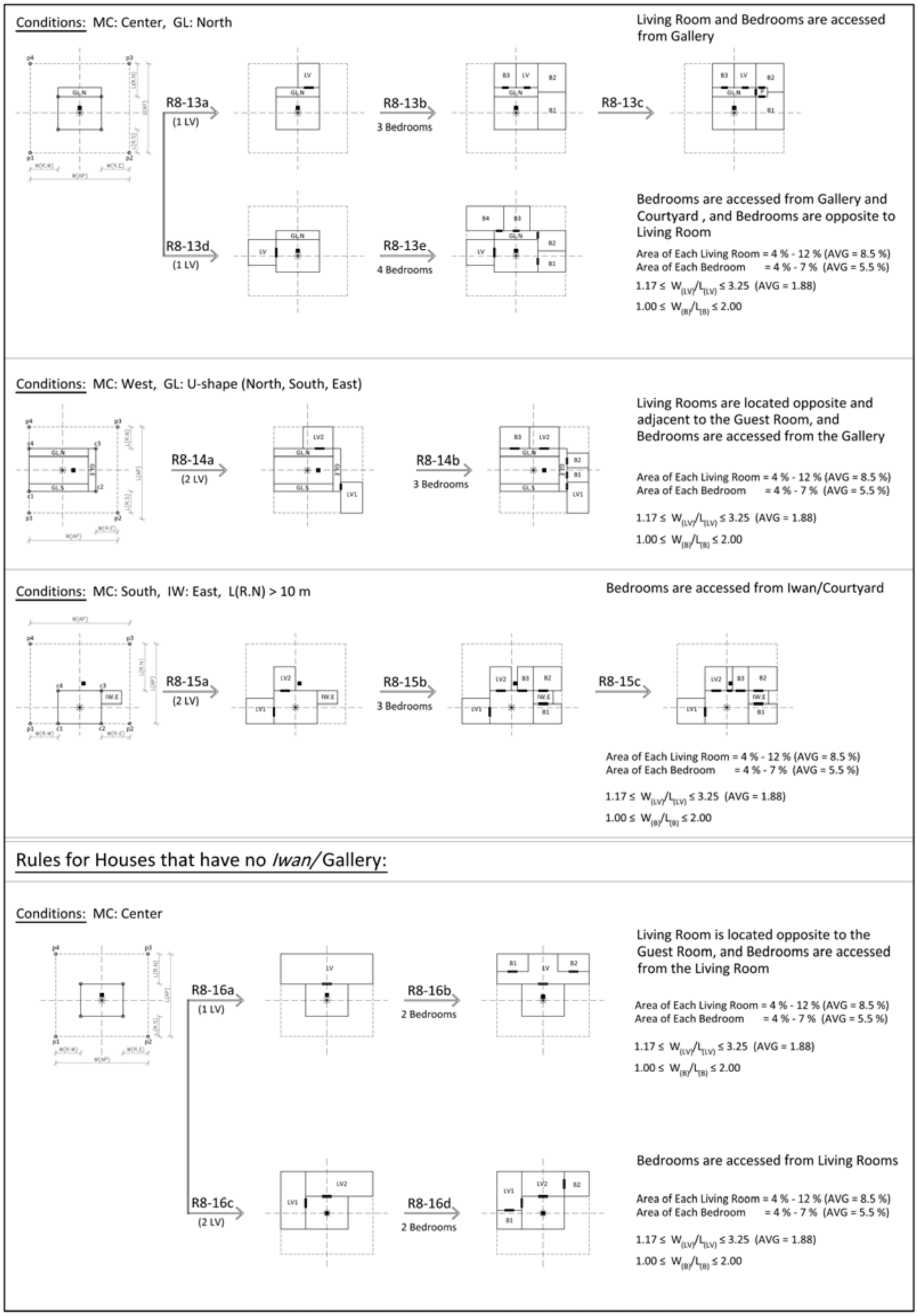


Figure 5.30: Sets of parametric rules for the configuration of living spaces and bedrooms in single-floor houses (part 4)

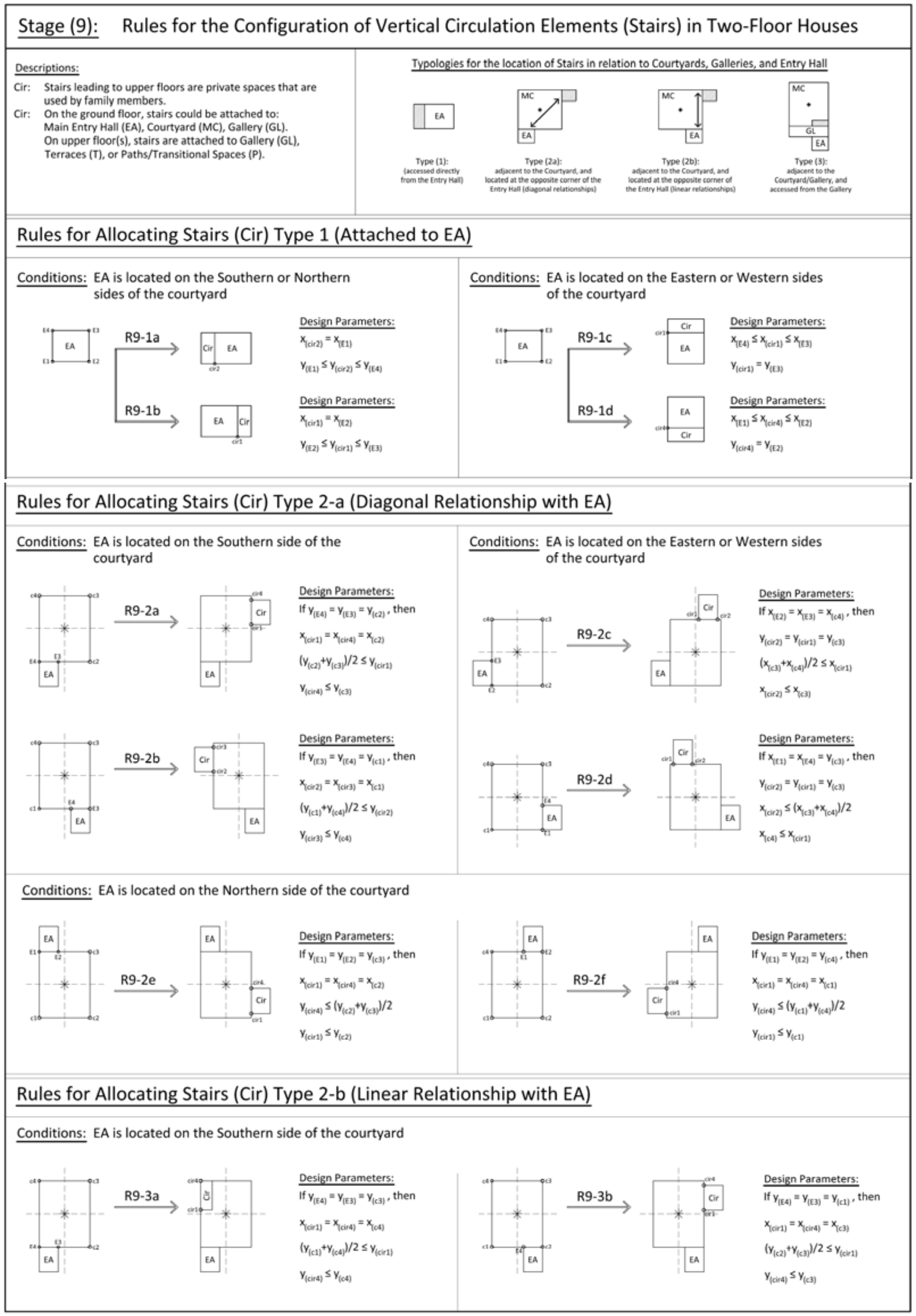


Figure 5.31: Sets of parametric rules for the configuration of vertical circulation elements in two-floor houses (part 1)

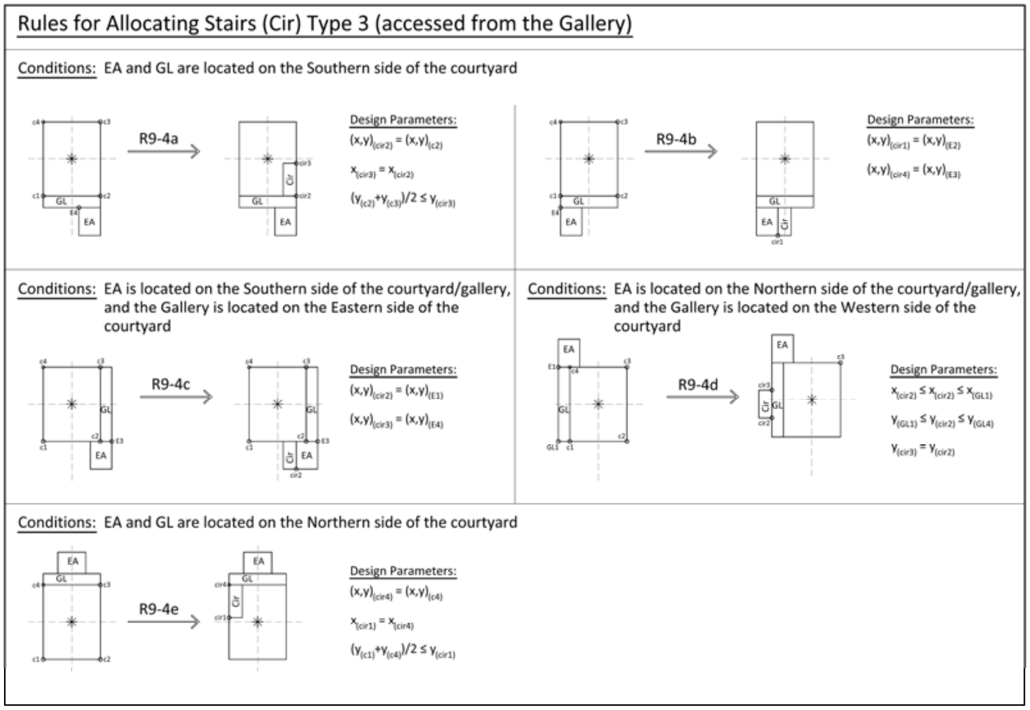


Figure 5.32: Sets of parametric rules for the configuration of vertical circulation elements in two-floor houses (part 2)

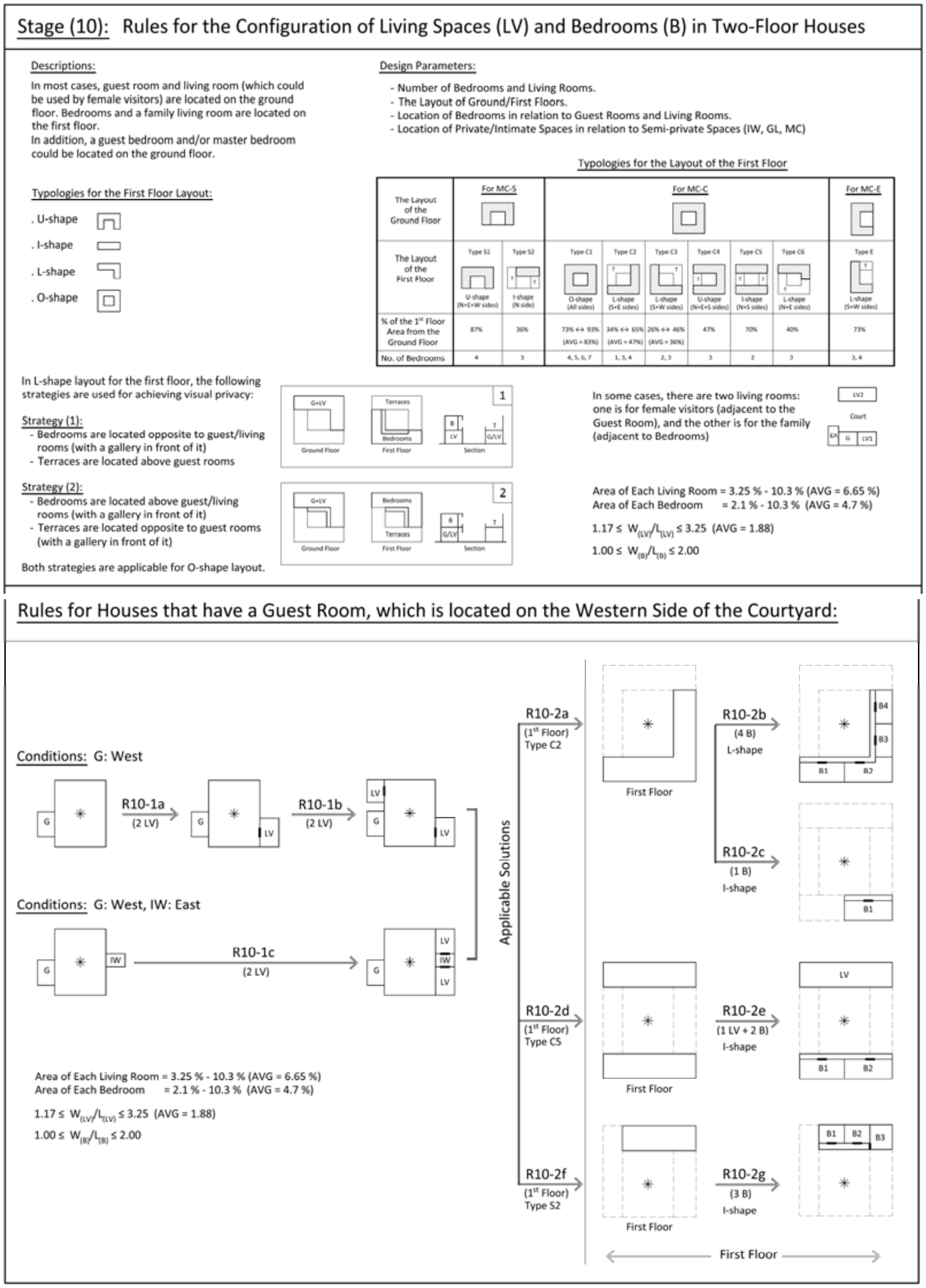


Figure 5.33: Sets of parametric rules for the configuration of living spaces and bedrooms in two-floor houses (part 1)

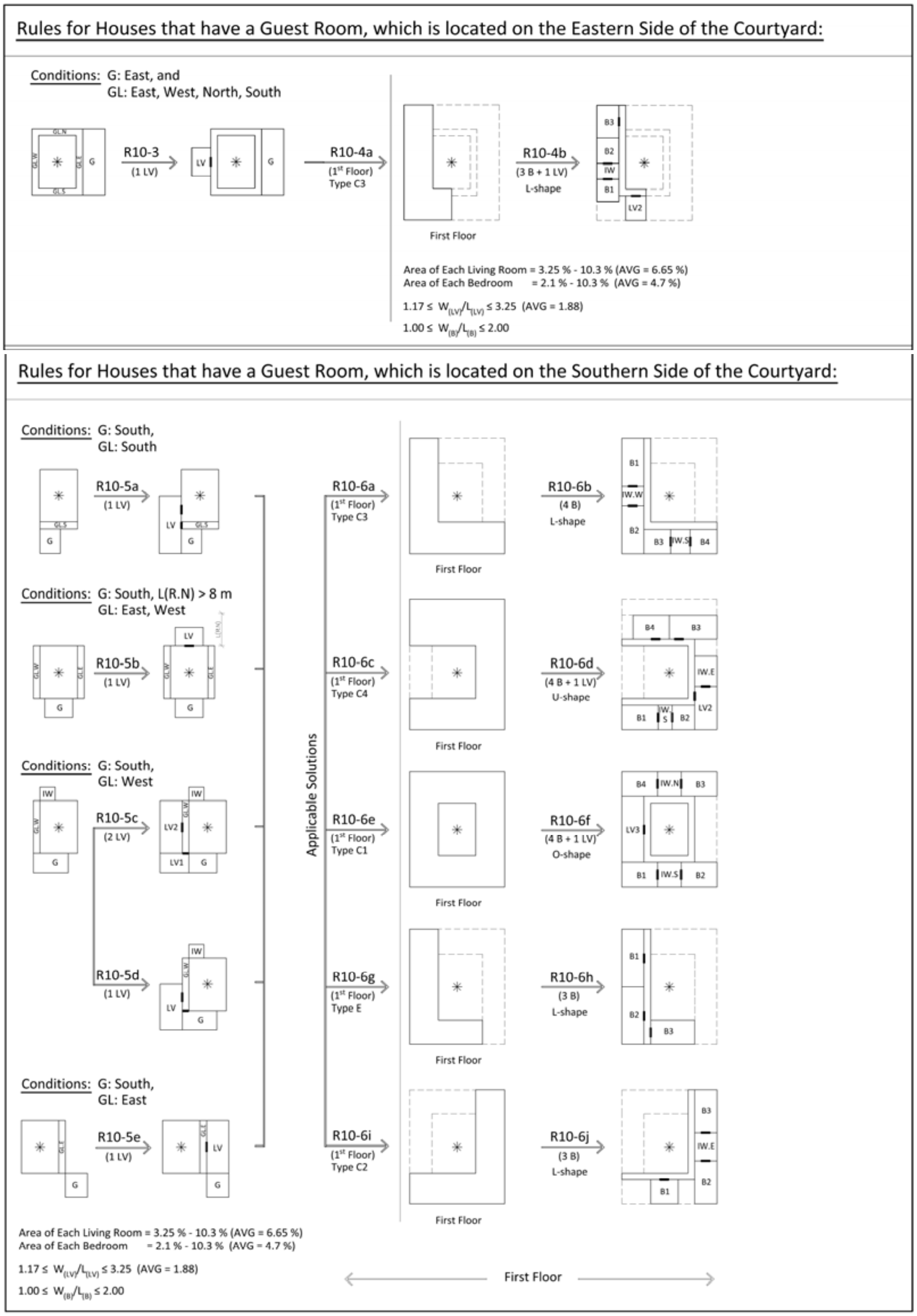


Figure 5.34: Sets of parametric rules for the configuration of living spaces and bedrooms in two-floor houses (part 2)

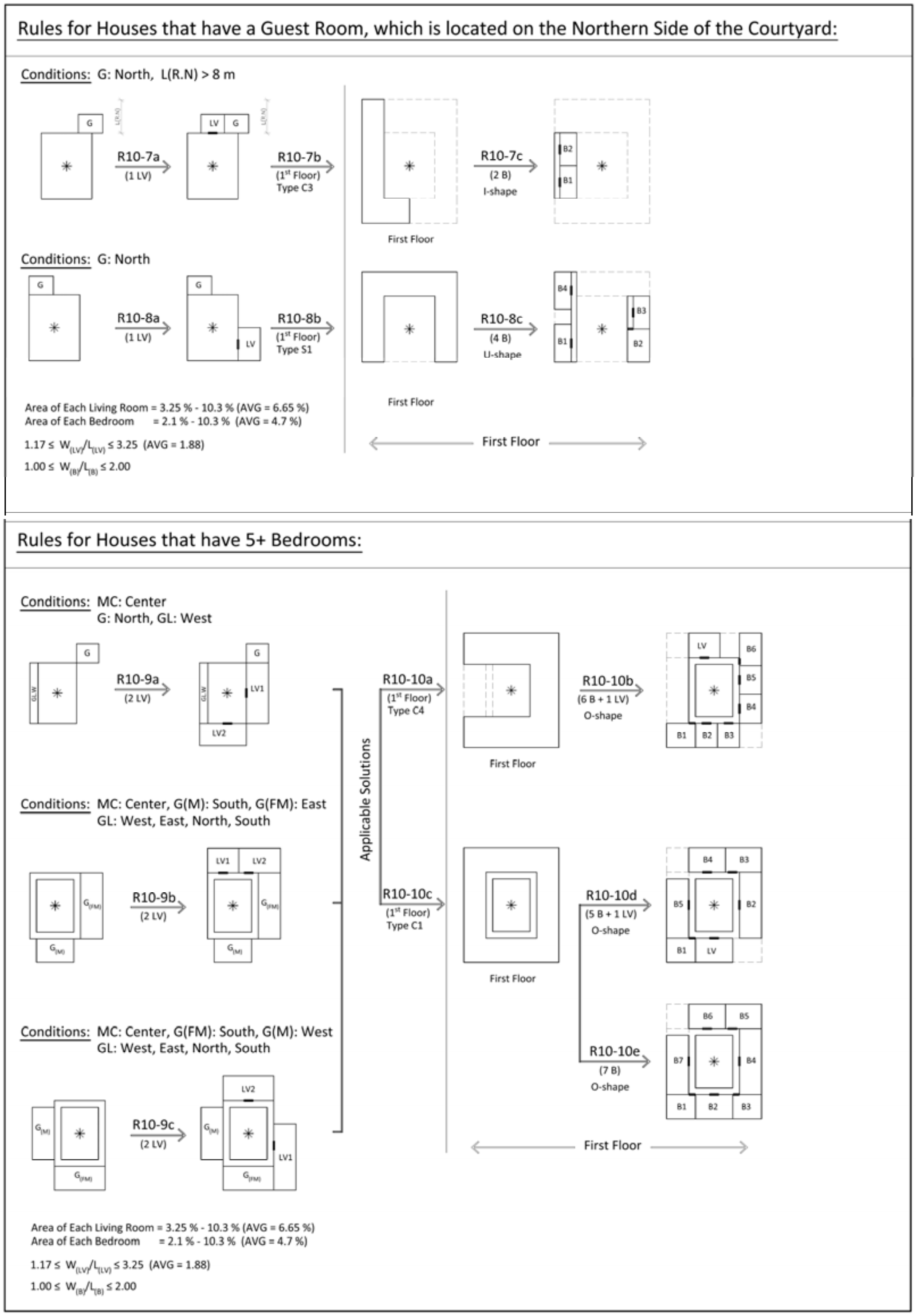


Figure 5.35: Sets of parametric rules for the configuration of living spaces and bedrooms in two-floor houses (part 3)

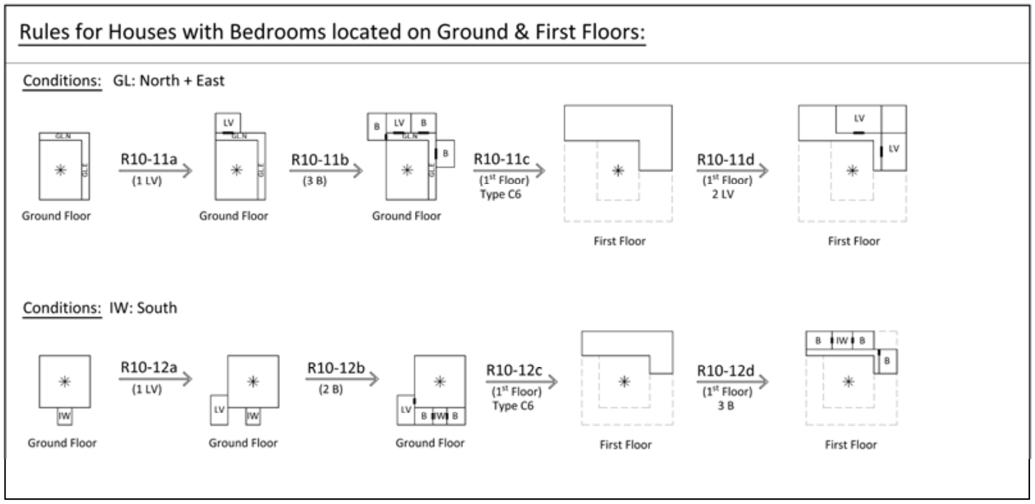


Figure 5.36: Sets of parametric rules for the configuration of living spaces and bedrooms in two-floor houses (part 4)

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).

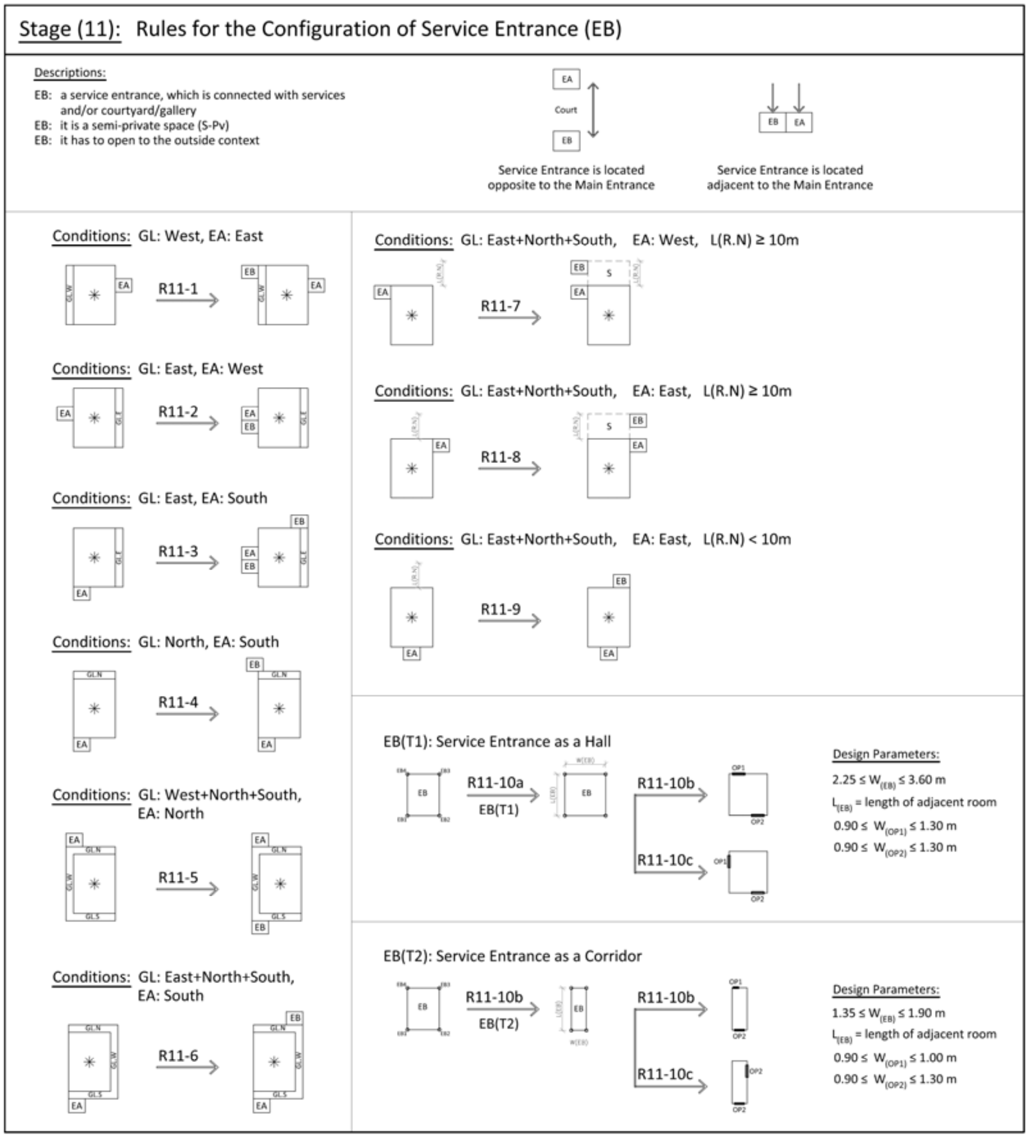


Figure 5.37: Sets of parametric rules for the configuration of service entrance

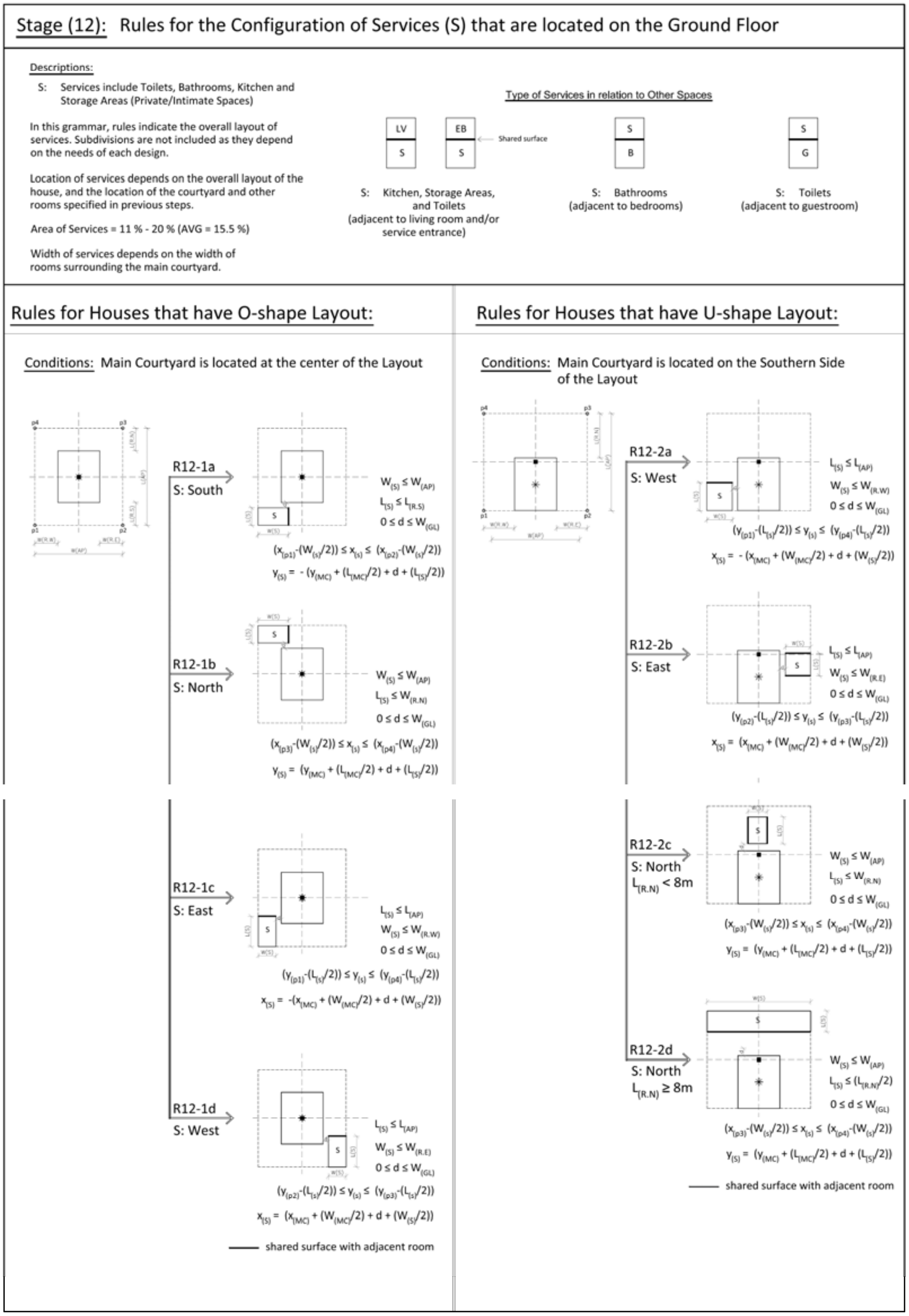


Figure 5.38: Sets of parametric rules for the configuration of services that are located on the ground floor (part 1)

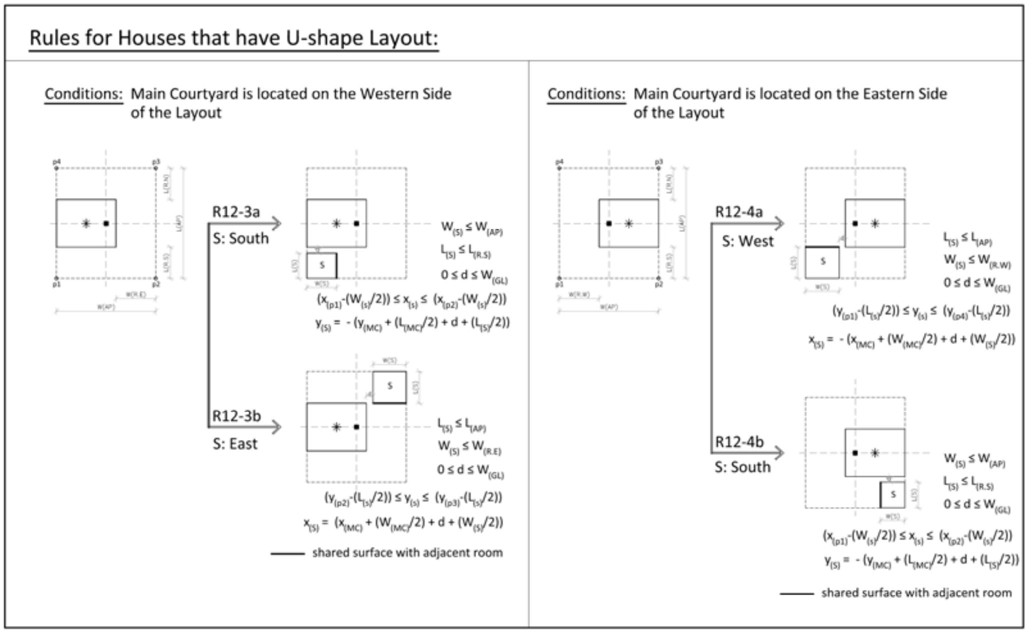


Figure 5.39: Sets of parametric rules for the configuration of services that are located on the ground floor (part 2)

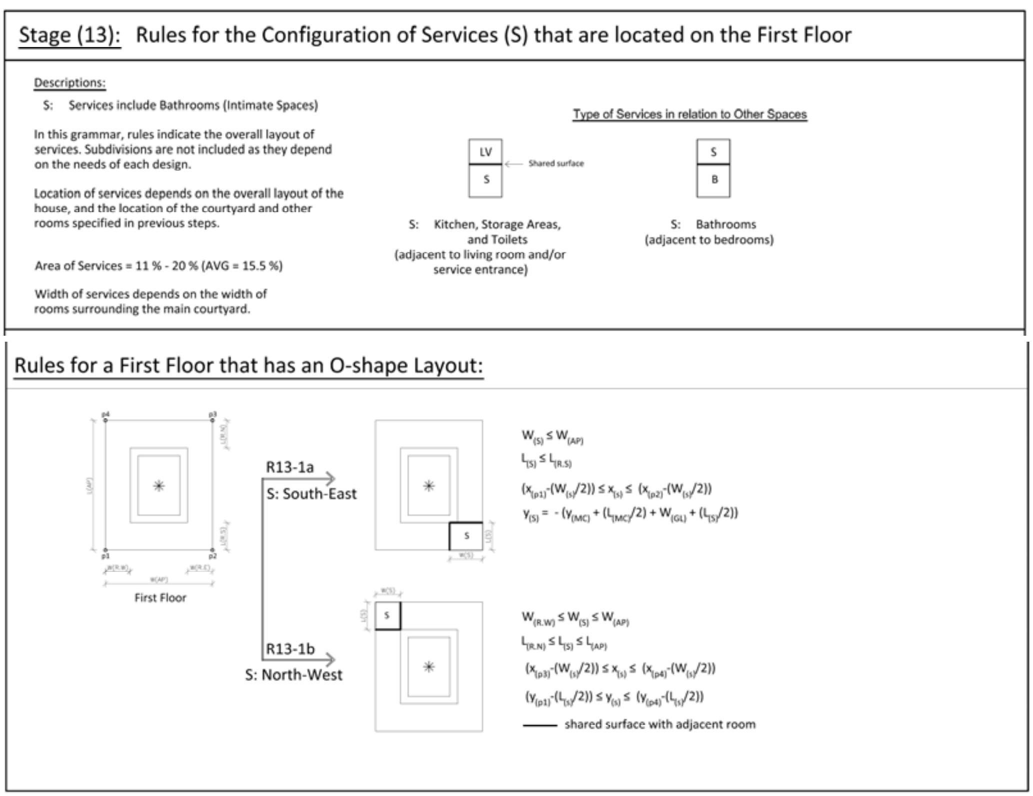


Figure 5.40: Sets of parametric rules for the configuration of services that are located on the first floor (part 1)

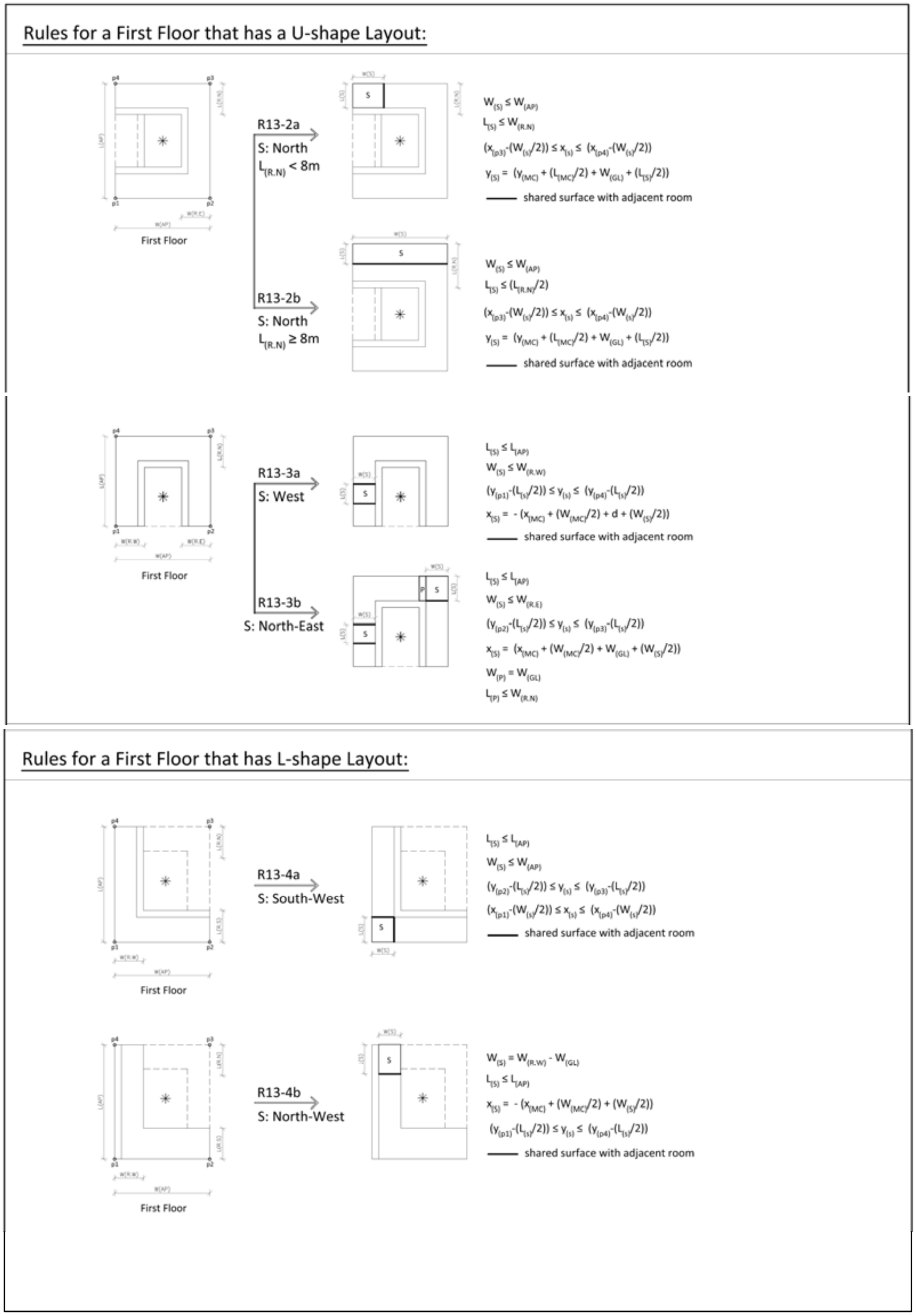


Figure 5.41: Sets of parametric rules for the configuration of services that are located on the first floor (part 2)

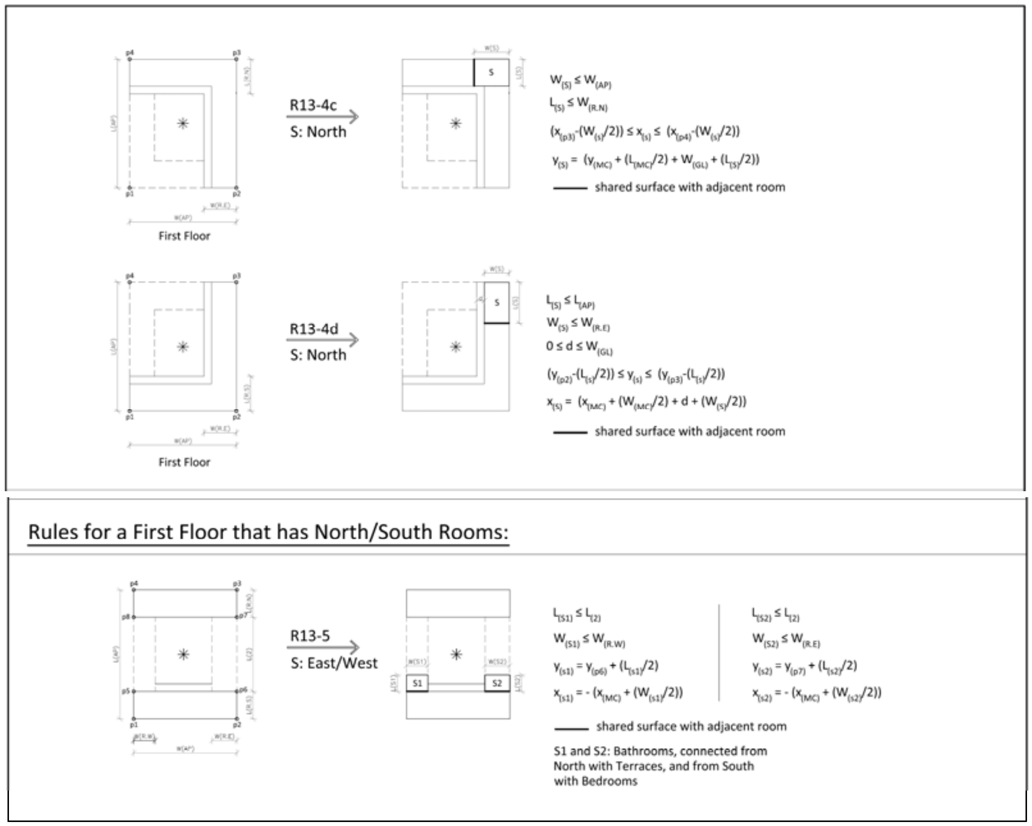


Figure 5.42: Sets of parametric rules for the configuration of services that are located on the first floor (part 3)

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).

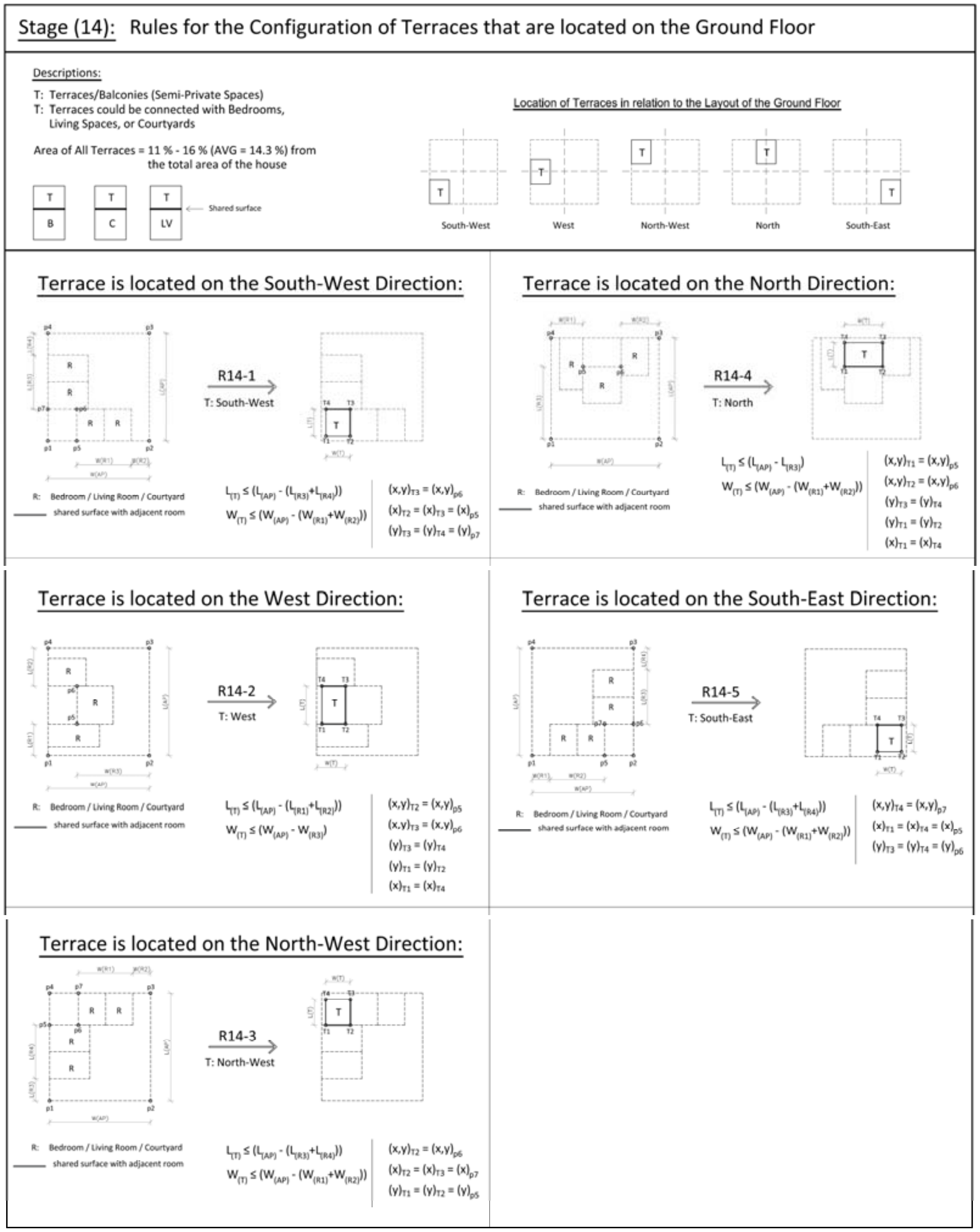


Figure 5.43: Sets of parametric rules for the configuration of terraces and balconies on the ground floor

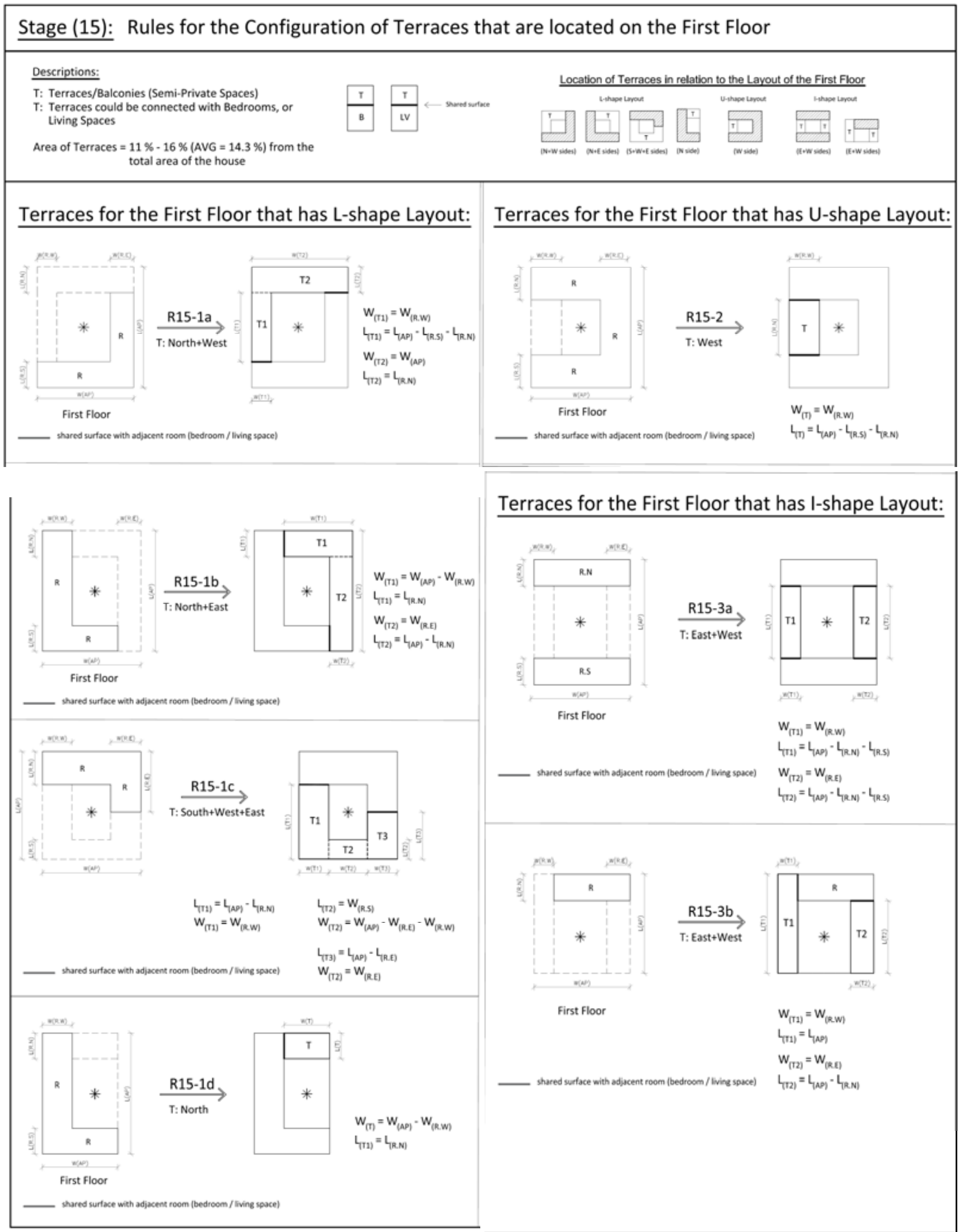


Figure 5.44: Sets of parametric rules for the configuration of terraces on the first floor

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).

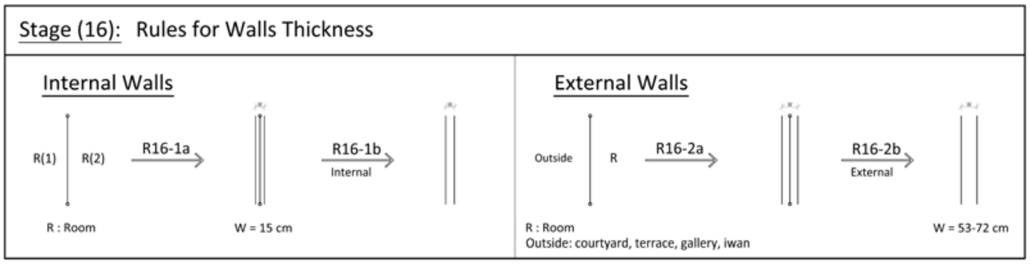


Figure 5.45: Parametric rules for determining internal/external wall thickness

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, fuction, 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 entring 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 paramters 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.

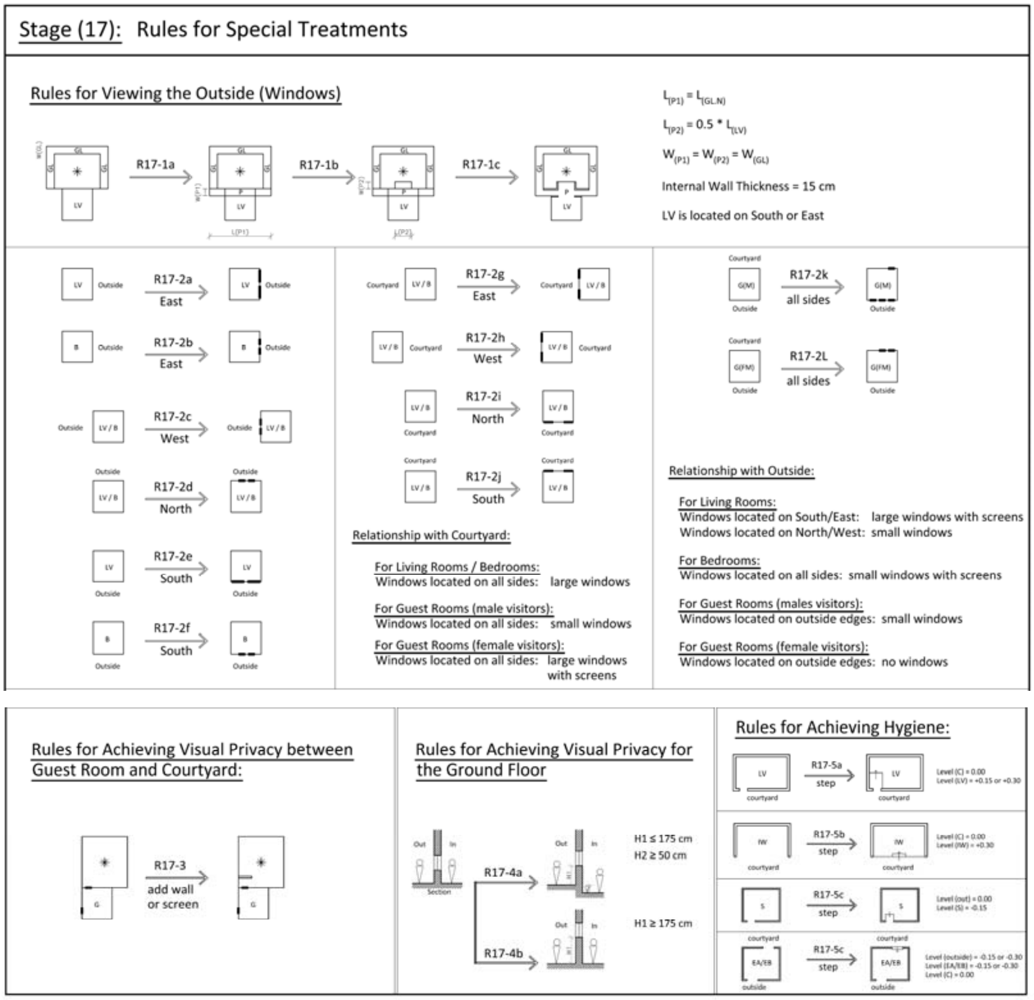


Figure 5.46: Parametric rules for attaining certain social qualities: viewing the outside, achieving visual privacy, and hygiene

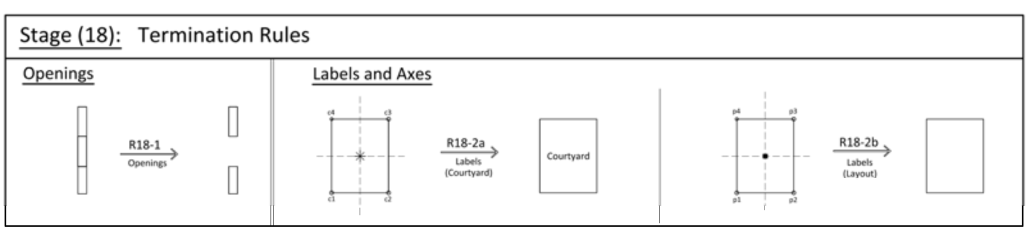


Figure 5.47: Termination rules

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^2 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).

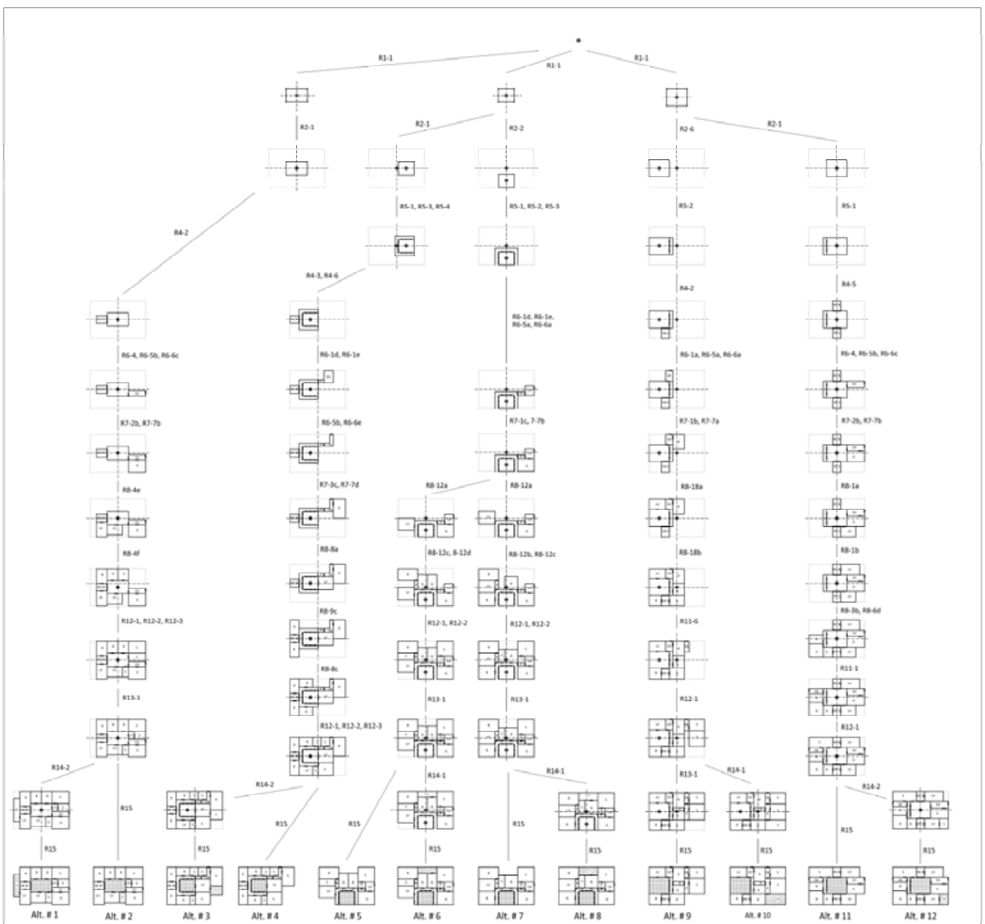


Figure 5.48: The generation process of 12 new solutions for courtyard houses

Figure 5.49: Evaluating the visual privacy between public and private zones for the new alternatives
(Produced by the Researcher, using Syntax2D software)

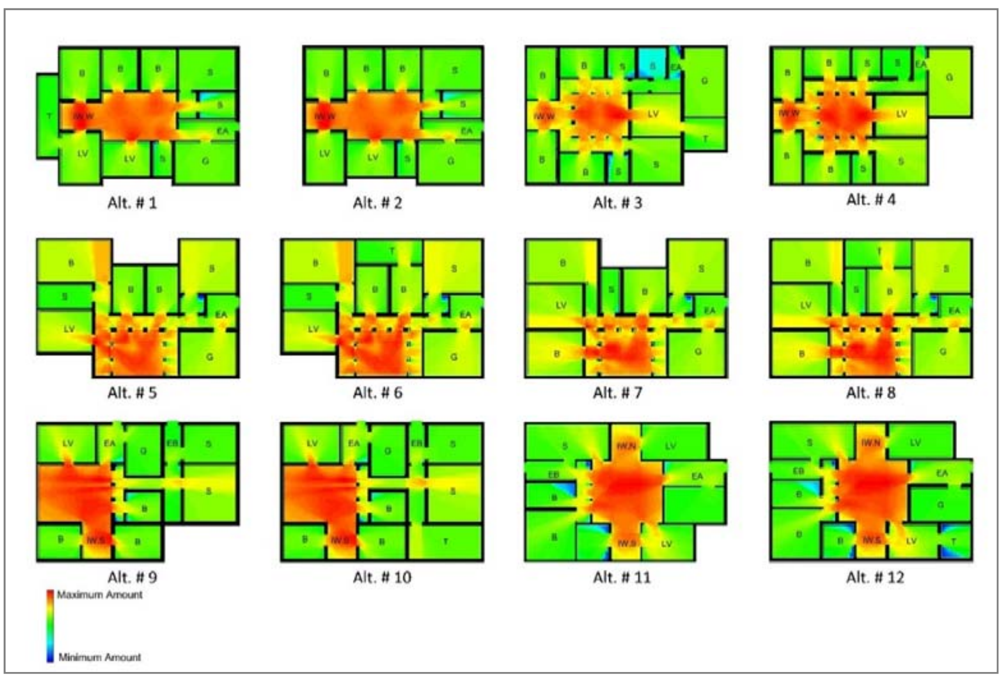


Figure 5.50: Visibility graph analysis for the new solutions showing the connectivity value for each space
(Produced by the Researcher, using DepthmapX software)

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).

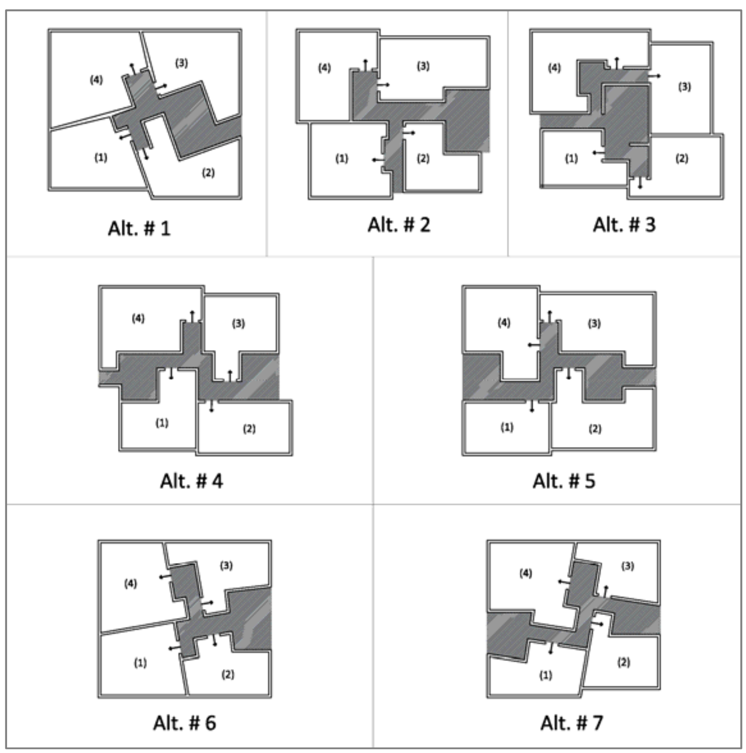


Figure 5.51: New solutions for clusters of houses generated by the constructed grammar

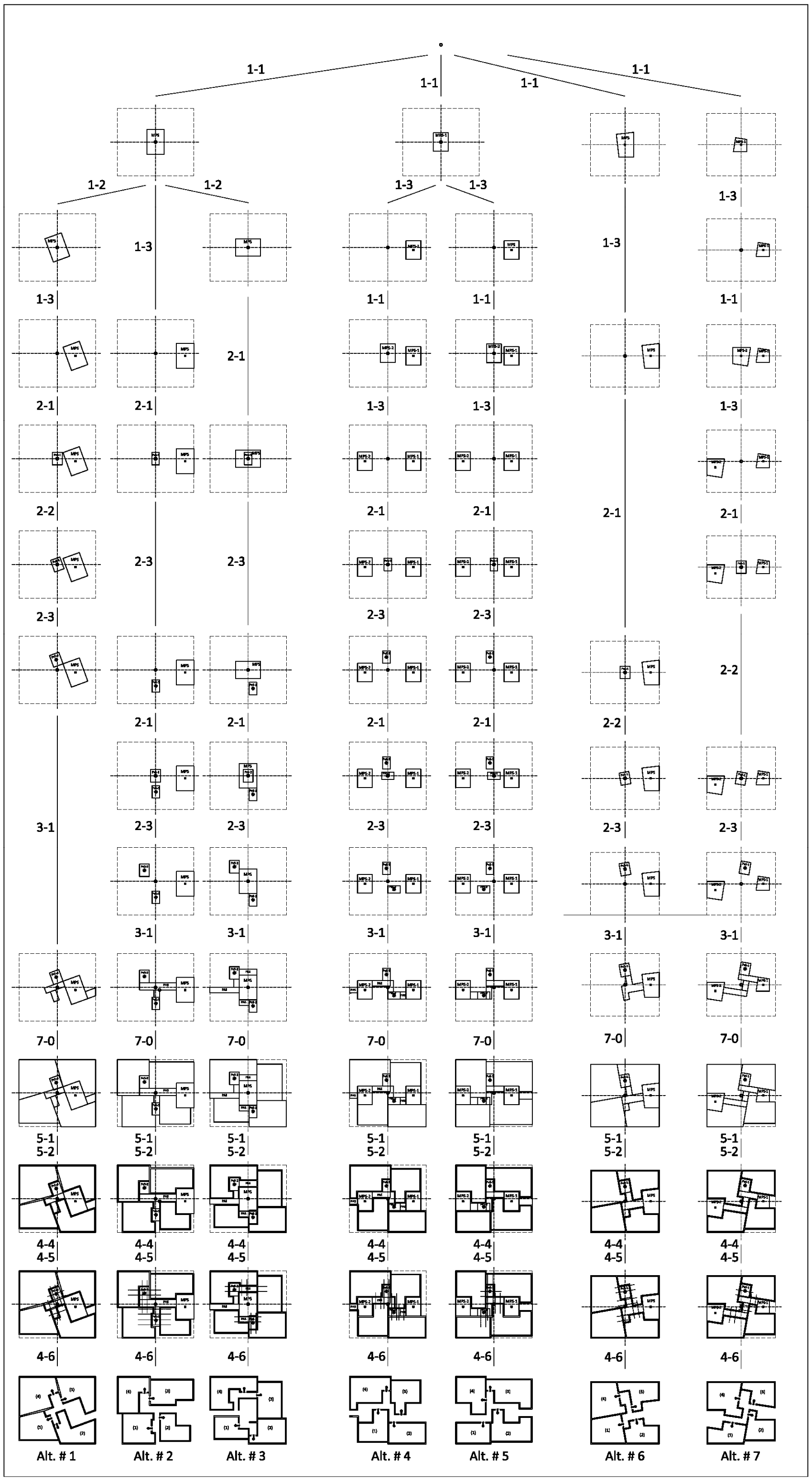


Figure 5.52: The generation process of seven new solutions for clusters of houses

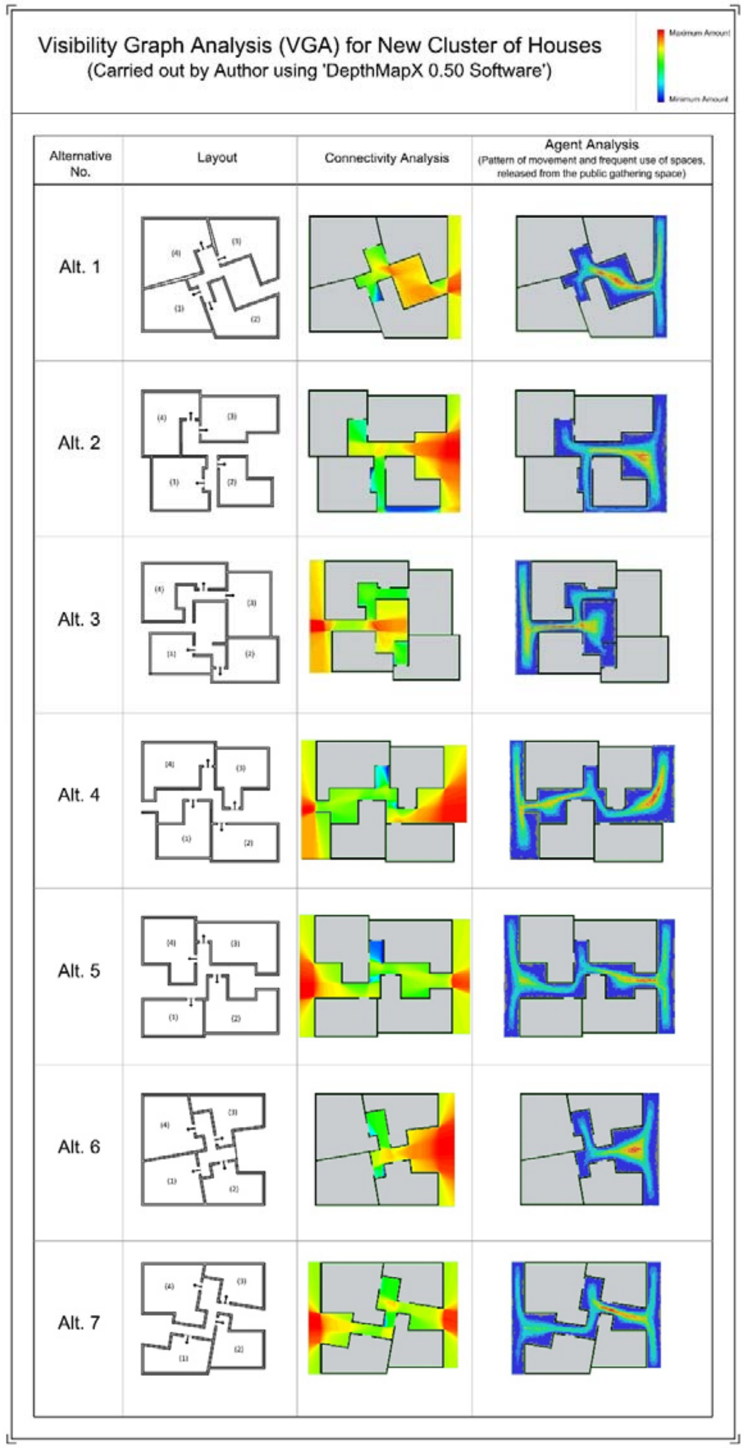


Figure 5.53: Visibility graph analysis for the new solutions showing connectivity values for common spaces
(Produced by the Researcher, using DepthmapX software)

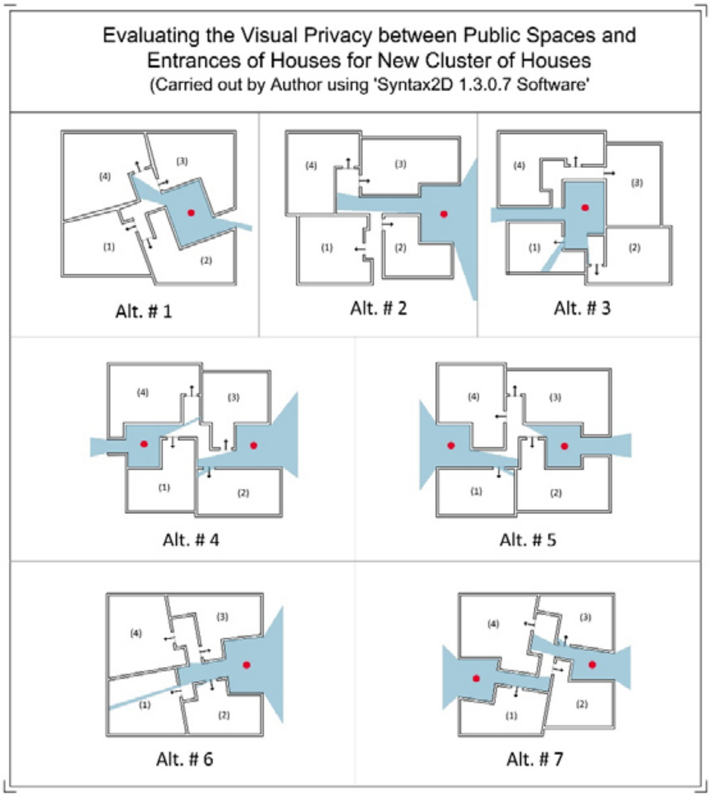


Figure 5.54: Evaluating the visual privacy between public spaces and entrances of houses for the new alternatives
(Produced by the Researcher, using Syntax2D software)

5.5. Conclusion

Based on information extracted from typological, syntactical and scaler 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; Dİno 2012; Segers *et al.* 2001). In this part, results extracted from spatial analysis of vernacular houses and neighbourhoods, and prefenreces 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.

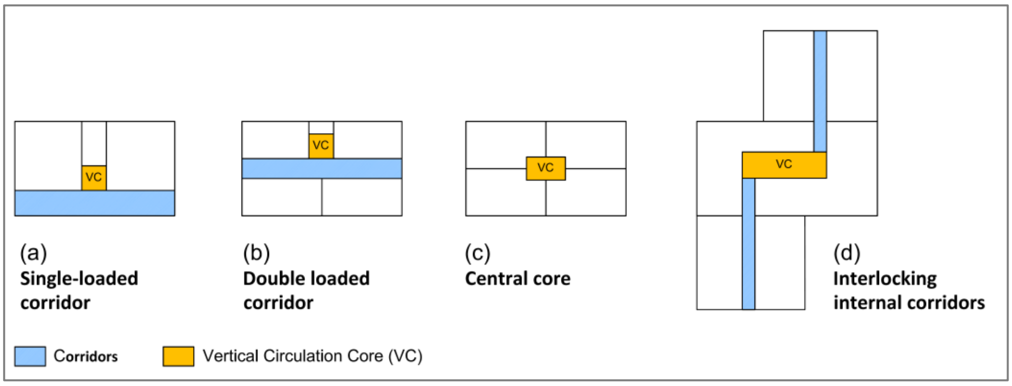


Figure 5.55: Different layouts for the arrangement of apartments in high-rise buildings

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 Auther, 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.

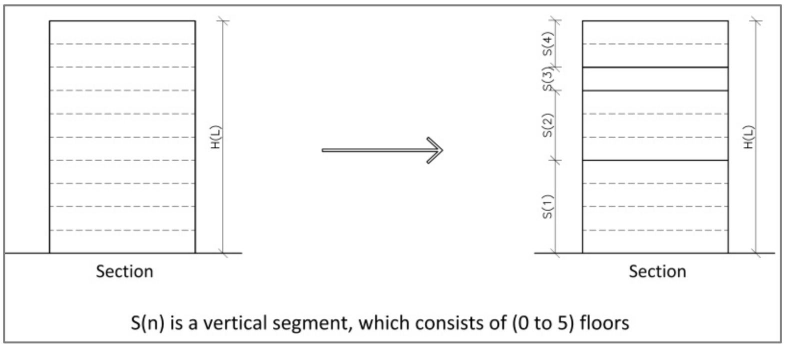


Figure 5.56: The concept of a vertical segmentation for a high-rise building into horizontal quarters

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.

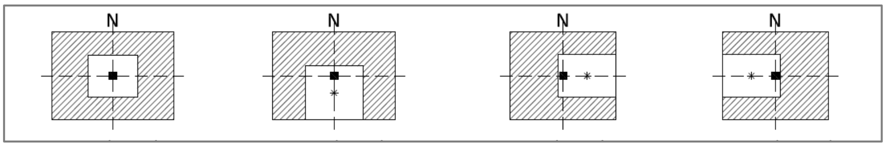


Figure 5.57: Diagrams showing possibilities for the location of the courtyard inside apartments

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.

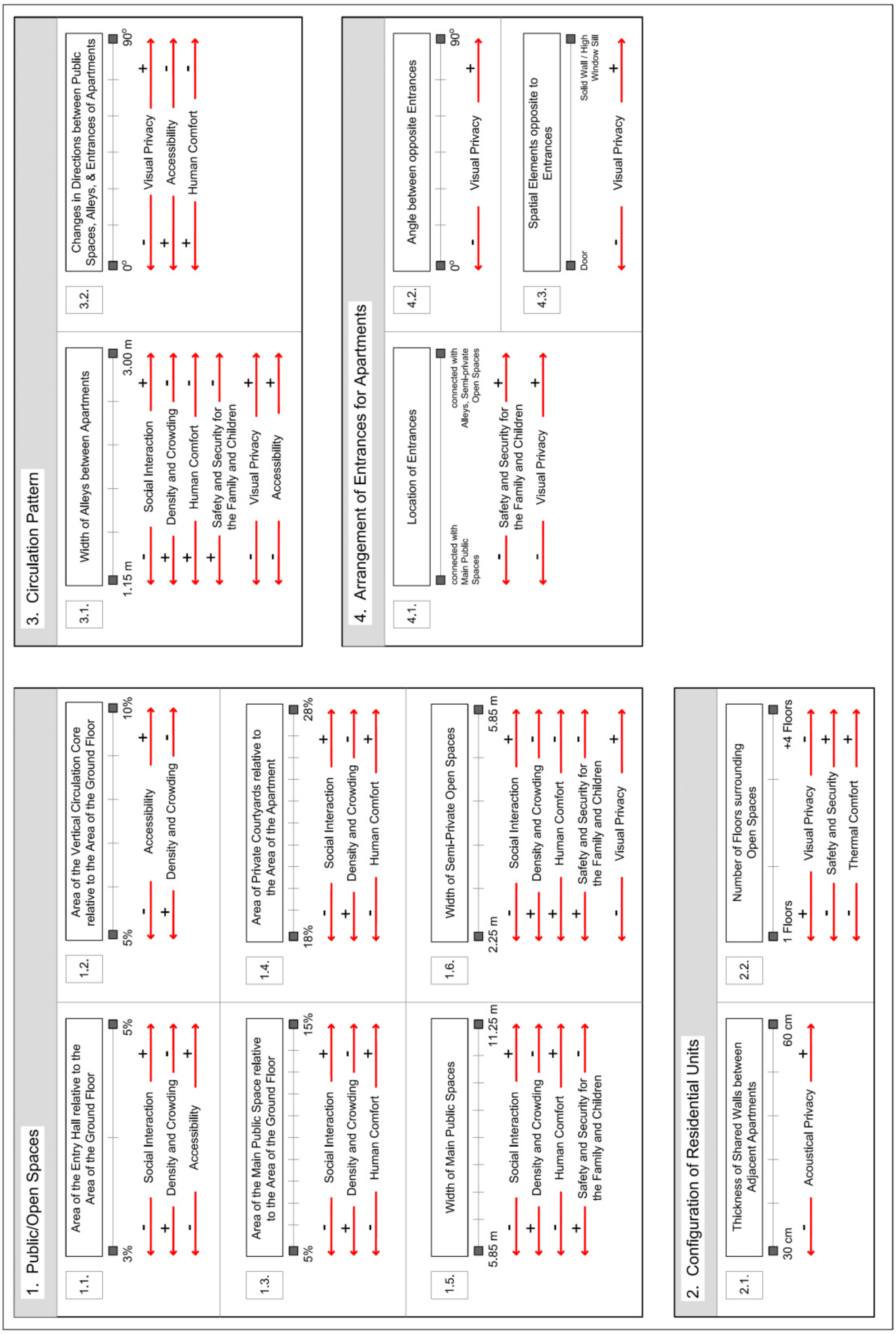


Figure 5.58: Parametric relationships between social sustainability and elements of design in residential buildings

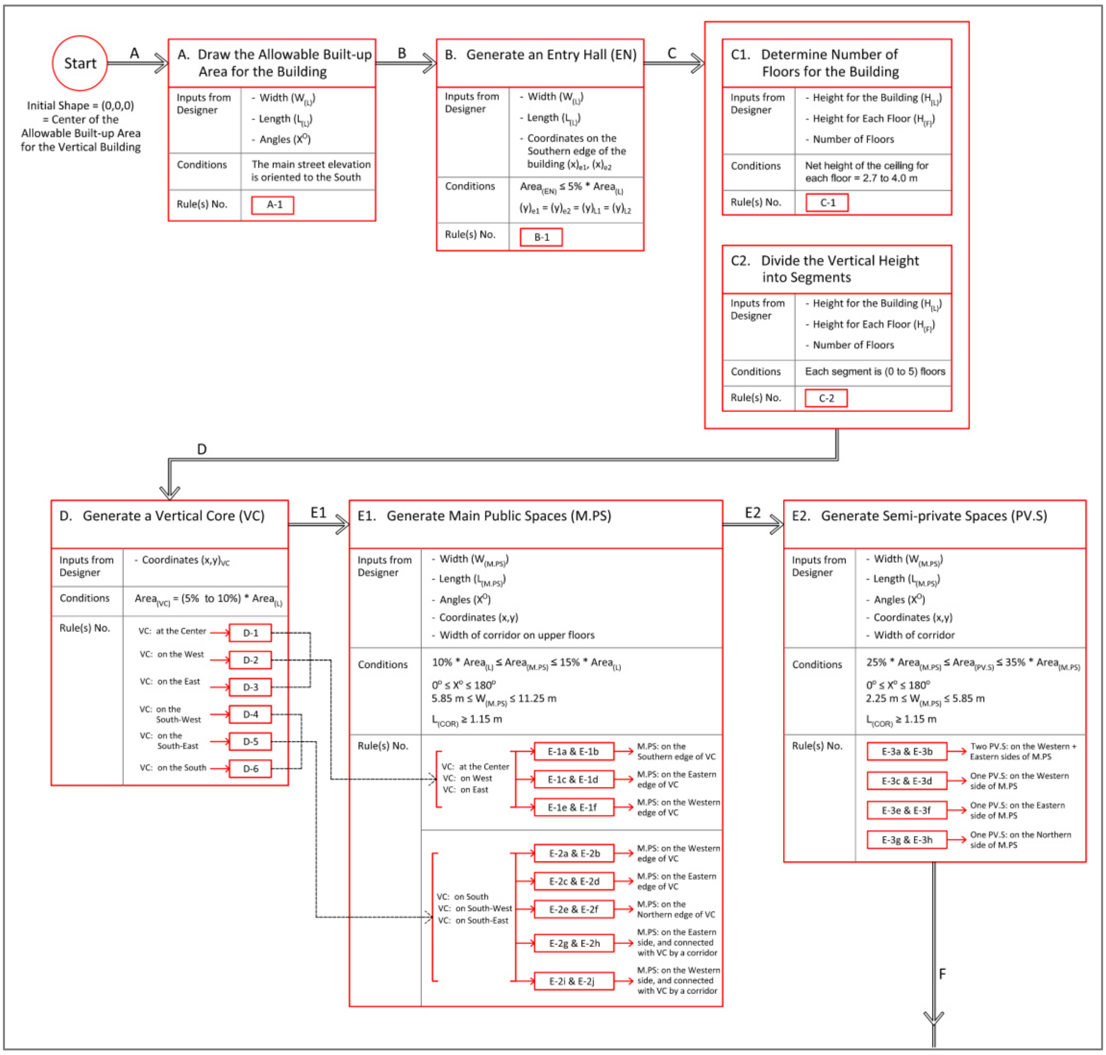


Figure 5.59: Groups of parametric rules for generating a high-rise residential building (Part 1)

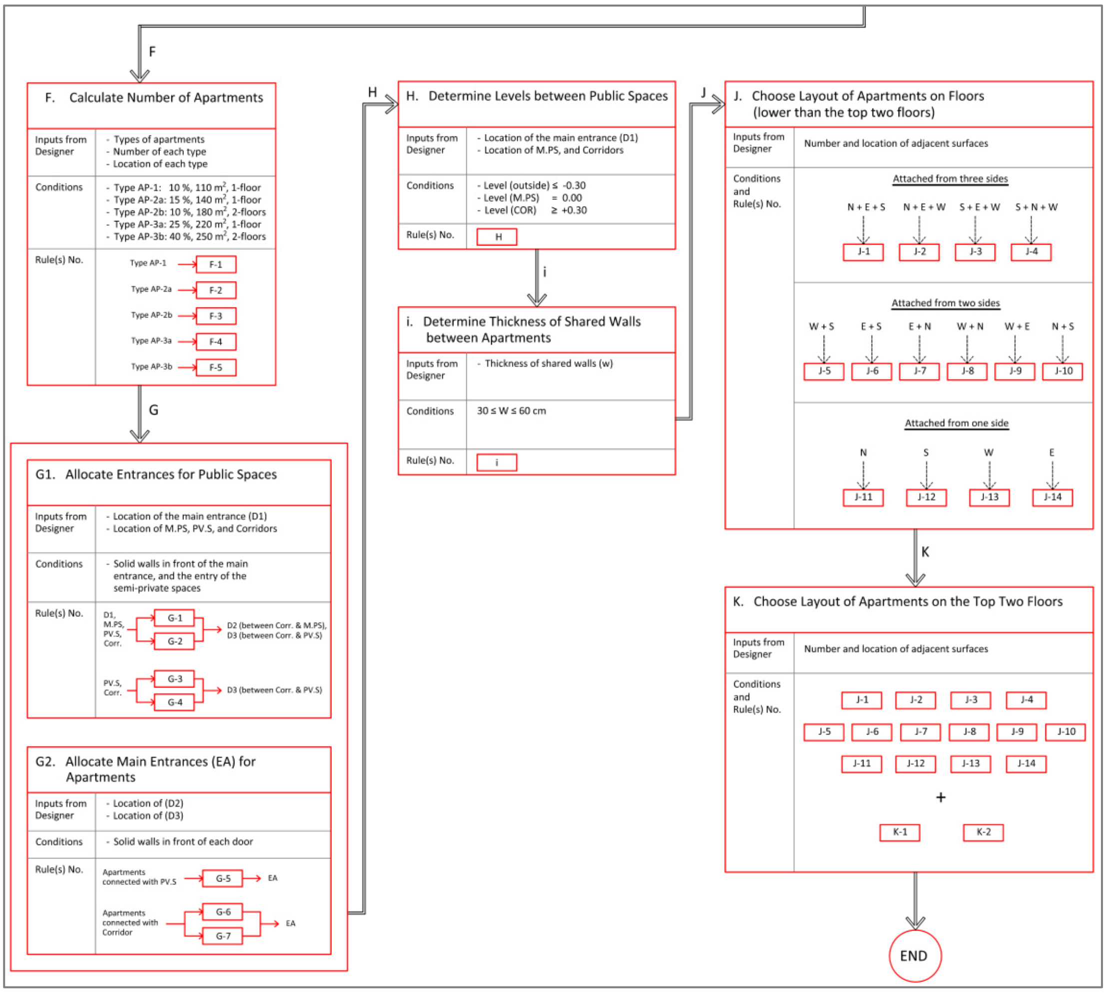


Figure 5.60: Groups of parametric rules for generating a high-rise residential building (Part 2)

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).

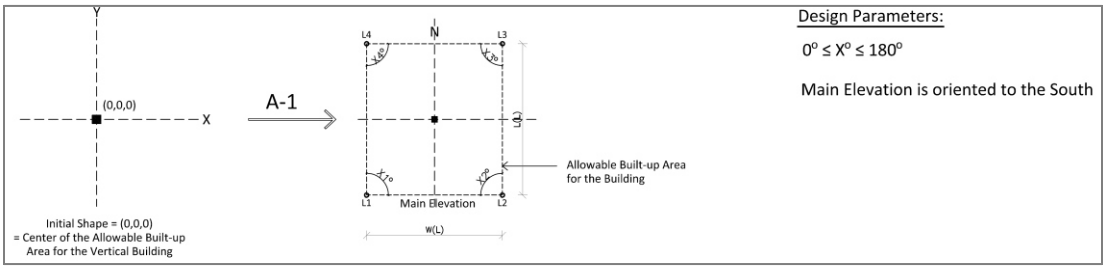


Figure 5.61: Stage (A): Rules for generating the allowable built-up area for the building

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.

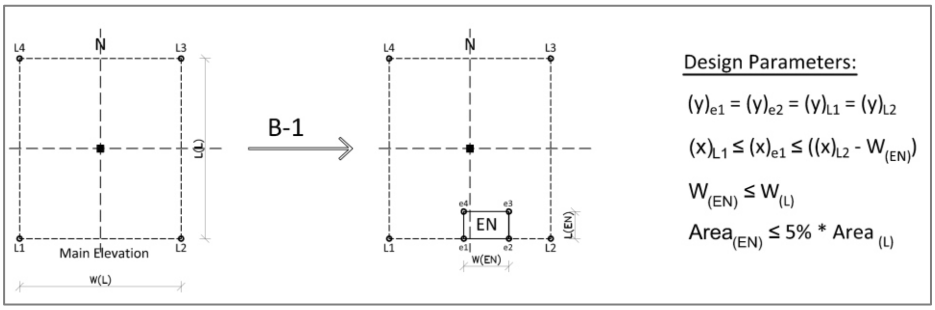


Figure 5.62: Stage (B): Rules for generating the entry hall (EN) on the ground floor

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).

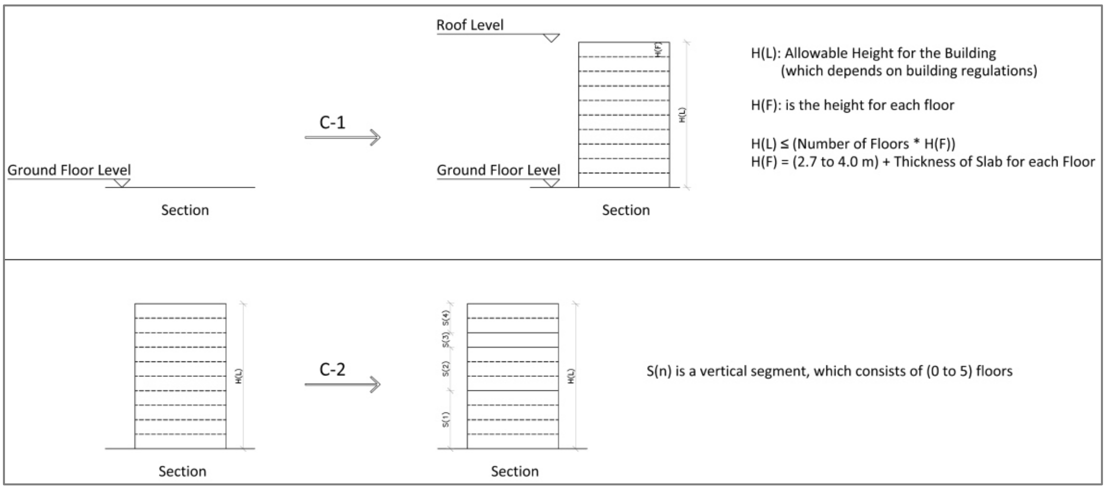


Figure 5.63: Stage (C): Rules for dividing the building into vertical segments

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).

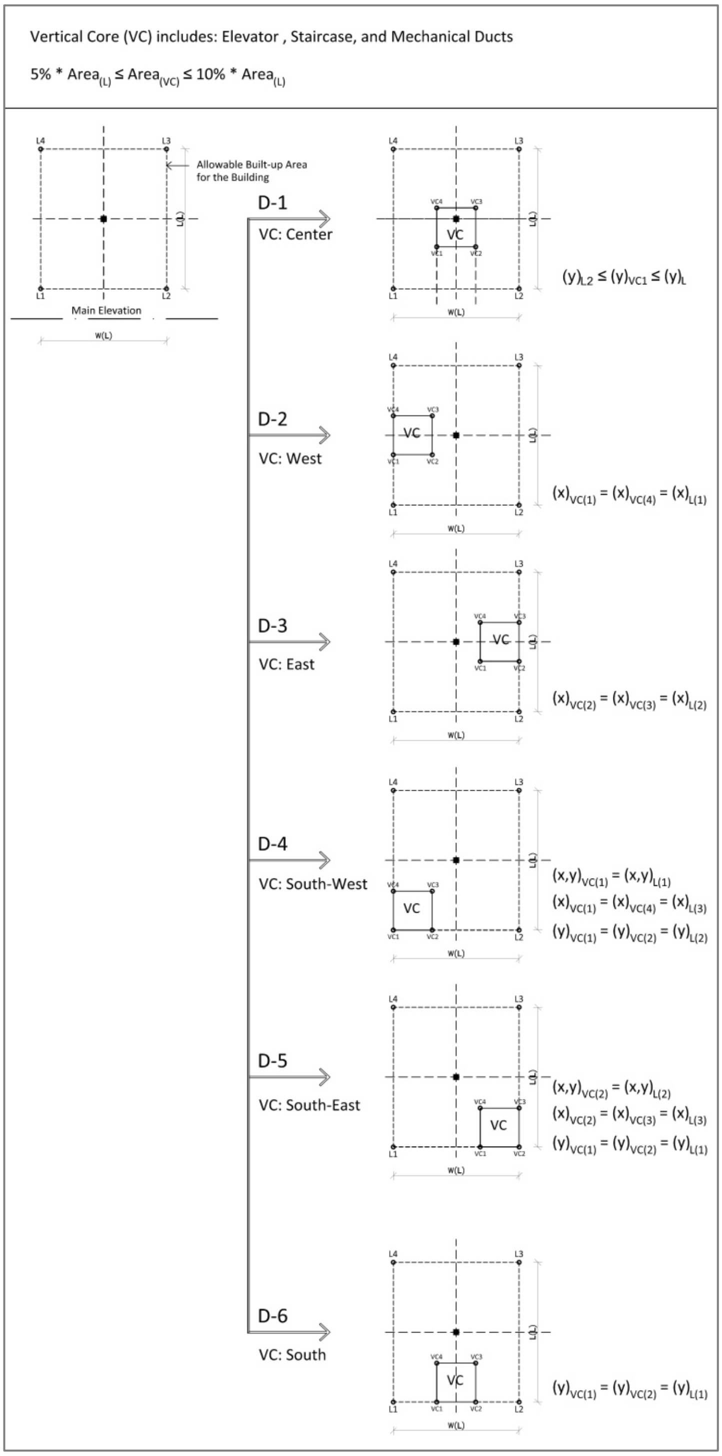


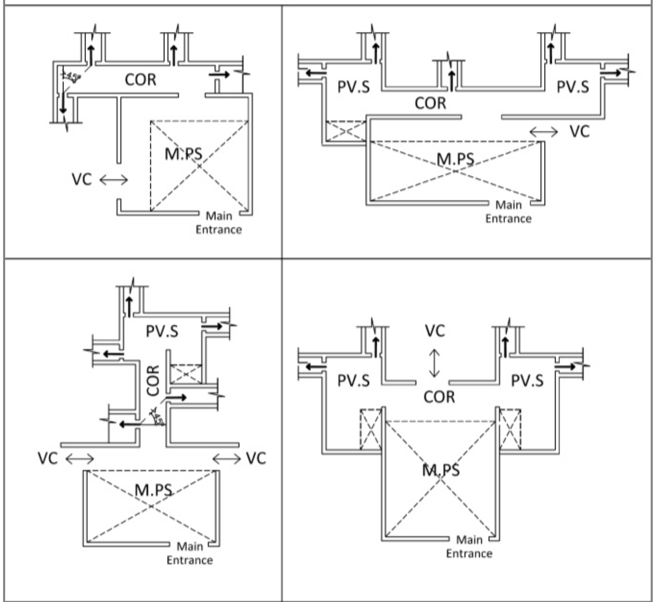
Figure 5.64: Stage (D): Rules for generating a vertical circulation core (VC)

Descriptions:

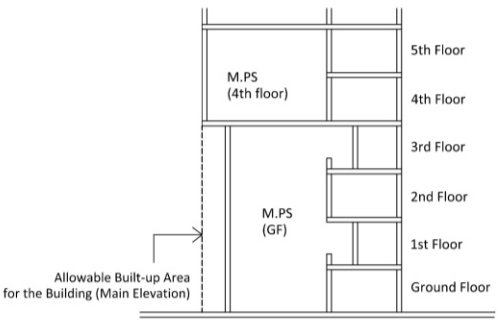
- There is a Hierarchy for the Configuration of Public Spaces on Each Floor
- Public Spaces include:
  M.PS: A Main Gathering Area (connected with the vertical circulation and/or the main entrance for the building)
  PV.S: A Semi-Private Space (connected with the entrance of each Apartment)
  COR: Corridors (connecting the M.PS with PV.S). Houses could be directly connected with corridors.

$10\% * Area_{(L)} \leq Area_{(M.PS)} \leq 15\% * Area_{(L)}$

Samples for topological relationships between public spaces and apartments



- M.PS is 1 to 5 storey atrium.
- PVS is 1 to 5 storey atrium.
- Dimensions of MPS and PVS on upper segments could be changed.



Section

Figure 5.65: Samples of topological relationships between public spaces and apartments

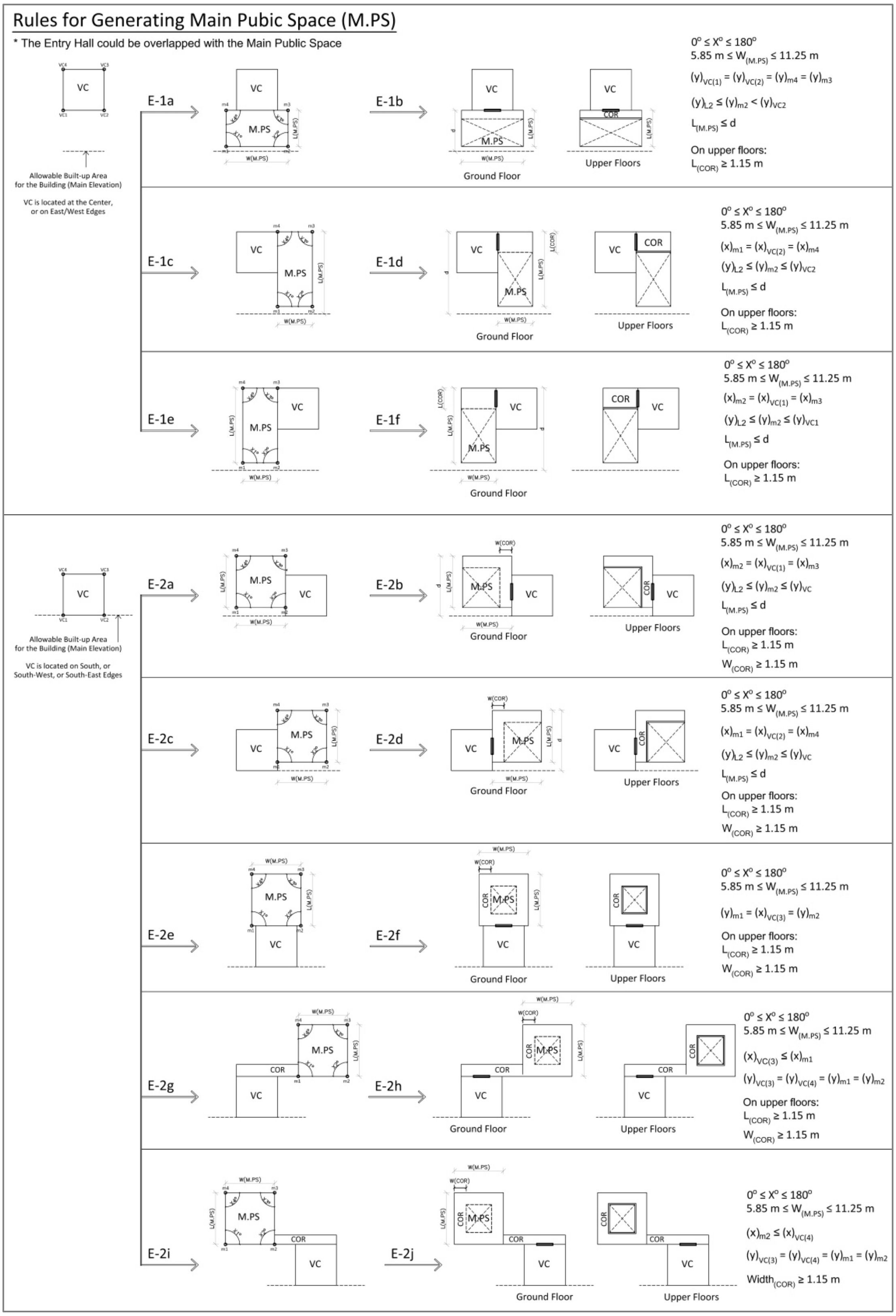


Figure 5.66: Stage (E1): Rules for generating a main public space (MPS)

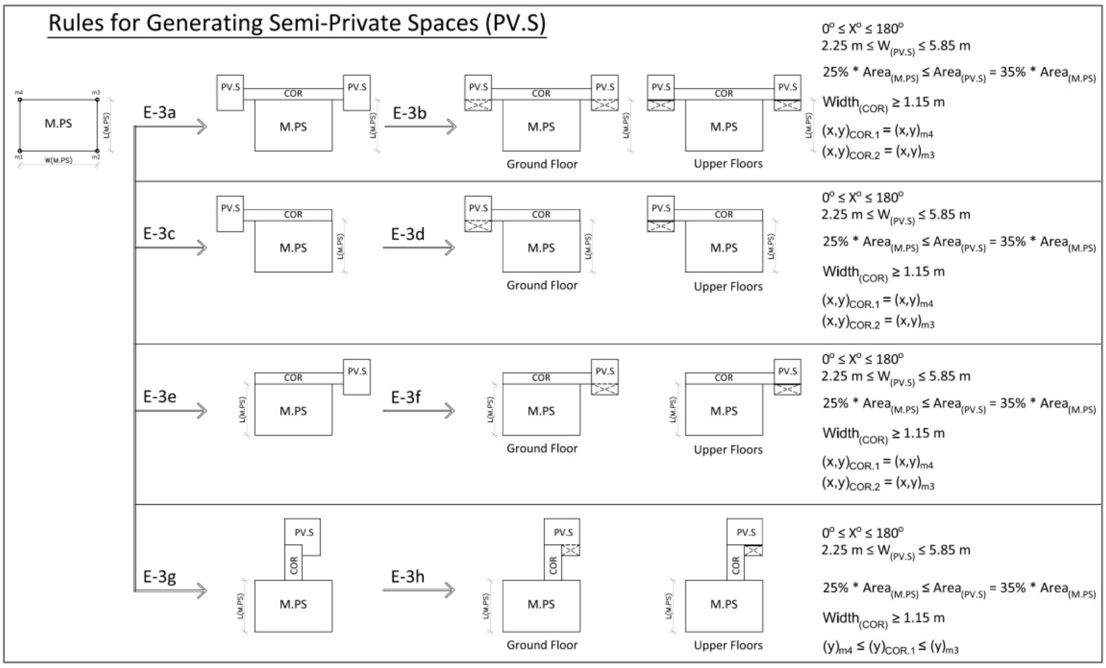


Figure 5.67: Stage (E2): Rules for generating semi-private spaces (PVS)

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^2	100 - 110 m^2	10 %	2 - 4
Type (AP-2a)	Single Floor	110 - 140 m^2	110 - 140 m^2	15 %	2 - 4
Type (AP-2b)	Two Floors	140 - 180 m^2	70 - 90 m^2	10 %	4 - 6
Type (AP-3a)	Single Floor	180 - 220 m^2	180 - 220 m^2	25 %	4 - 6
Type (AP-3b)	Two Floors	220 - 250 m^2	110 - 125 m^2	40 %	5 - 8

The maximum number of apartments on each floor is: Five apartments, which could be from the same type, or different types

Area of Apartments = (Allowable Built-up Area for the Building − Area of Vertical Circulation − Area of Public Spaces and Corridors) * Number of Floors

Rule F-1

Total Area of (Type AP-1) = Area of Apartments * 10 %

Number of Apartments (Type AP-1) = Total Area of (Type AP-1) / 110

Rule F-2

Total Area of (Type AP-2a) = Area of Apartments * 15 %

Number of Apartments (Type AP-2a) = Total Area of (Type AP-2a) / 140

Rule F-3

Total Area of (Type AP-2b) = Area of Apartments * 10 %

Number of Apartments (Type AP-2b) = Total Area of (Type AP-2b) / 180

Rule F-4

Total Area of (Type AP-3a) = Area of Apartments * 25 %

Number of Apartments (Type AP-3a) = Total Area of (Type AP-3a) / 220

Rule F-5

Total Area of (Type AP-3b) = Area of Apartments * 40 %

Number of Apartments (Type AP-3b) = Total Area of (Type AP-3b) / 250

Figure 5.68: Stage (F): Rules for determining types and percentages of apartments

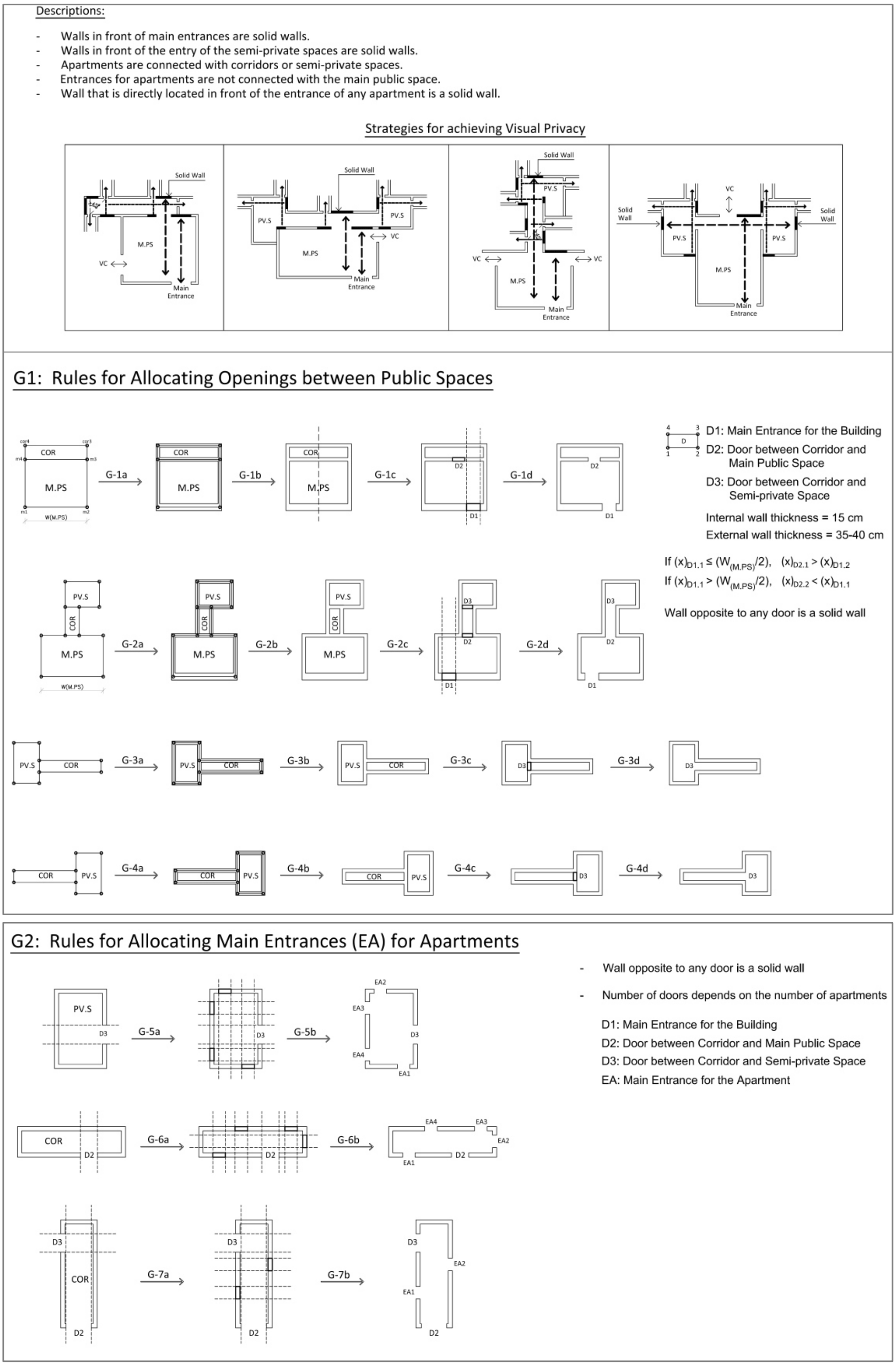


Figure 5.69: Stage (G): Rules for allocating entrances

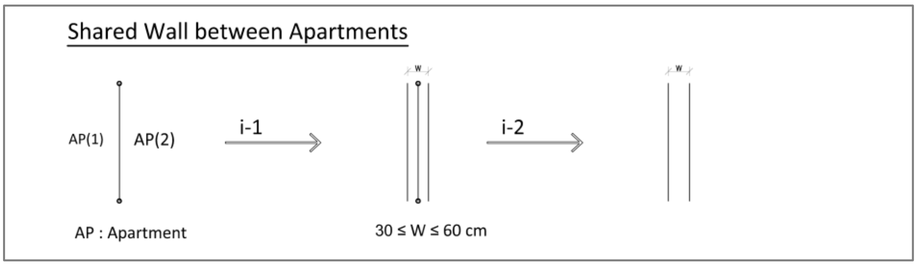


Figure 5.70: Stage (i): Rules for specifying thicknesses of shared partitions between apartments

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).

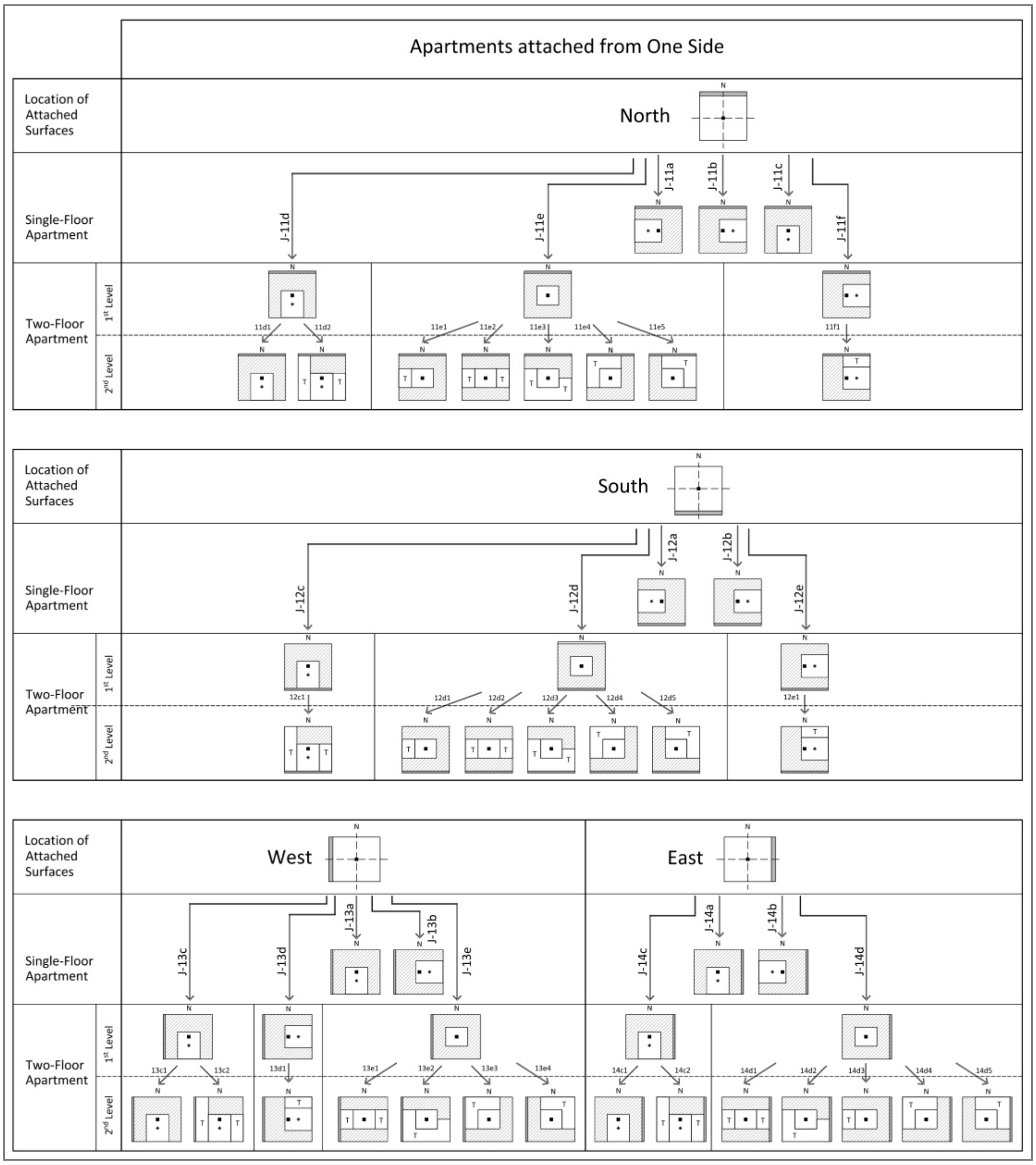


Figure 5.71: Stage (J): Rules for allocating courtyards inside apartments that are attached from one side

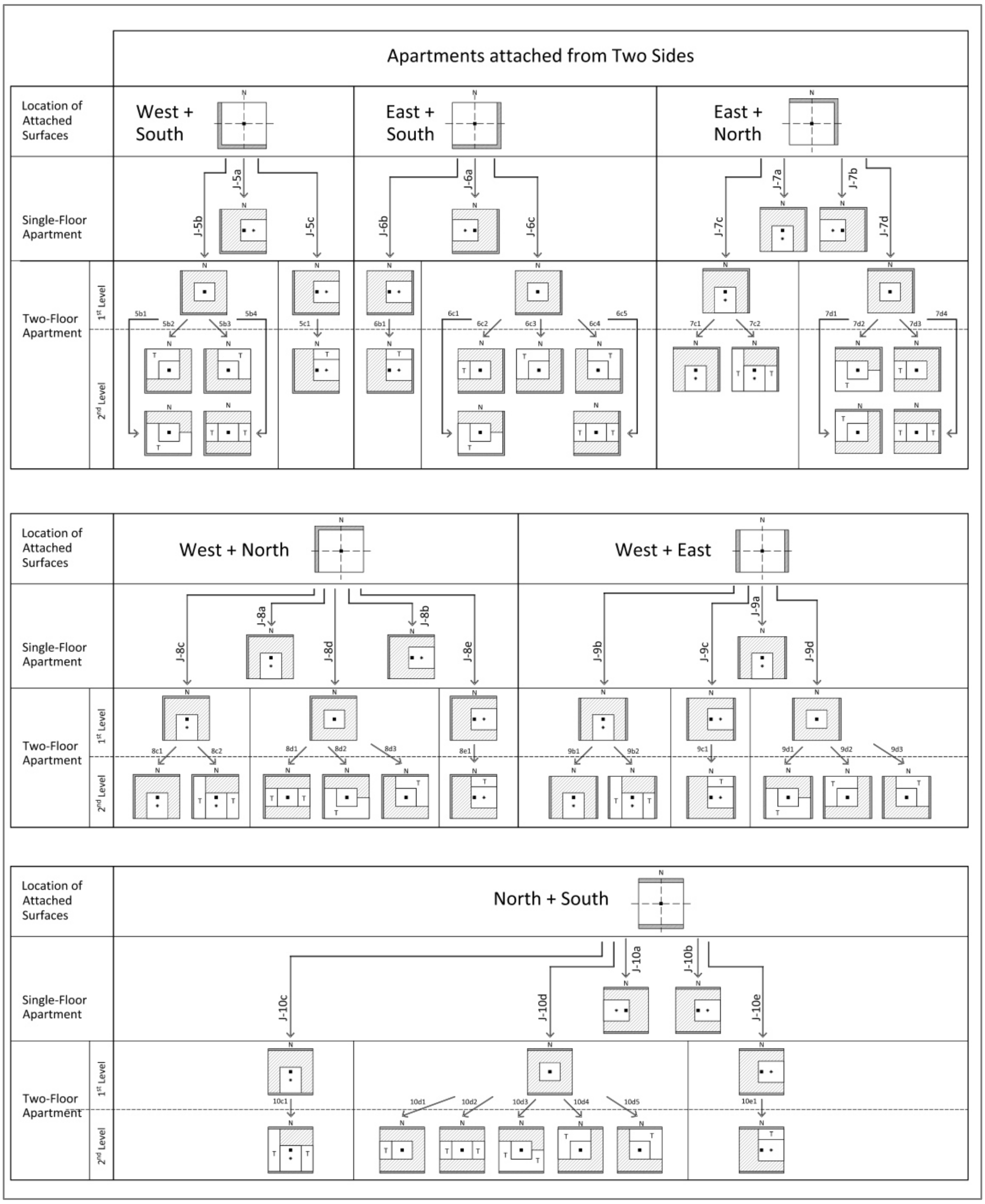


Figure 5.72: Stage (J): Rules for allocating courtyards inside apartments that are attached from two sides

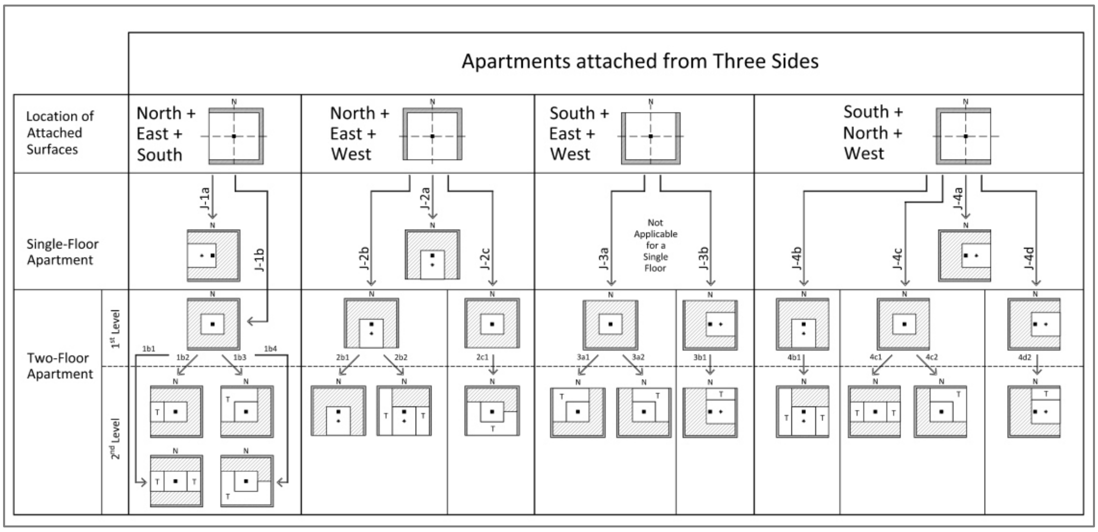


Figure 5.73: Stage (J): Rules for allocating courtyards inside apartments that are attached from three sides

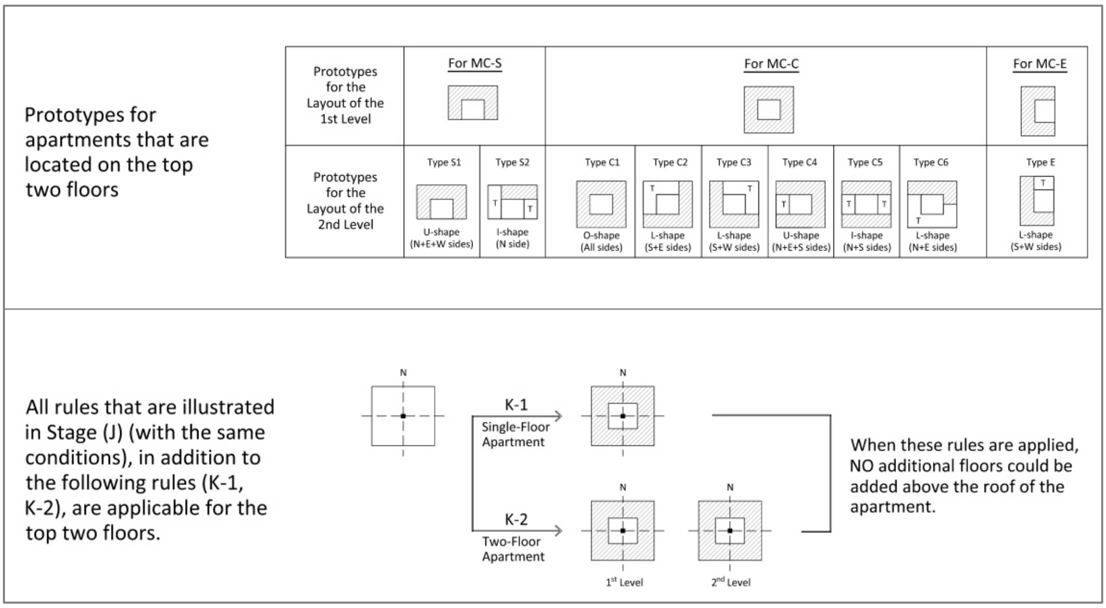


Figure 5.74: Stage (K): Rules for allocating courtyards inside apartments that are located on the top two floors

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 4th segment. However, the user can change the width, the length, and the location of that space (see Figure 5.77).

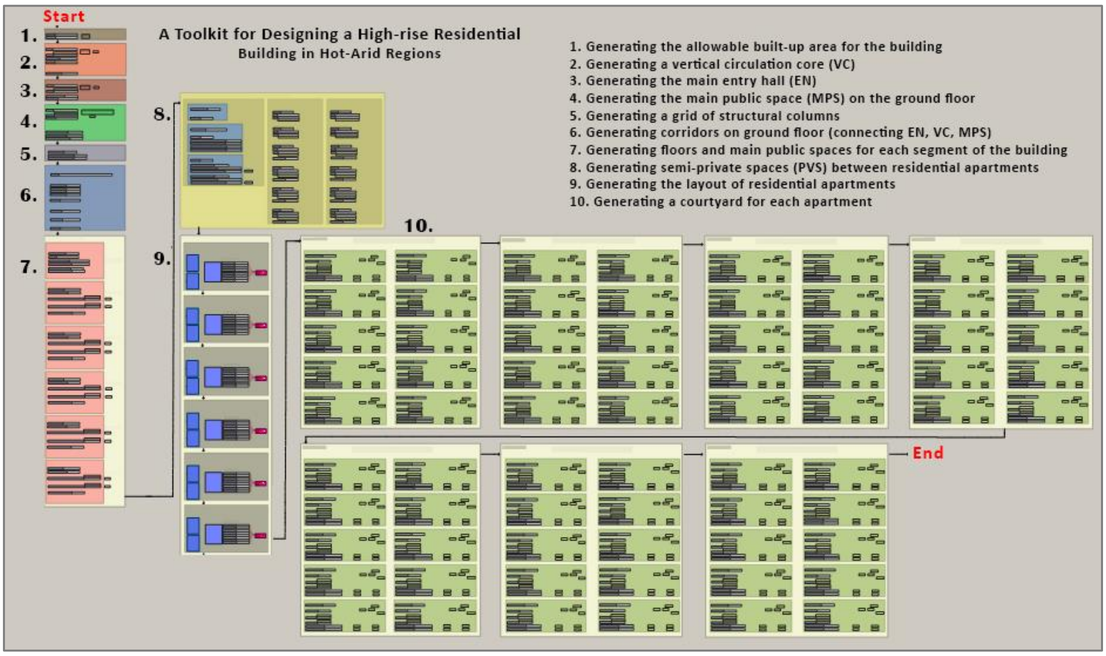


Figure 5.75: A screenshot of the interface for designing a high-rise residential building in hot-arid regions

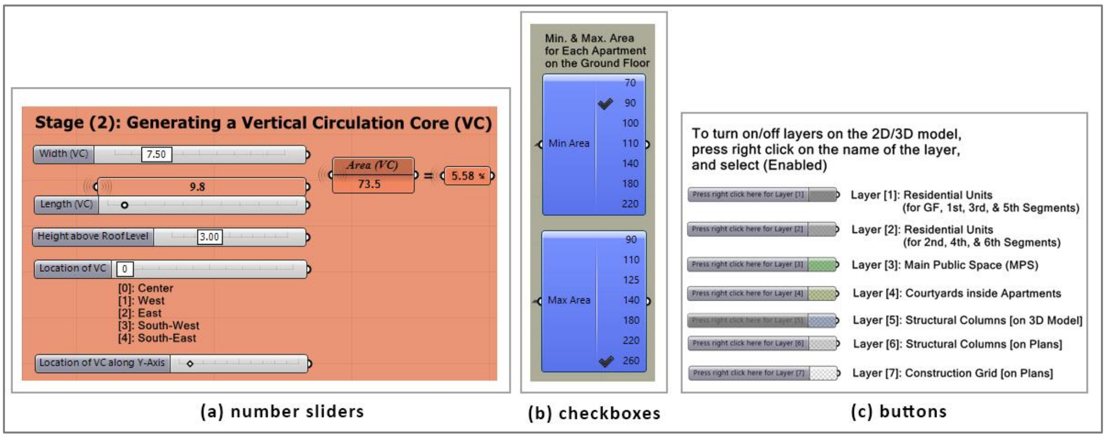


Figure 5.76: Types of dialogue boxes and entities to control geometric parameters and conditions

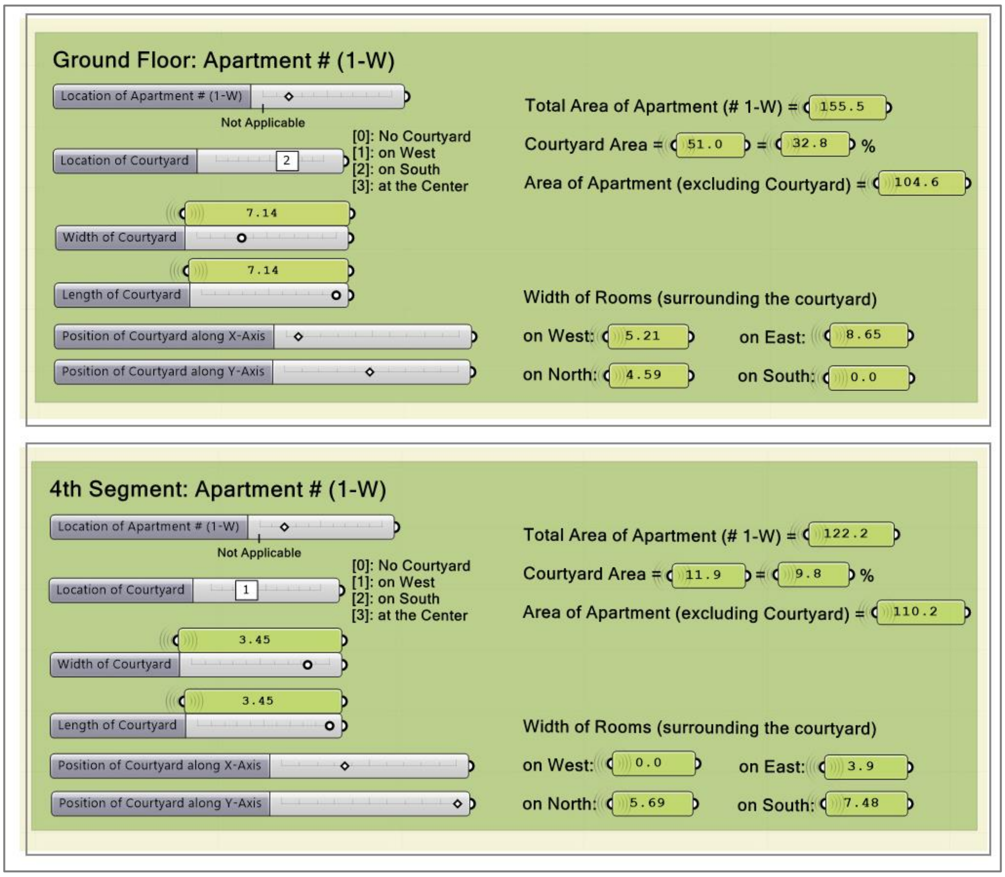


Figure 5.77: Parameters that enable the user to change width, length, and location of a private courtyard in an apartment that is located on: (a) the ground floor, and (b) the 4th segment of the building

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 (Dİno 2012). The following section illustrates the code flowchart that includes these components to generate high-rise buildings.

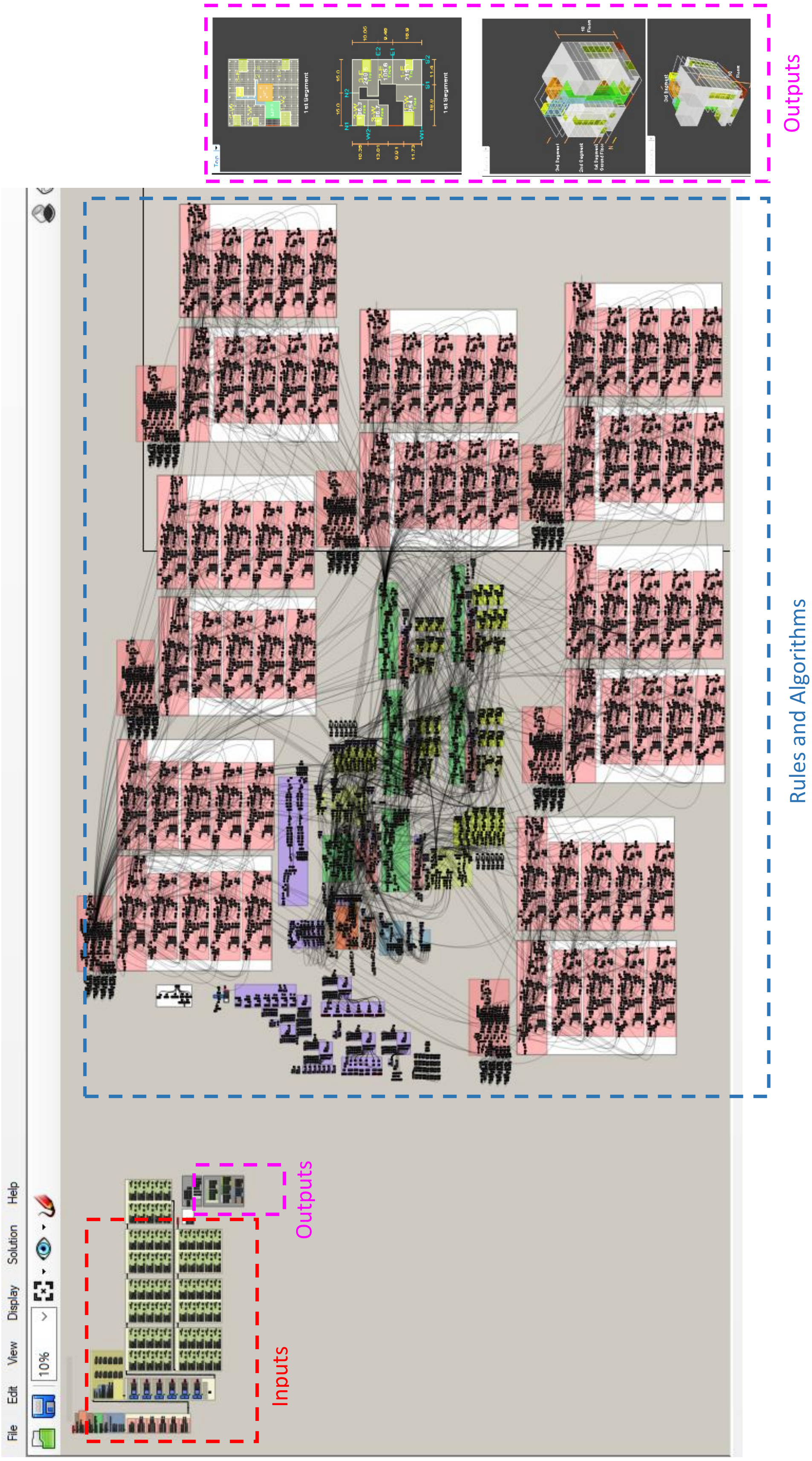


Figure 5.78: A screenshot of the computational process of form generation showing: inputs, outputs, rules and algorithms

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 . Length	2
2. Generating a vertical circulation core (VC)	. Width . Length . Height above roof level . Location	5
3. Generating the main entry hall (EN)	. Width . Length . Location	3
4. Generating the main public space (MPS) on the ground floor	. Width . Length . Location	5
5. Generating a grid of structural columns	. Size of columns . Distances between columns (X-axis) . Distances between columns (Y-axis)	3
6. Generating corridors on the ground floor (connecting EN, VC, MPS)	. Width . Location	6
7. Generating floors and main public spaces for each segment of the building	. Height of each floor . Number of floors on each segment . Width and length of the MPS on each segment . 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, . Width and length of PVS . Location of PVS	16
9. Generating the layout of residential apartments	. Maximum and minimum Area of apartments on each segment . Width and length of apartments	10
10. Generating a courtyard inside each apartment	. Width . Location	5
Total Number of Parameters		***66***

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.

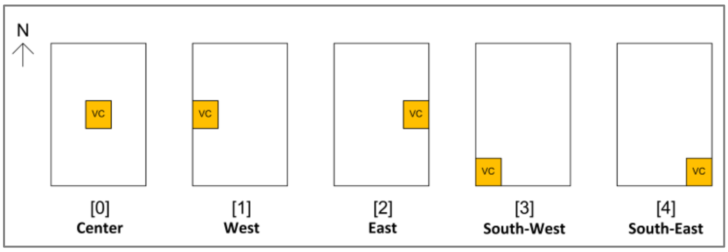


Figure 5.79: Diagrams showing possibilities for the location of the vertical circulation core (VC)

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 [1] West [2] East [3] South-West [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 [1] East [2] South-West [3] South-East [4] South [5] North-West [6] North-East	Integer
Position along Y-axis: 7. If the MPS is located on East or West 8. If the MPS is located on North or South	 Factor, range = (0 to 100) Factor, range = (0 to 100)	 Integer Integer
Position along X-axis: 9. If the MPS is located on North or South	 Factor, range = (0 to 100)	 Integer

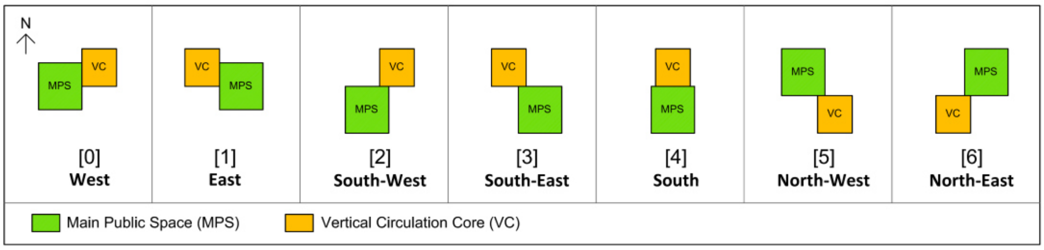


Figure 5.80: Diagrams showing alternatives for the location of the main public space (MPS)

- *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 pubic 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**
Corridors connected with EN & VC (on Y-axis) (COR.Y)		
Alternatives for corridors (COR.Y)	[0] Not applicable [1] Connecting VC & the Eastern edge of MPS [2] Connecting VC & the Western edge of MPS [3] Connecting VC & the Southern edge of MPS [4] Connecting EN & VC [5] Connecting EN & the Southern-East edge of MPS [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
Corridors connected with EN or MPS (on X-axis) (COR.X)		
Alternatives for corridors that are connected with EN	[0] Not applicable [1] or [4] on the Eastern edge of EN [2] or [3] on the Western edge of EN	Integer
Alternatives for corridors that are connected with MPS	[0] Not applicable [1] or [4] on the Eastern edge of MPS [2] or [3] on the Western edge of MPS	Integer
Width of corridors (COR.X)	(1.15 to 3.00) meters	Float number

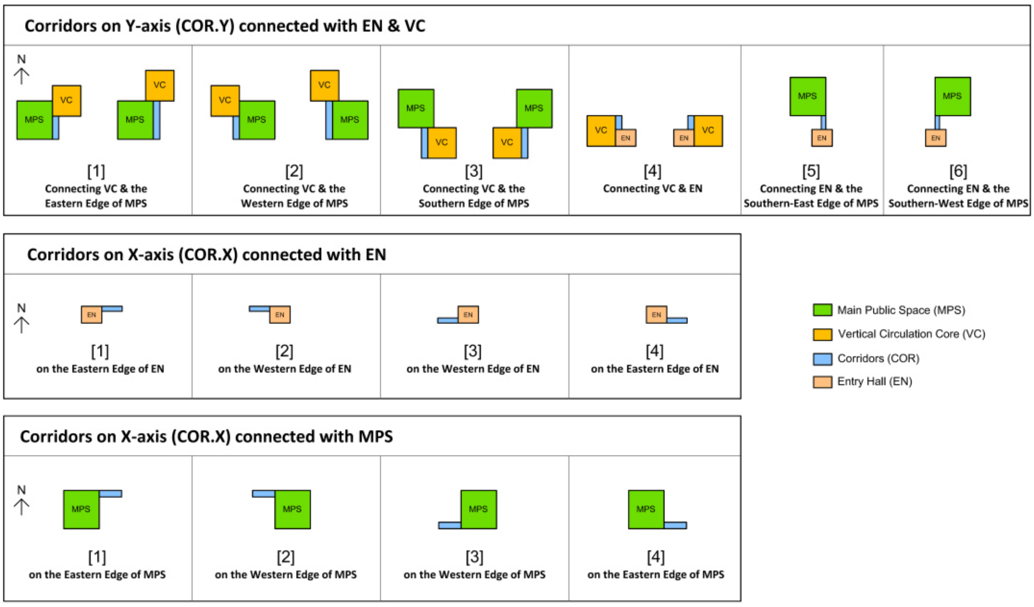


Figure 5.81: Diagrams showing possibilities for the location of corridors that are connected with EN, VC, and MPS

- *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
Floors on the Ground Floor and the 1st Segment of the Building		
Thickness of slab for all floors	(0.40 to 0.60) meters	Float number
Number of floors above the ground floor (1st 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 1st segment	(2.70 to 4.00) meters	Float number
Facades connected with the MPS on the ground floor	[0] East or West [1] East/West and South [2] East, South, and West [3] South-East or South-West corners	Integer
Facades connected with the MPS on the 1st segment	[0] East or West [1] East/West and South [2] East, South, and West [3] South-East or South-West corners	Integer
Floors on the 2nd, 3rd, 4th, 5th, and 6th Segments of the Building		
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 [1] East/West and South [2] East, South, and West [3] South-East or South-West corners	Integer

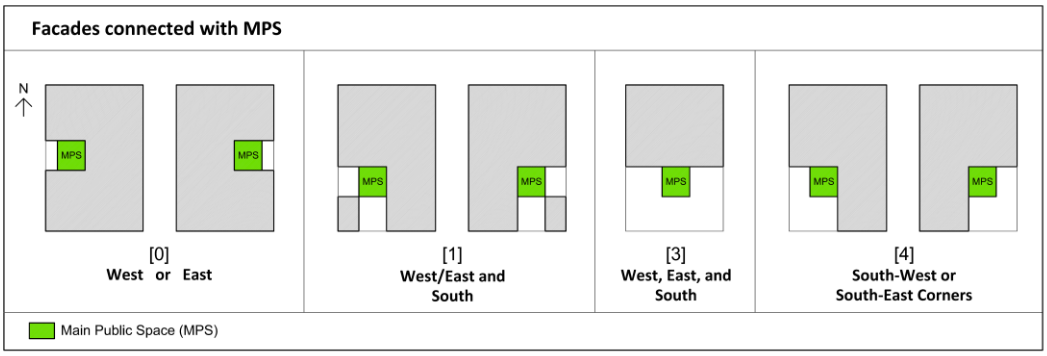


Figure 5.82: Diagrams showing alternative for the connection of the main public space with the outside environment

- *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).

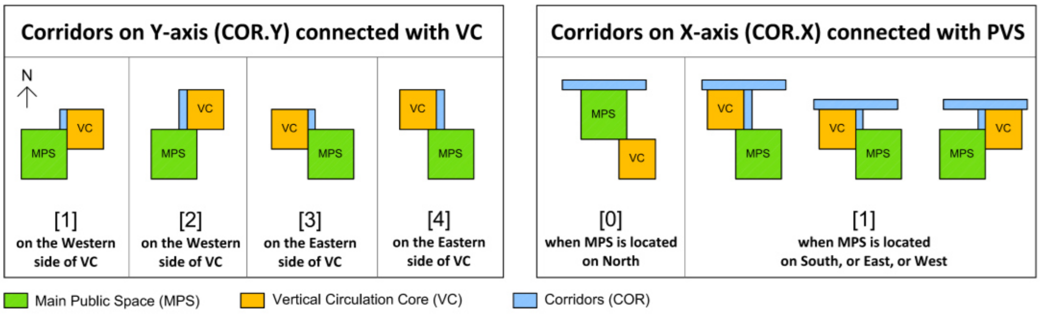


Figure 5.83: Diagrams showing alternatives for the location of corridors that are connected with VC and PVS

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).

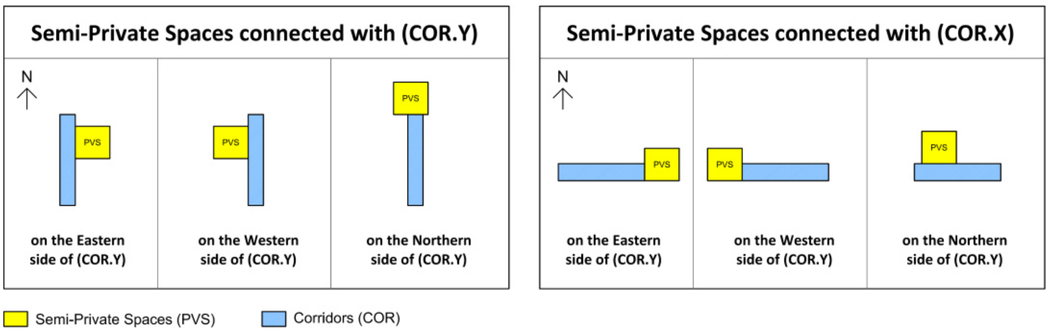


Figure 5.84: Diagrams showing alternative for the location of semi-private spaces (PVS)

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
Corridors (on the Y-axis) connecting MPS and VC		
Alternatives for the location of corridors (COR.Y)	[0] Not applicable [1] or [2] on the Western side of the VC [3] or [4] on the Eastern side of the VC	Integer
Width of corridors (COR.Y)	(1.15 to 3.00) meters	Float number
Corridors (on the X-axis) connected with PVS		
Applicability of corridors (COR.X)	[0] when MPS is located on North [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, 1st, 3rd, and 5th segments	Factor, range = (0 to 100)	Integer
b. For 2nd, 4th, and 6th segments	Factor, range = (0 to 100)	Integer
Extension of (COR.X) towards East direction:		
a. For GF, 1st, 3rd, and 5th segments	Factor, range = (0 to 100)	Integer
b. For 2nd, 4th, and 6th segments	Factor, range = (0 to 100)	Integer
Corridors (on the Y-axis) connected with PVS		
Width of corridors (COR.Y)		
Applicability of (COR.Y):		
a. GF, 1st, 3rd, and 5th segments	[0] Yes, [1] No	Integer
b. 2nd, 4th, and 6th segments	[0] Yes, [1] No	Integer
Length of (COR.Y):		
a. GF, 1st, 3rd, and 5th segments	Factor, range = (0 to 100)	Integer
b. 2nd, 4th, and 6th segments	Factor, range = (0 to 100)	Integer
Position of (COR.Y):		
a. GF, 1st, 3rd, and 5th segments	Factor, range = (0 to 100)	Integer
b. 2nd, 4th, and 6th 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
Semi-private spaces (PVS) on GF, 1st, 3rd, and 5th segments ***Semi-private spaces (PVS) on 2nd, 4th, and 6th segments***		
When PVS is located on the Eastern side of (COR.X)		
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
When PVS is located on the Western side of (COR.X)		
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
When PVS is located on the Northern side of the (COR.X)		
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
When PVS is located on the Northern side of the (COR.Y)		
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
When PVS is located on the Eastern side of the (COR.Y)		
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
When PVS is located on the Western side of the (COR.Y)		
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 (Dİno 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^2	Integer
Maximum area for each apartment (*)	90, 110, 125, 140, 180, 220, 260 m^2	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.

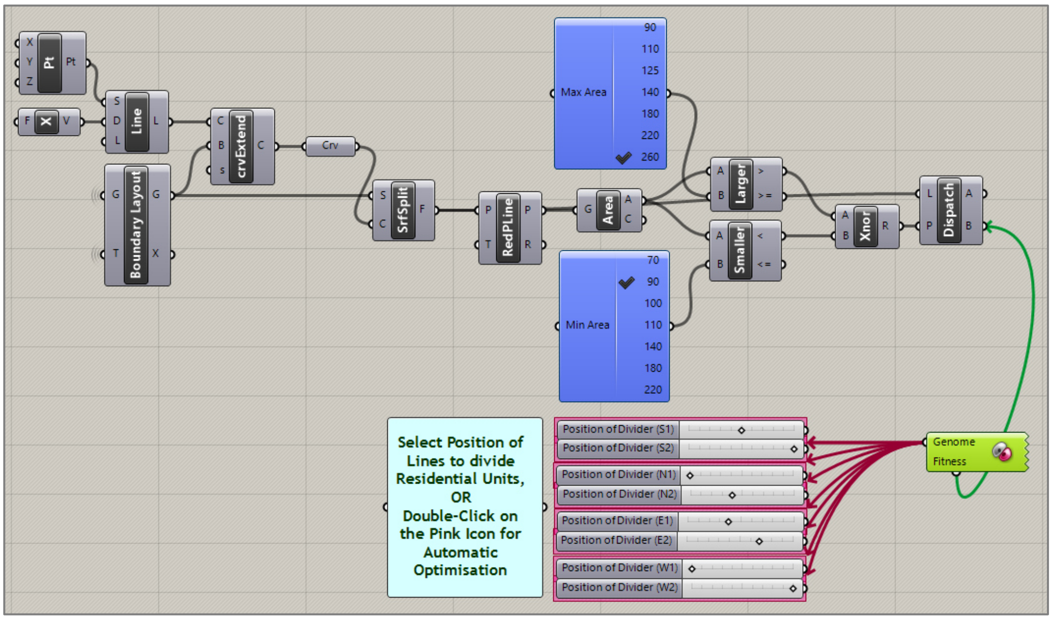


Figure 5.85: Part of the script for generating the layout of residential units

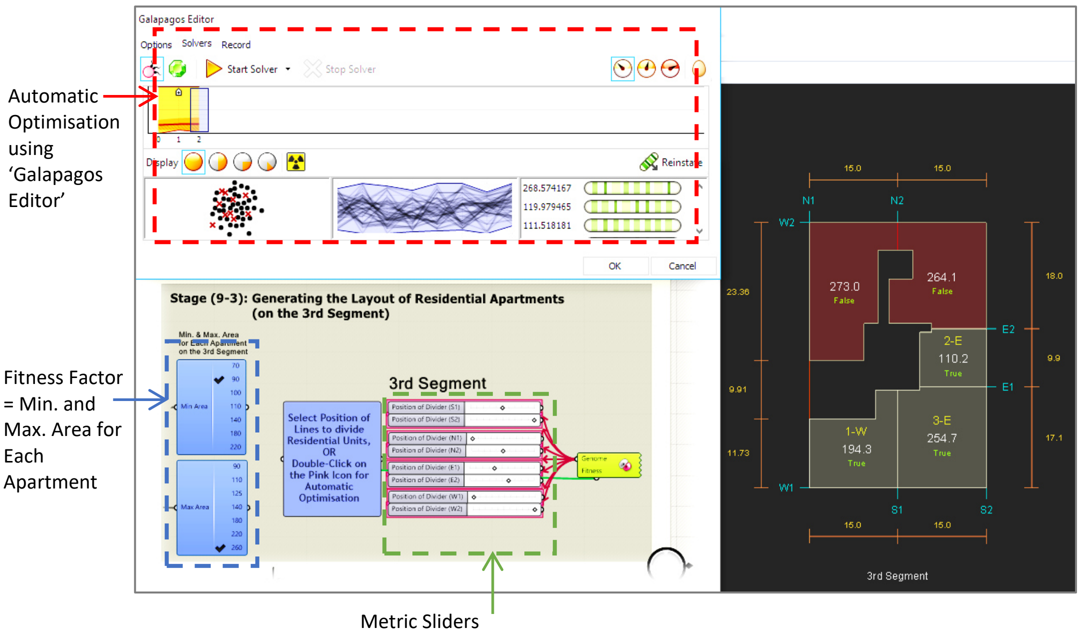


Figure 5.86: A sample for the optimisation process for generating the layout of apartments

- *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 [1] on West or East [2] on South [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

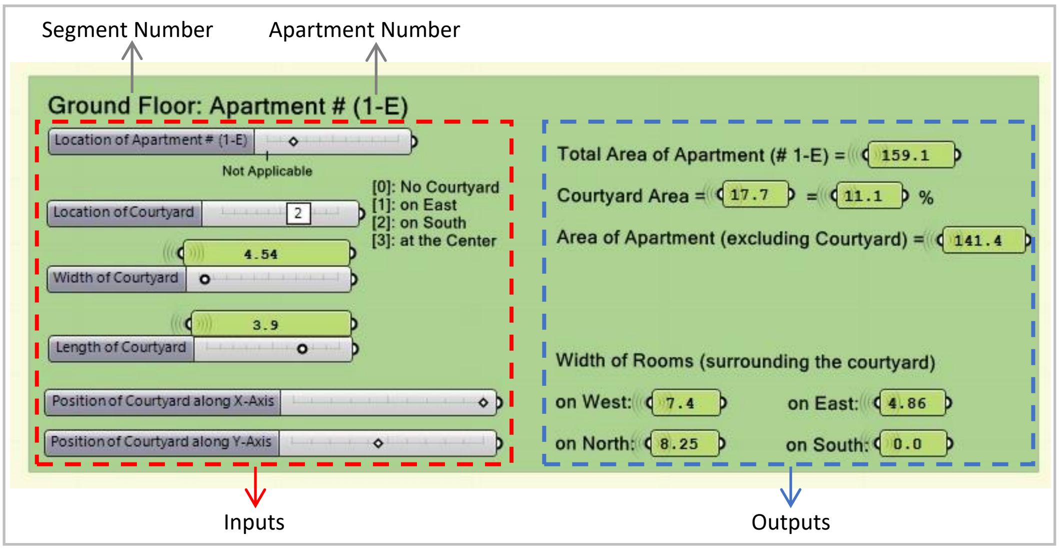


Figure 5.88: Inputs and outputs for generating a courtyard inside a residential unit

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).

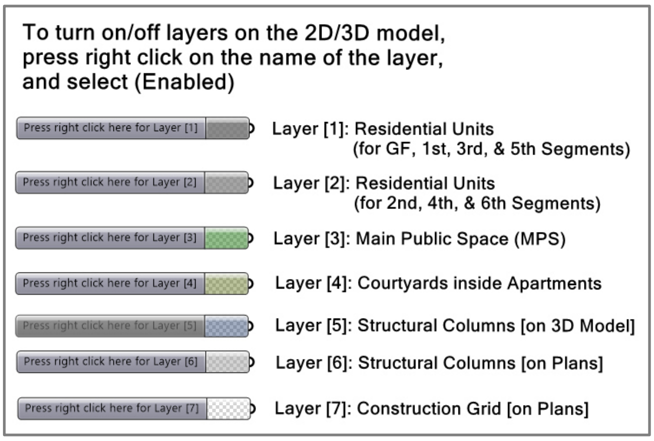


Figure 5.89: Layers of the 2D/3D model

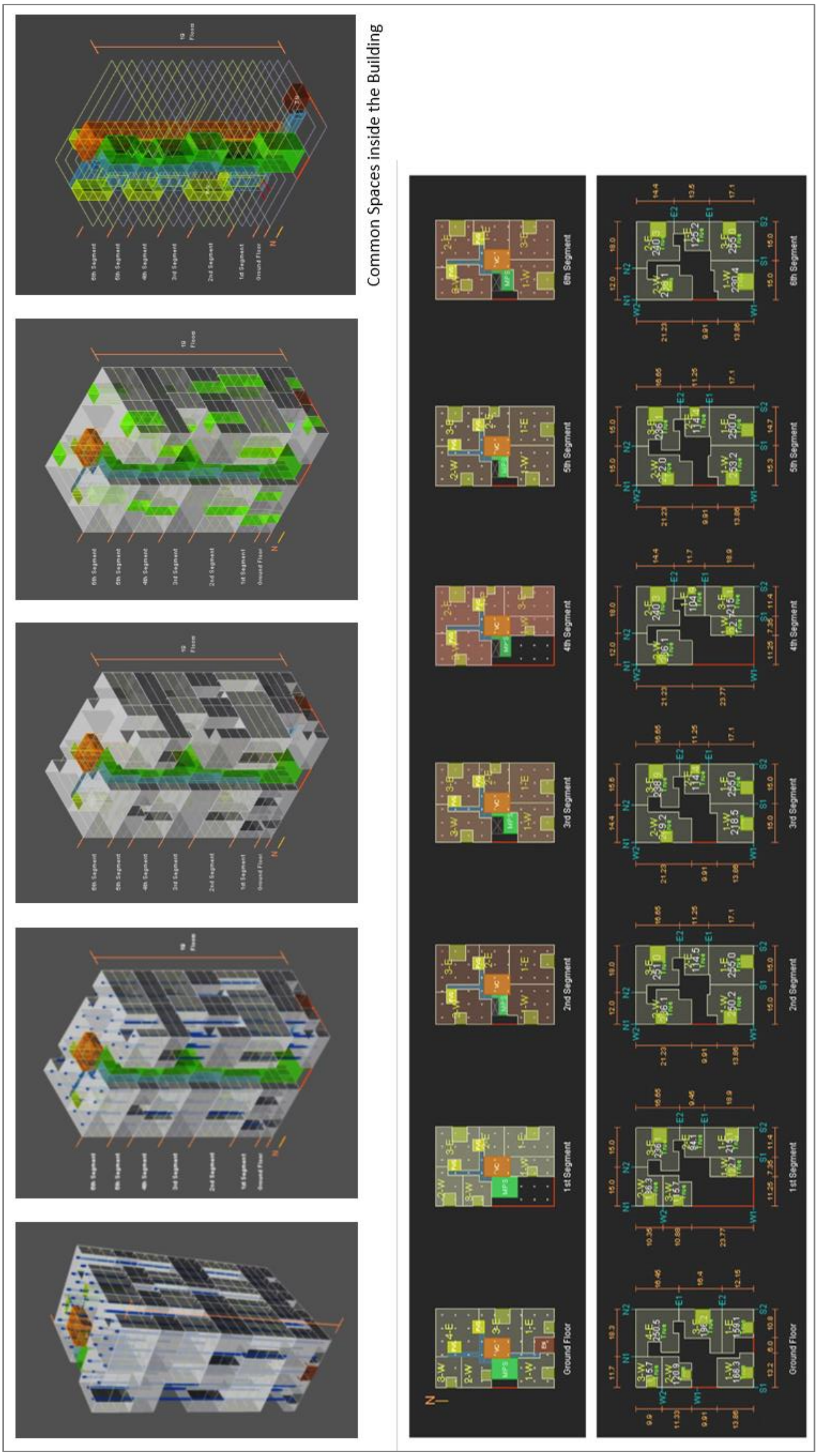


Figure 5.90: Drawings and diagrams produced by the tool

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^2),
   - Total designed area of the building (m^2),
   - Total area of common spaces on all floors (m^2), and its percentage from the total designed area,
   - Total area of residential apartments on all floors (m^2), 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.

Overall Calculations for the Building

Total Number of Floors	18
Total Height of the Building (meter)	70.4
Total Allowable Area for the Building (m2)	24300.0
Total Designed Area for the Building (m2)	22517.51
Total Area of Common Spaces on All Floors (m2)	4158.49 = 18.47 % of the Total Designed Area
Total Area of Residential Apartments on All Floors (m2)	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 (m2)	Total Designed Area for All Floors on Each Segment (m2)	% 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 %
TOTAL	18	94			22517.51	

Detailed Calculations for Residential Apartments

	Private Courtyards inside Apartments					Area of Apartments (including Courtyards)			
	Area on Each Floor (m2)	% 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 (m2)	% 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	74.73 %	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 = 10.82 % from the Total Area of Apartments	8.83 %			18359.02	81.53 %

Detailed Calculations for Common Spaces inside the Building

	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
Ground Floor	79.28	6.02 %	79.28	0.35 %	39.64	3.01 %	39.64	0.18 %
1st Segment	79.28	6.82 %	237.84	1.06 %	39.64	3.41 %	118.92	0.53 %
2nd Segment	30.09	2.28 %	60.18	0.27 %	39.61	3.01 %	79.22	0.35 %
3rd Segment	49.74	3.77 %	149.22	0.66 %	39.64	3.01 %	118.92	0.53 %
4th Segment	38.49	3.39 %	153.96	0.68 %	39.61	3.49 %	158.44	0.7 %
5th Segment	31.8	2.41 %	63.6	0.28 %	39.64	3.01 %	79.28	0.35 %
6th Segment	43.84	3.33 %	131.52	0.58 %	39.61	3.01 %	118.83	0.53 %
TOTAL			875.6	3.88 %			713.25	3.17 %

	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 %
TOTAL	45.0	3.41 %	0.2 %			920.38	4.09 %			1323.0	5.88 %

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 3rd-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^2
Number of floors in each segment:	
- 1st segment (including the ground floor)	4 floors
- 2nd segment	2 floors
- 3rd segment	3 floors
- 4th segment	4 floors
- 5th segment	2 floors
- 6th segment	3 floors
Height of each floor	4.0 m (GF), 2.8 m (1st segment), 3.5 m (2nd, 3rd, 4th, 5th, 6th 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^2 and 260 m^2, 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 1st 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 (1st)	South-West	South	South-West	East	South-West
- 2nd segment	Length	5.95 m	6.12 m	6.07 m	7.50 m	10.12 m
	Connections	West	-	West	East	West
- 3rd segment	Length	9.91 m	10.20 m	10.12 m	7.50 m	10.12 m
	Connections	West	-	West	East	West
- 4th 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
- 5th segment	Length	6.19 m	10.20 m	6.32 m	7.50 m	10.12 m
	Connections	West	South	West	East	West
- 6th 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, 1st segment, 3rd segment, 5th 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
	Location	East	East	East	North	East
2nd segment, 4th segment, 6th 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
	Location	East	East	North-East	West	East
Semi-Private Space (PVS) # 2						
Ground floor, 1st segment, 3rd segment, 5th 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
	Location	North	North-West	North	-	North
2nd segment, 4th segment, 6th segment	Width	5.31 m	-	-	4.80 m	5.00 m
	Length	3.73 m	-	-	3.52 m	4.18 m
	Location	North-West	-	-	North	North-East

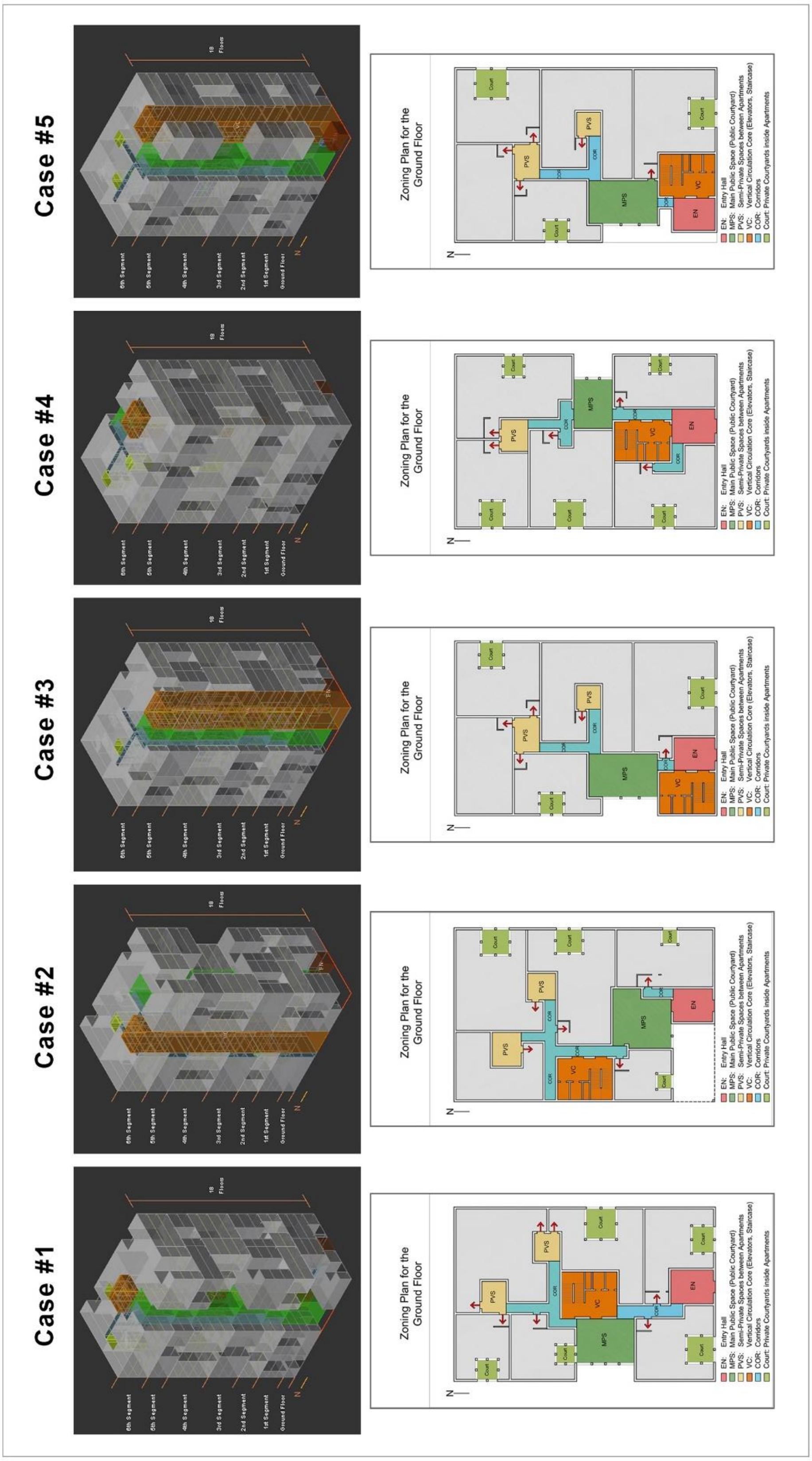


Figure 5.92: Three-dimensional views and the layout of the ground floor for new solutions generated by the researcher using the developed computational model

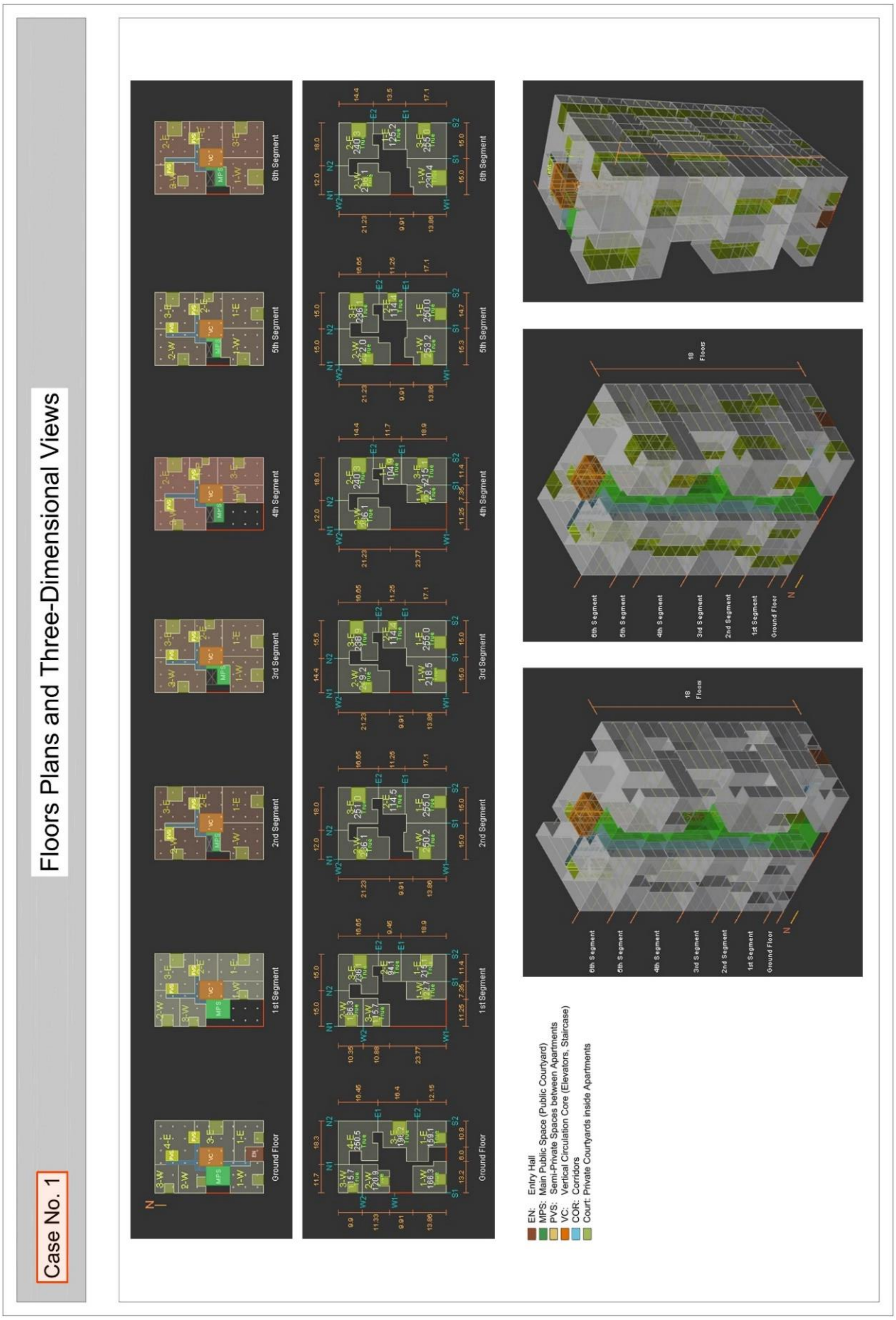


Figure 5.93: Three-dimensional views and the layout of the different segments for Case # 1

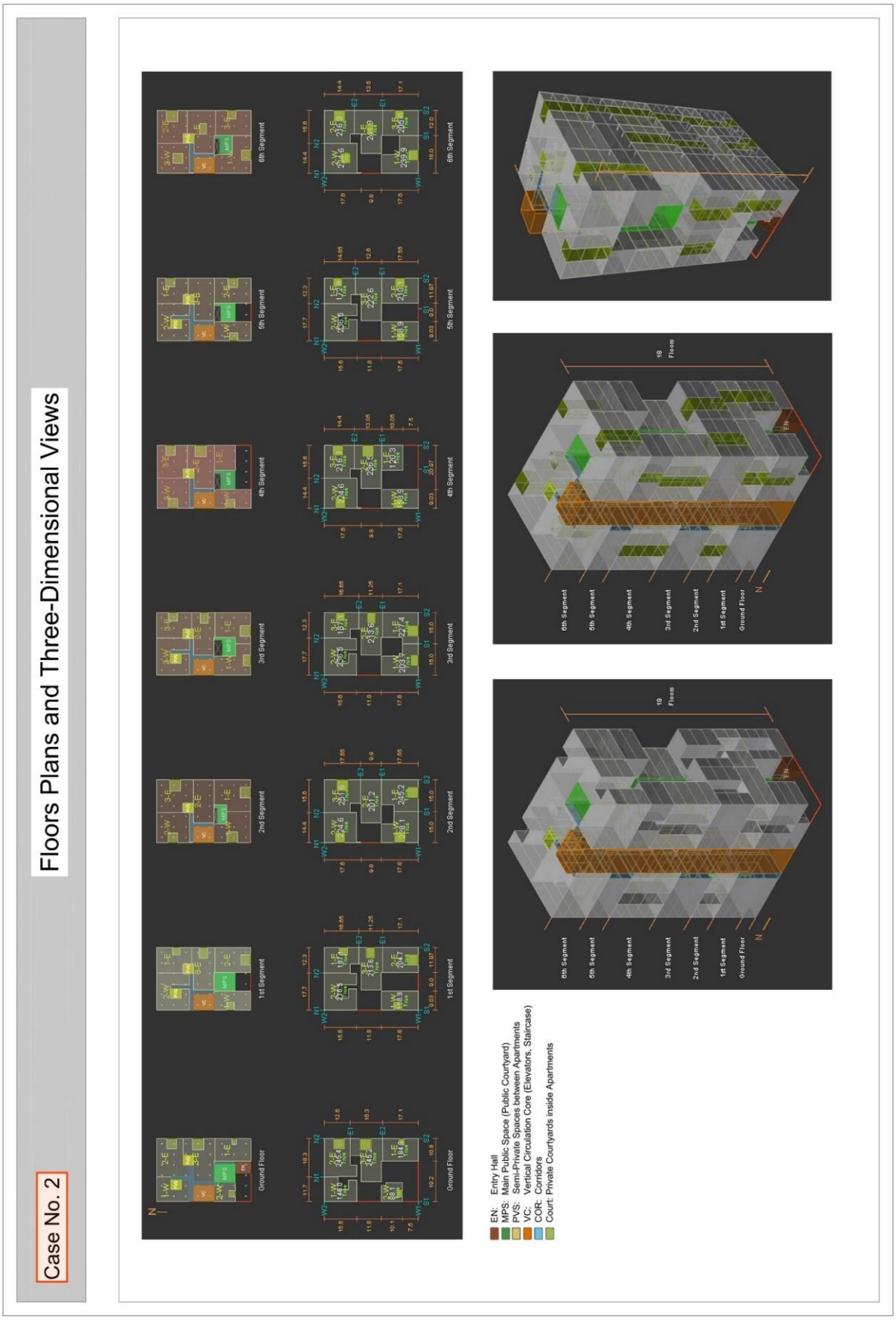


Figure 5.94: Three-dimensional views and the layout of the different segments for Case # 2

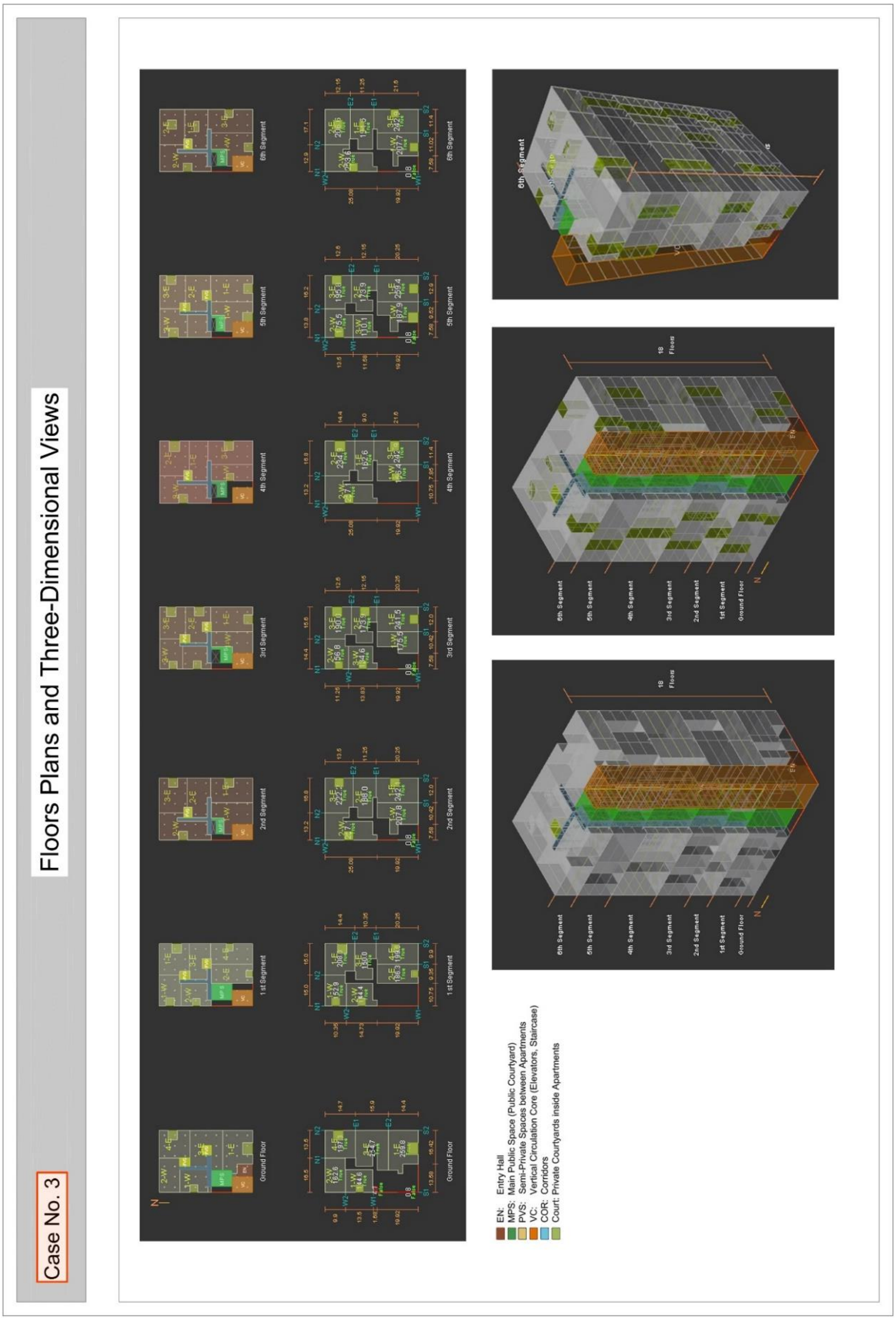


Figure 5.95: Three-dimensional views and the layout of the different segments for Case # 3

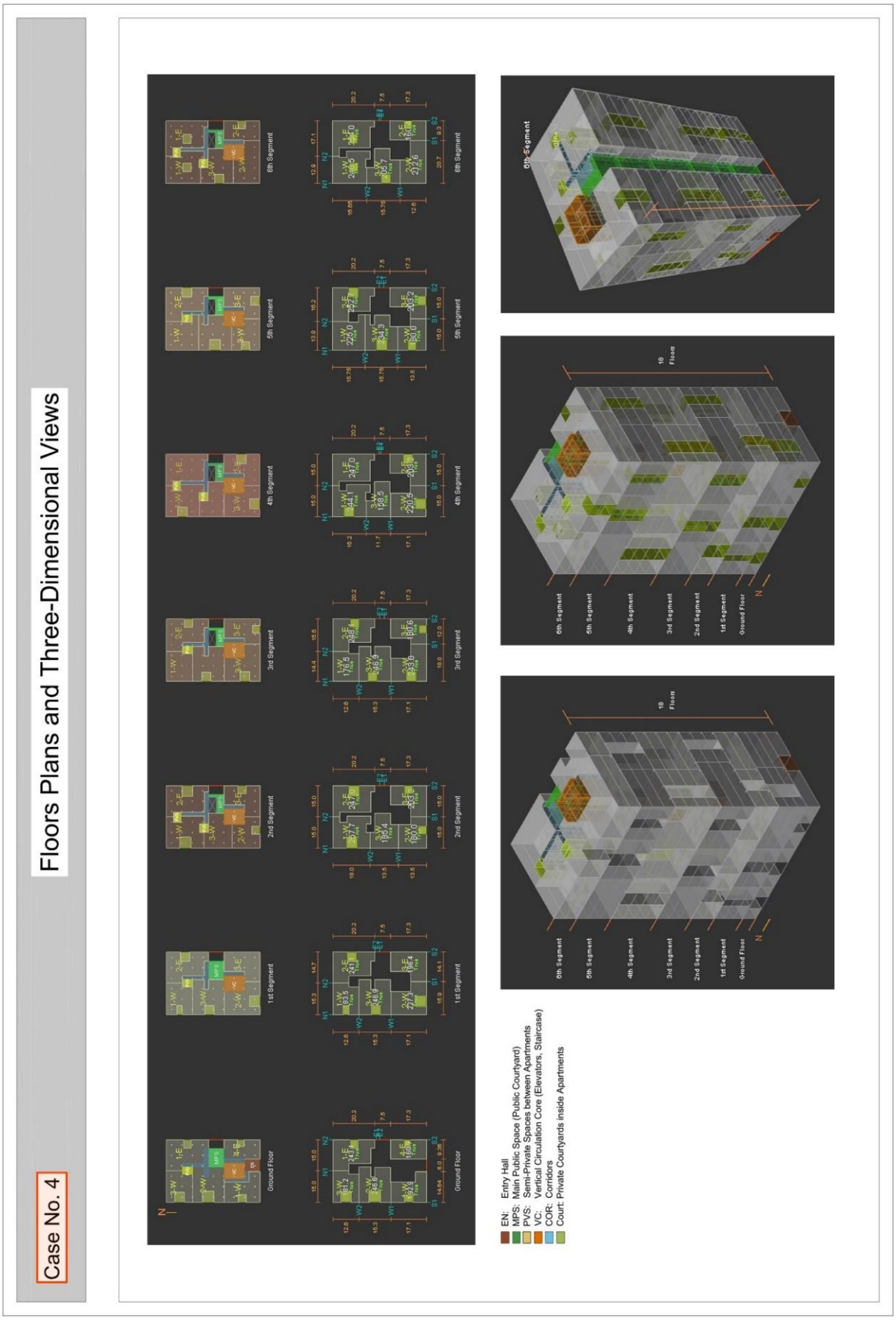


Figure 5.96: Three-dimensional views and the layout of the different segments for Case # 4

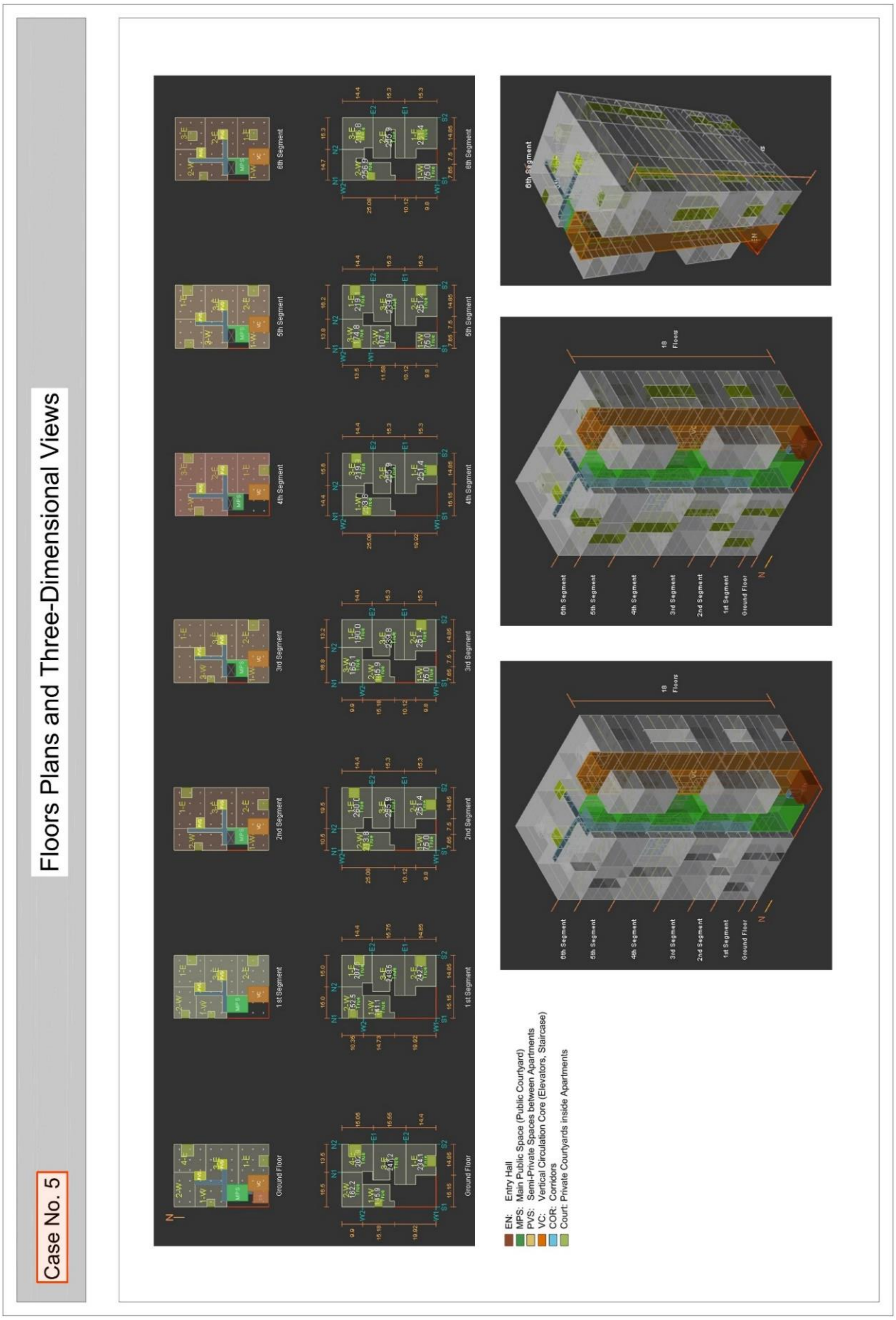


Figure 5.97: Three-dimensional views and the layout of the different segments for Case # 5

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 6th 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 1st segment, and a typical floor on the 6th segment for (Case # 1). Detailed spatial analysis for each case is included in (Volume 2 - Appendix (5-C-1)).

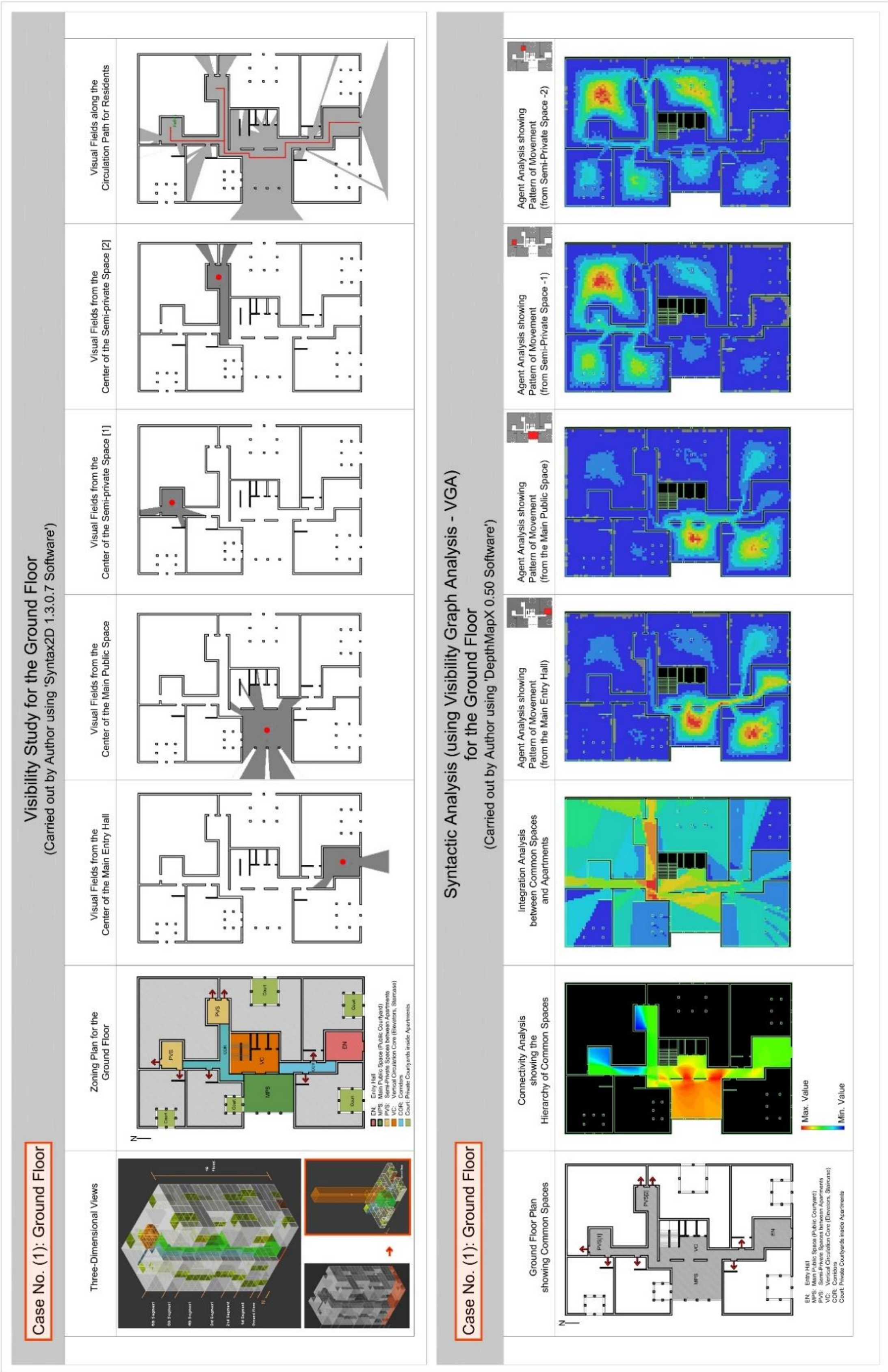


Figure 5.98: Visibility study and syntactic analysis for the ground floor for Case # 1

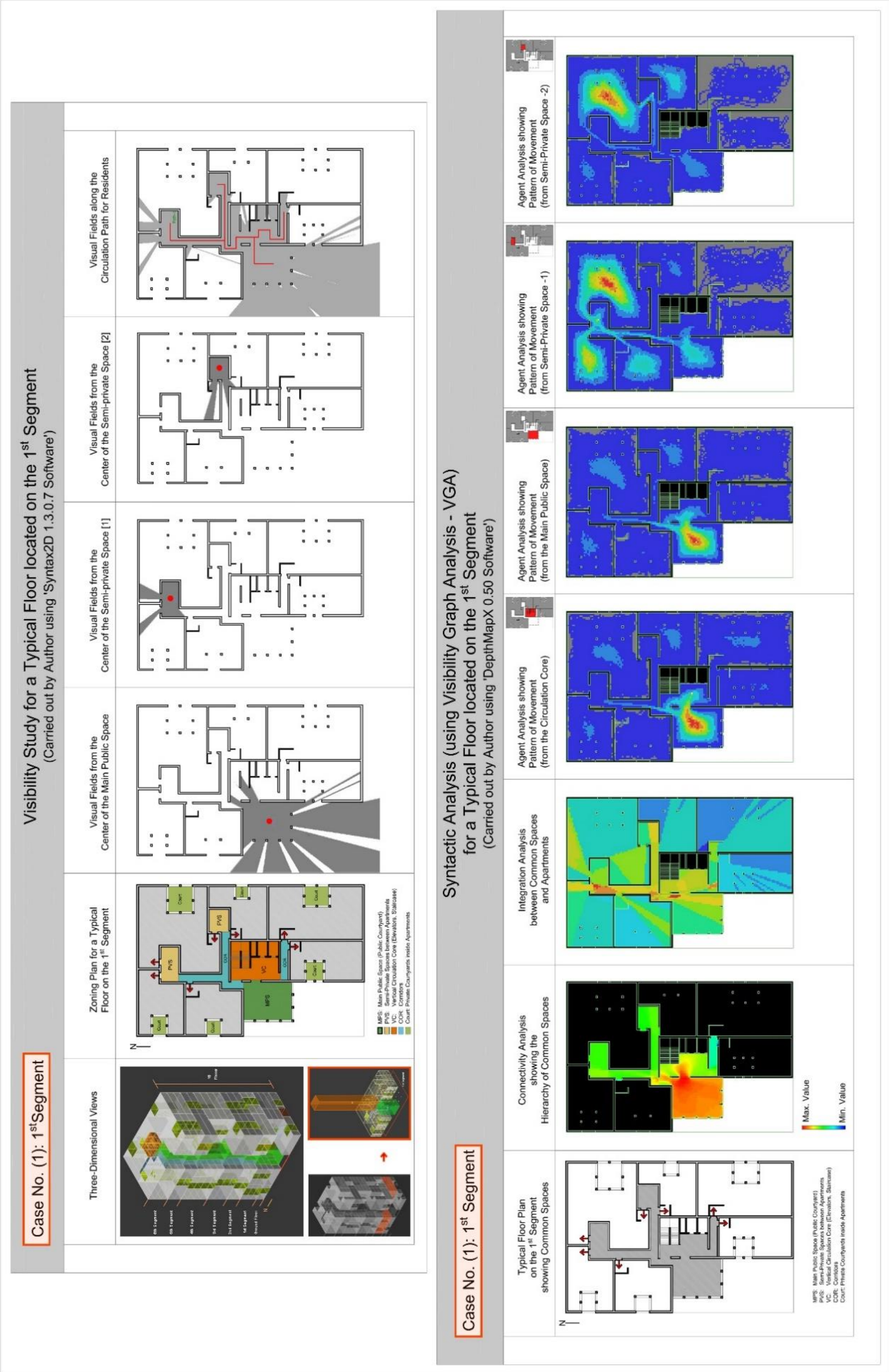


Figure 5.99: Visibility study and syntactic analysis for a typical floor on the 1st segment for Case # 1

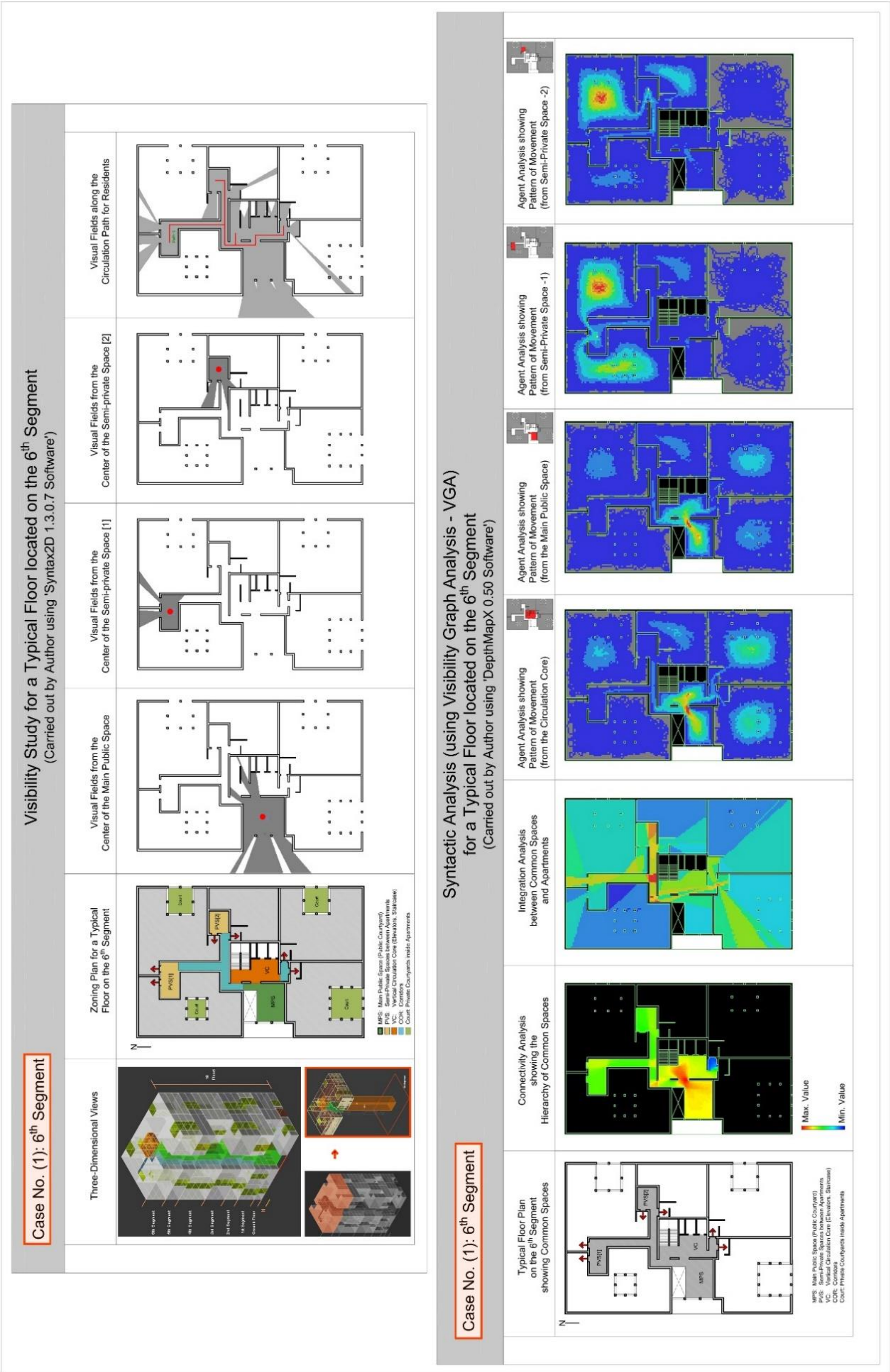


Figure 5.100: Visibility study and syntactic analysis for a typical floor on the 6th segment for Case # 1

- *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.
	1st Segment	MPS > VC > PVS-2. > PVS-1.
	6th Segment	MPS > VC > PVS-1. > PVS-2.
Case # 2	Ground Floor	MPS > EN > VC > PVS-2. > PVS-1.
	4th Segment	MPS > VC > PVS-1.
	6th Segment	MPS > VC > PVS-1.
Case # 3	Ground Floor	MPS > EN > PVS-2. > VC > PVS-1.
	1st Segment	MPS > VC > PVS-2. > PVS-1.
	6th Segment	MPS > VC > PVS-1.
Case # 4	Ground Floor	MPS > EN > VC > PVS-1.
	5th Segment	MPS > VC > PVS-1.
	6th Segment	MPS > VC > PVS-2. > PVS-1.
Case # 5	Ground Floor	MPS > EN > VC > PVS-2. > PVS-1.
	1st Segment	MPS > VC > PVS-2. > PVS-1.
	6th 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
	1st Segment	10.38	5.84	-	2.91	3.36
	6th Segment	5.38	4.73	-	2.82	2.67
Case # 2	Ground Floor	13.17	4.96	9.48	3.55	4.79
	4th Segment	7.73	4.28	-	3.74	-
	6th Segment	7.71	4.33	-	3.67	-
Case # 3	Ground Floor	12.63	5.58	8.41	3.18	5.99
	1st Segment	12.61	9.83	-	3.12	6.02
	6th Segment	8.29	6.24	-	3.03	-
Case # 4	Ground Floor	11.68	8.06	8.40	3.11	-
	5th Segment	5.87	4.59	-	3.00	-
	6th Segment	5.86	4.08	-	2.43	3.06
Case # 5	Ground Floor	12.31	5.57	7.65	3.00	3.45
	1st Segment	12.88	9.08	-	3.04	4.30
	6th Segment	13.05	10.39	-	3.14	4.51

Key: The highest connectivity value ...... The lowest connectivity value

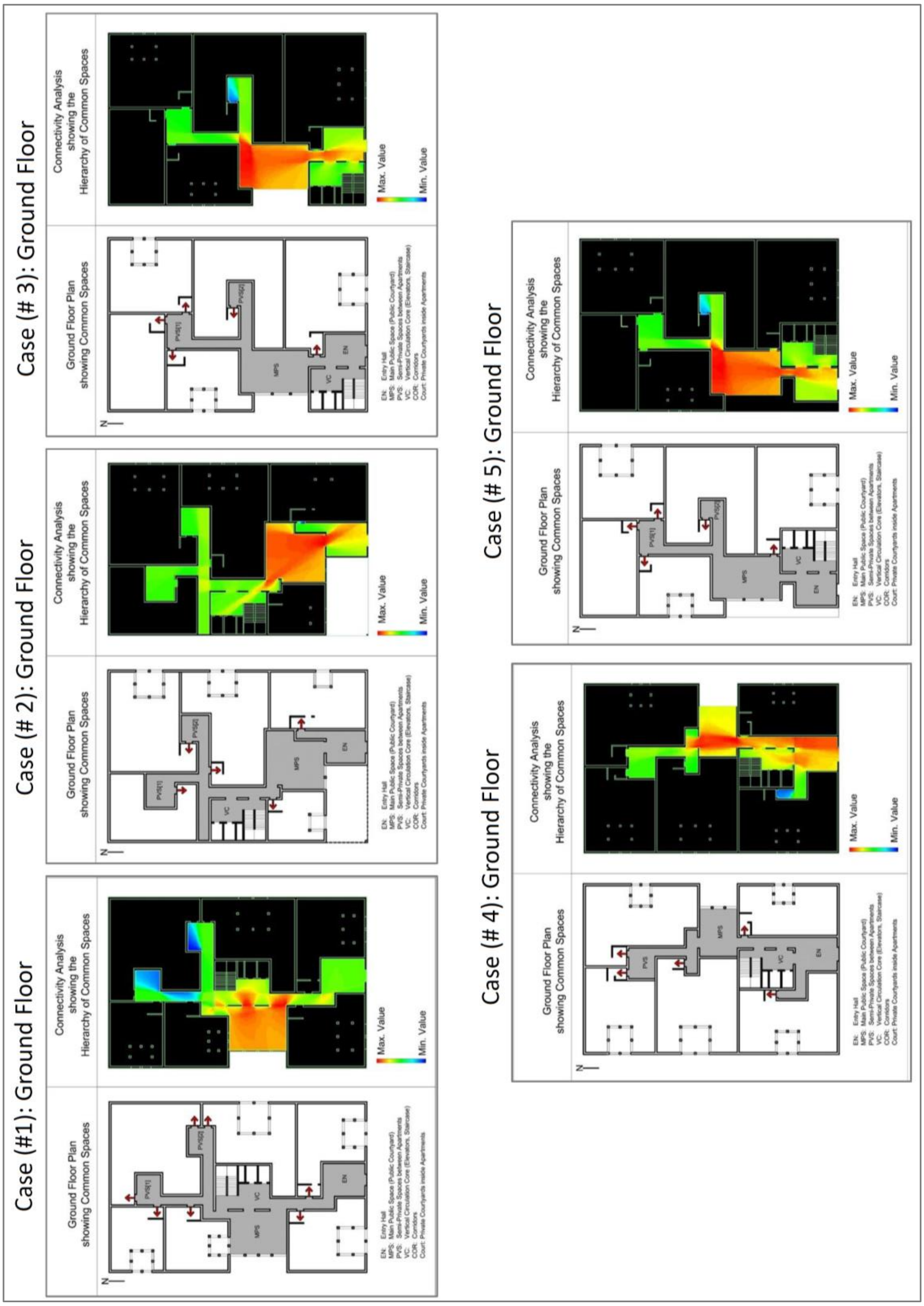


Figure 5.11: Connectivity analysis showing hierarchy of common spaces on the ground floor for the five cases

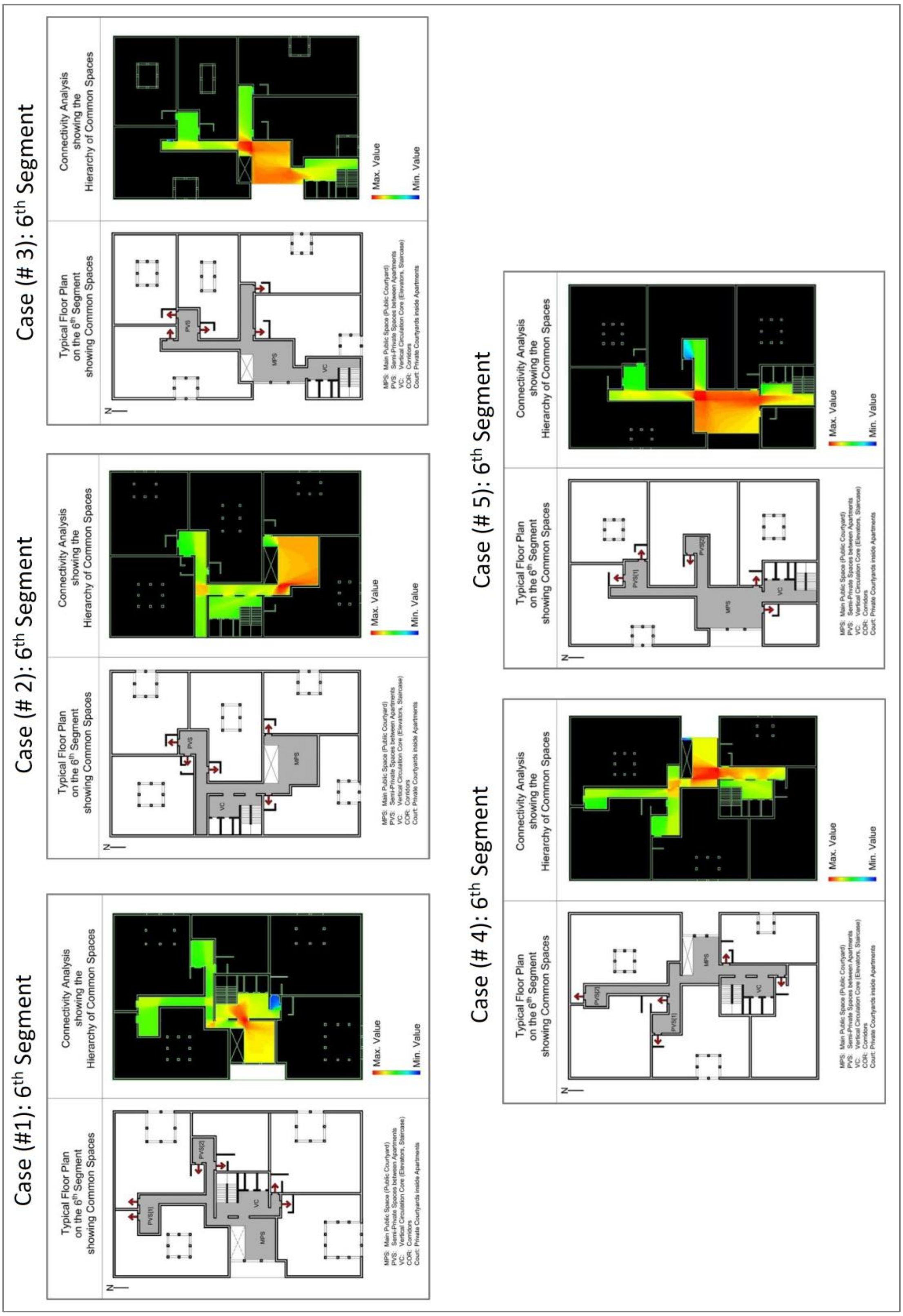


Figure 5.102: Connectivity analysis showing hierarchy of common spaces on a typical floor on the 6th segment for the five cases

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
	1st Segment	VC > PVS-1 > MPS > PVS-2 > AP. 1+2+3+4+5+6
	6th 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
	4th Segment	PVS-1 > MPS > AP. 1+2 > VC > AP. 3+4+5
	6th 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
	1st Segment	PVS-2 > PVS-1 > MPS > AP. 1 > VC > AP. 2+3+4+5+6
	6th 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
	5th Segment	VC > PVS-1 > MPS > AP. 1+2+3+4+5
	6th 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
	1st Segment	PVS-2 > PVS-1 > MPS > VC > AP. 1+2+3+4+5
	6th 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
	1st Segment	4.26	5.13	-	4.46	4.18	3.90, 3.88, 3.63, 3.59, 3.40, 3.38
	6th 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
	4th Segment	3.74	3.55	-	6.27	-	3.65, 3.59, 3.48, 3.30, 2.85
	6th 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
	1st Segment	3.98	3.95	-	4.37	5.01	4.03, 3.55, 3.43, 3.34, 3.04, 2.93
	6th 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
	5th Segment	4.01	4.34	-	4.31	-	3.69, 3.42, 3.28, 3.13, 2.67
	6th 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
	1st Segment	4.17	3.94	-	4.23	4.46	3.75, 3.48, 3.03, 2.70, 2.35
	6th Segment	3.98	4.63	-	3.92	4.25	3.06, 3.02, 2.58, 2.52, 2.29

Key: (red) The highest integration value
(blue) 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.

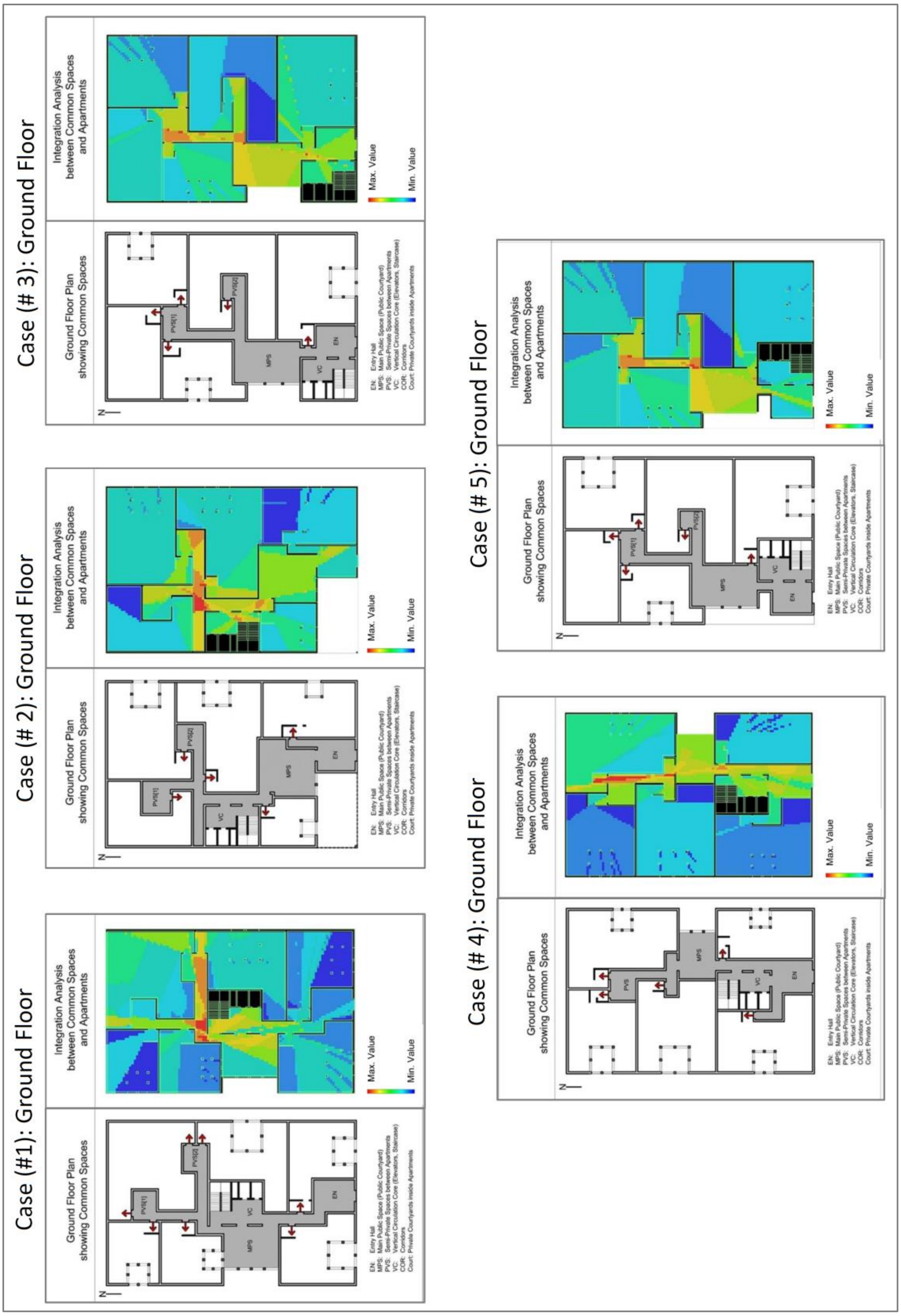


Figure 5.103: Integration analysis between common spaces and apartments on the ground floor for the five cases

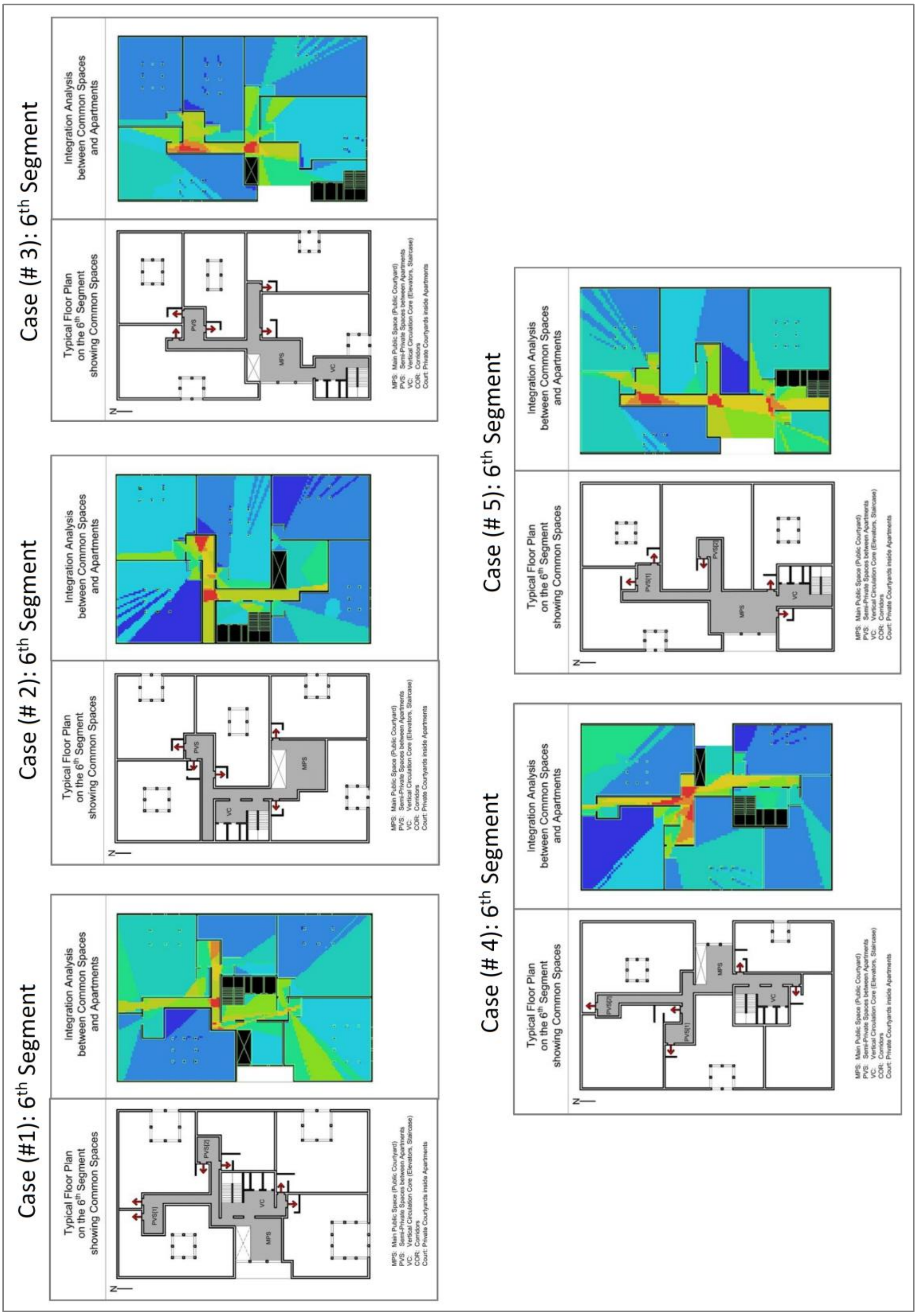


Figure 5.104: Integration analysis between common spaces and apartments on a typical floor on the 6th segment for the five cases

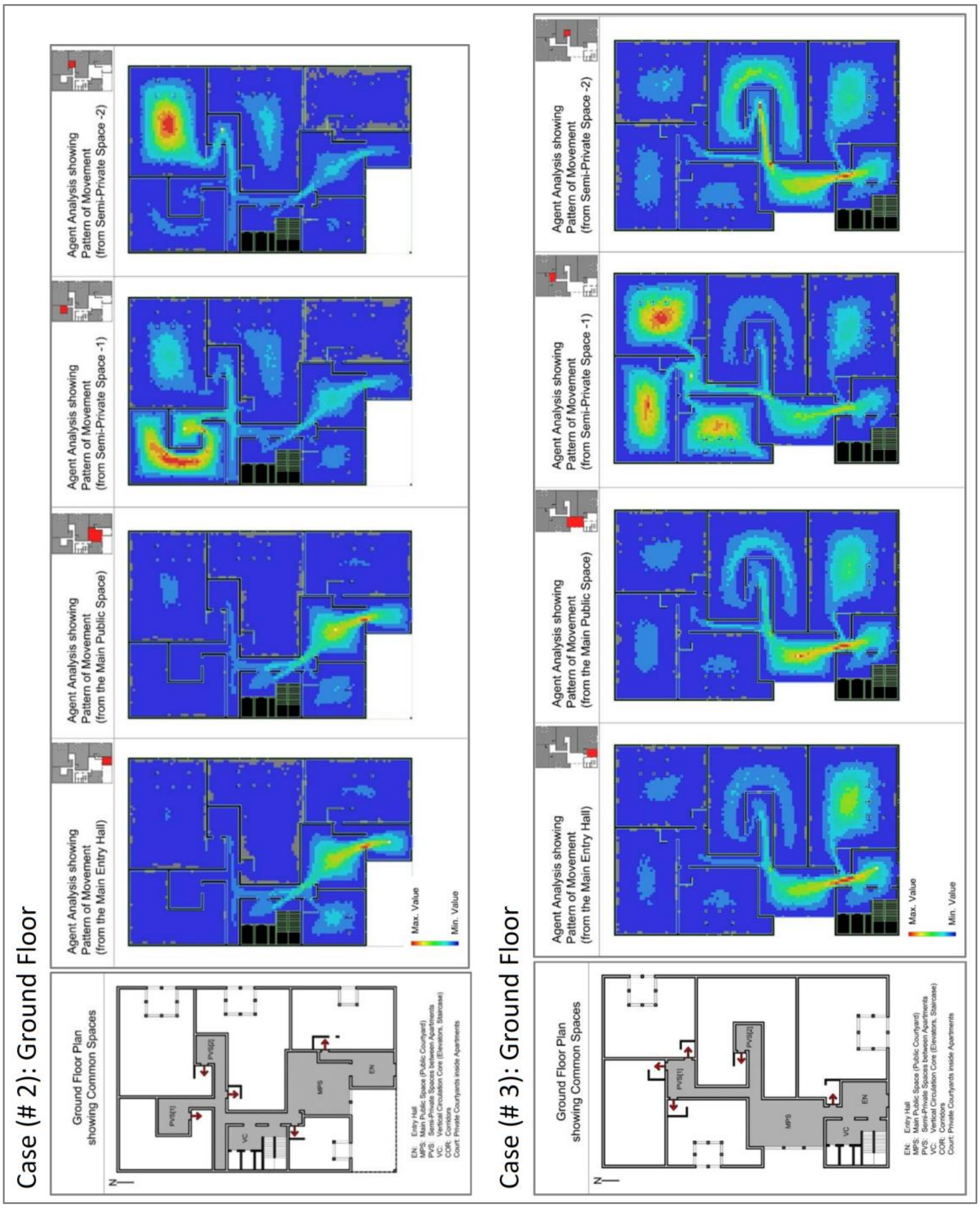


Figure 5.105: Agent analysis from the centre of each common area on the ground floor for Case # 2 and Case # 3

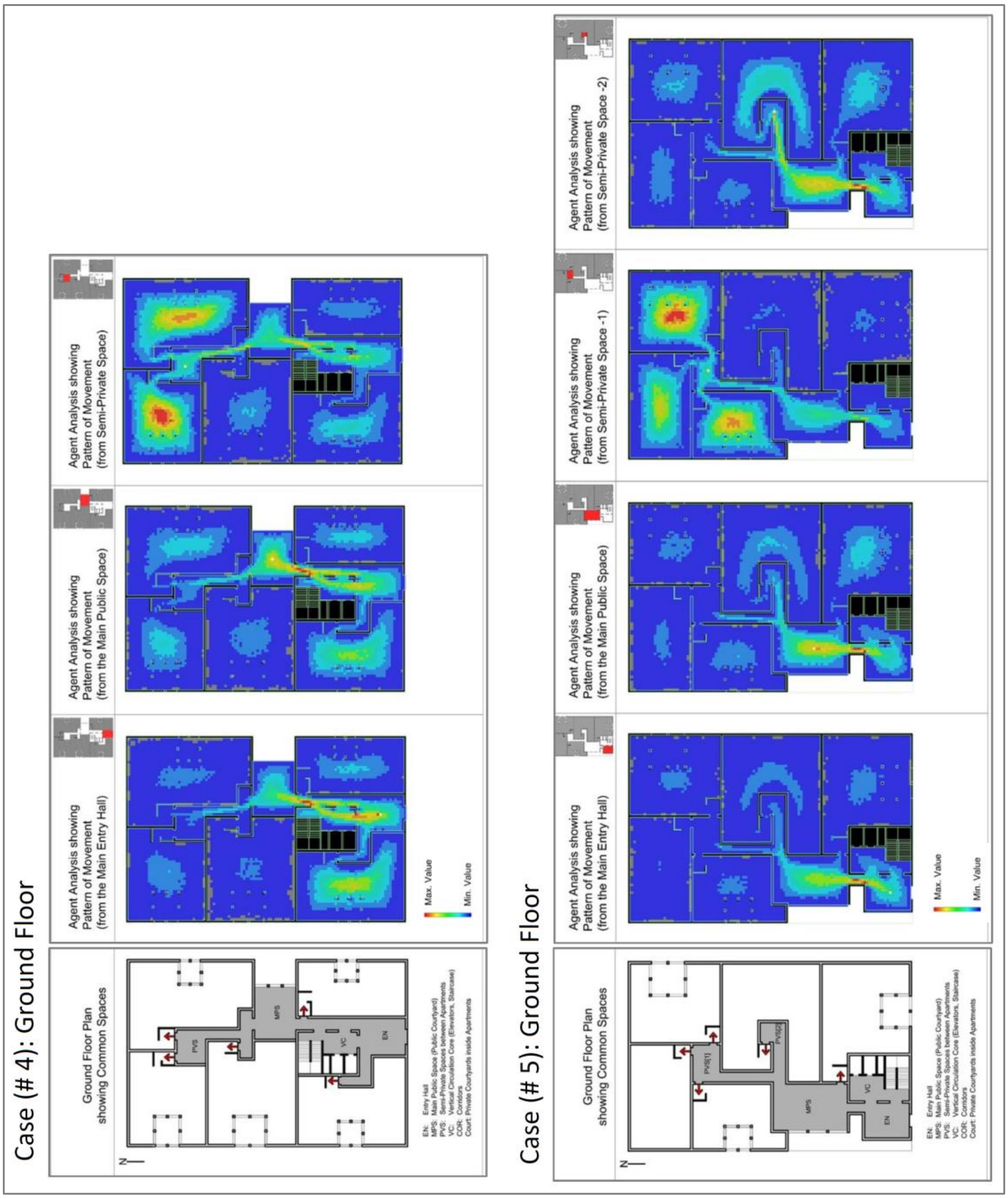


Figure 5.106: Agent analysis from the centre of each common space on the ground floor for Case # 4 and Case # 5

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).

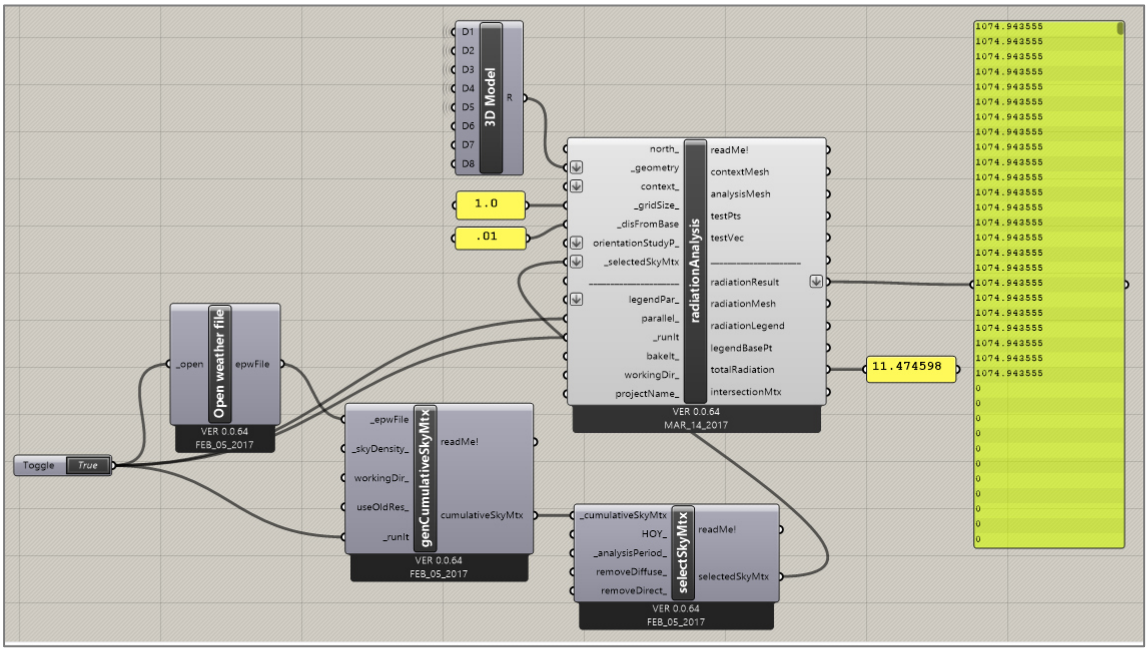


Figure 5.109: Grasshopper code for carrying out radiation analysis

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^2), 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 Length = 45 m Height = 70 m (18 floors)
Description of the building	- Base model: Solid building mass with no courtyards - Proposed design: Includes public and private courtyards
Weather data	Riyadh, KSA (obtained from http://Energyplus.net/weather, *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^2, 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^2, and between 1500.1 and 2215.6 KWh/m^2, 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^2)			Total Radiation (KWh)
		0.0 to 800.0 KWh/m^2	800.1 to 1500.0 KWh/m^2	1500.1 to 2215.6 KWh/m^2	
Base Model (A Building Mass with No Courtyards)		**26.1 %**	**58.0 %**	**15.9 %**	**11,736,821**
Proposed Designs	Case (# 1)	82.8 % (Increased: + 315 %)	14.4 % Reduced: (- 403 %)	2.8 % Reduced: (- 568 %)	11,401,993
	Case (# 2)	82.4 % (Increased: + 315 %)	14.2 % Reduced: (- 410 %)	3.4 % Reduced: (- 470 %)	11,443,531
	Case (# 3)	83.3 % (Increased: + 320 %)	14.0 % Reduced: (- 415 %)	2.7 % Reduced: (- 590 %)	11,454,201
	Case (# 4)	82.3 % (Increased: + 315 %)	14.8 % Reduced: (- 392 %)	2.9 % Reduced: (- 550 %)	11,474,006
	Case (# 5)	83.2 % (Increased: + 320 %)	14.1 % Reduced: (- 411 %)	2.7 % Reduced: (- 590 %)	11,324,268
	Average	**82.8 %** (Increased: + 317 %)	**14.3 %** Reduced: (- 406 %)	**2.9 %** Reduced: (- 554 %)	**11,419,600** Reduced: (- 0.97 %)

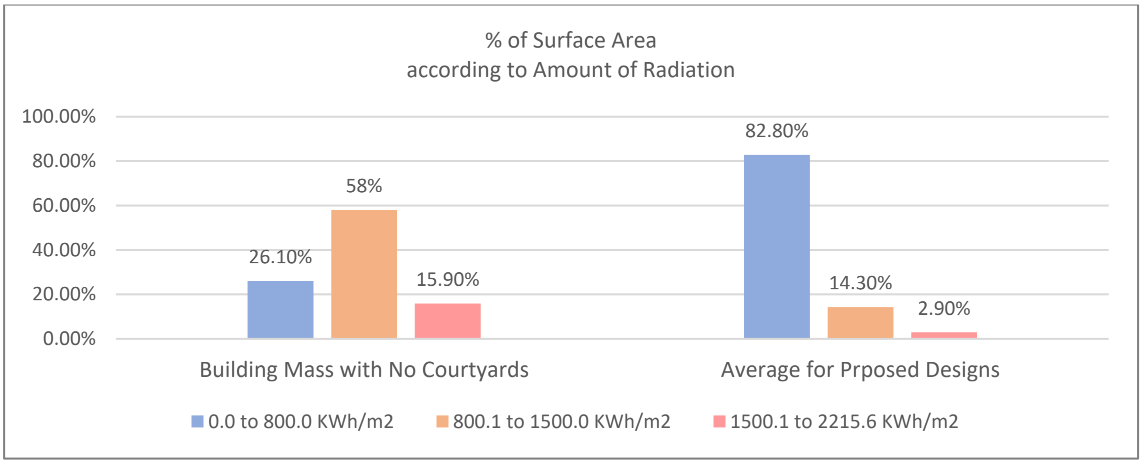


Figure 5.110: Differences between new solutions and a building mass that has no courtyards, according to amounts of radiation

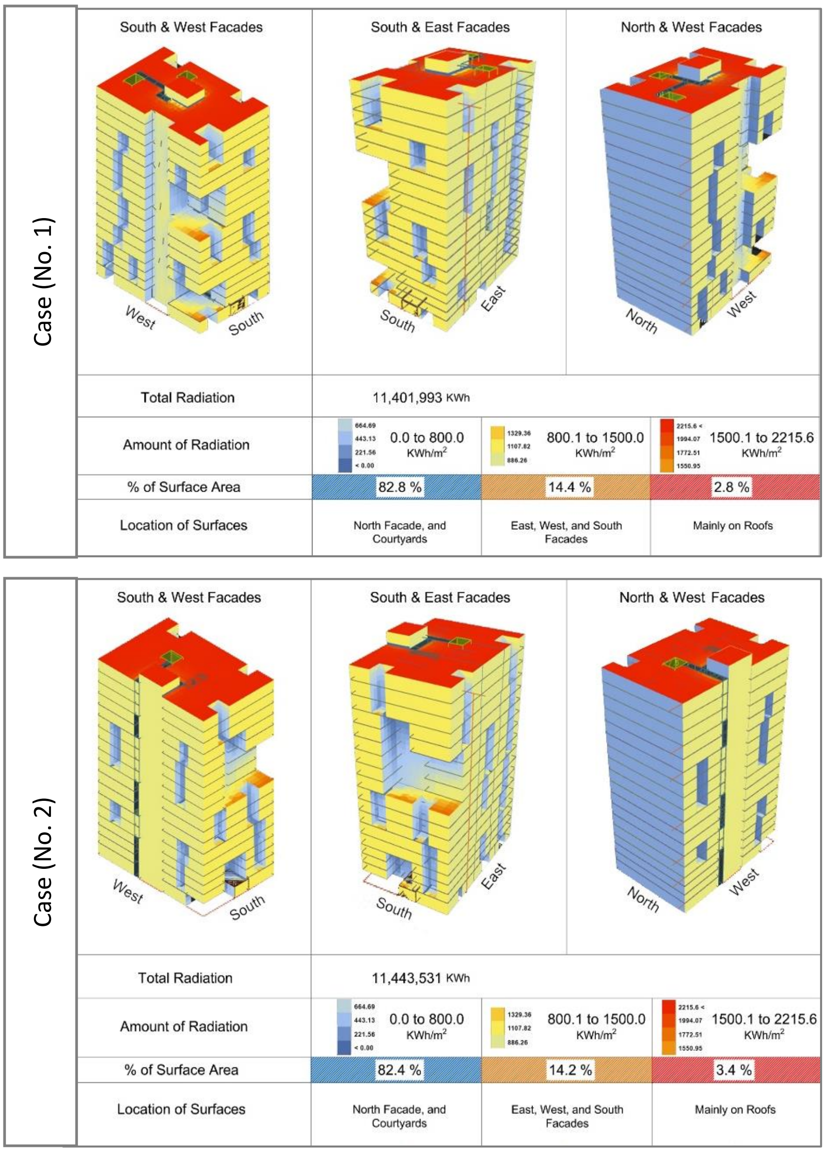


Figure 5.111: Radiation analysis for Case # 1, and Case # 2

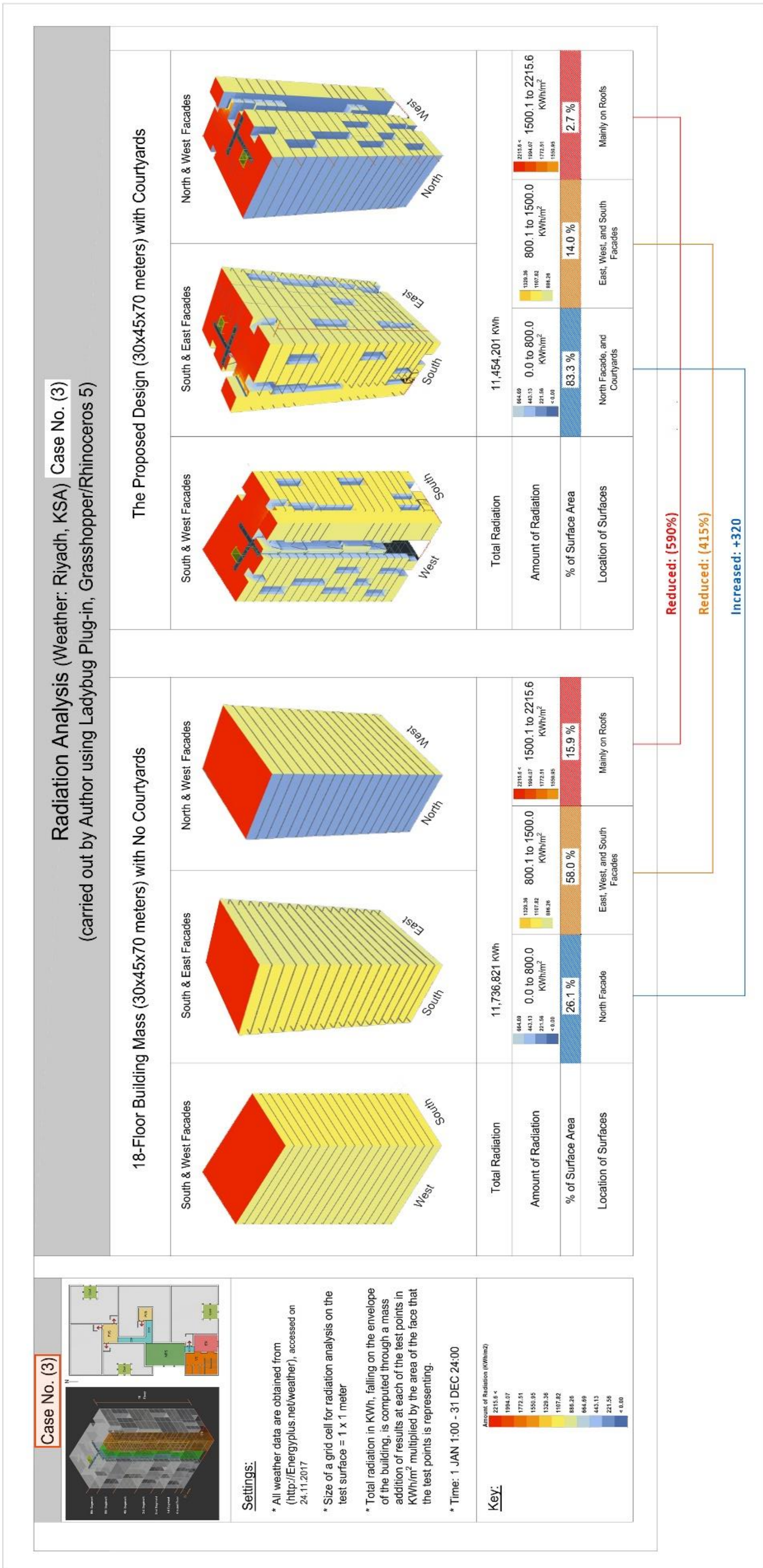


Figure 5.112: A comparative radiation analysis between the base model and Case # 3

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^2 for each floor, an average number of 95 units could be generated. Each apartment has an average area of 200 m^2.

Table 5.25: Percentages of designed spaces from the total allowable area

Case No.	Total Allowable Area (m^2)	Total Designed Spaces (m^2)	% of Designed Spaces	% of Common Spaces from Designed Areas	% of Residential Units from Designed Areas	No. of Units	Average Area of Each Unit (m^2)
Case #1	24300 m^2	22518 m^2	92.7 %	18.5 %	81.5 %	94	195.3 m^2
Case #2		22923 m^2	94.3 %	18.7 %	81.3 %	94	198.2 m^2
Case #3		23248 m^2	95.7 %	16.8 %	83.2 %	100	193.4 m^2
Case #4		23733 m^2	97.7 %	18.0 %	82.0 %	92	211.6 m^2
Case #5		22855 m^2	94.1 %	19.0 %	81.0 %	93	199.2 m^2
Average				**18.2 %**	**81.8 %**	**95**	**200.0 m^2**

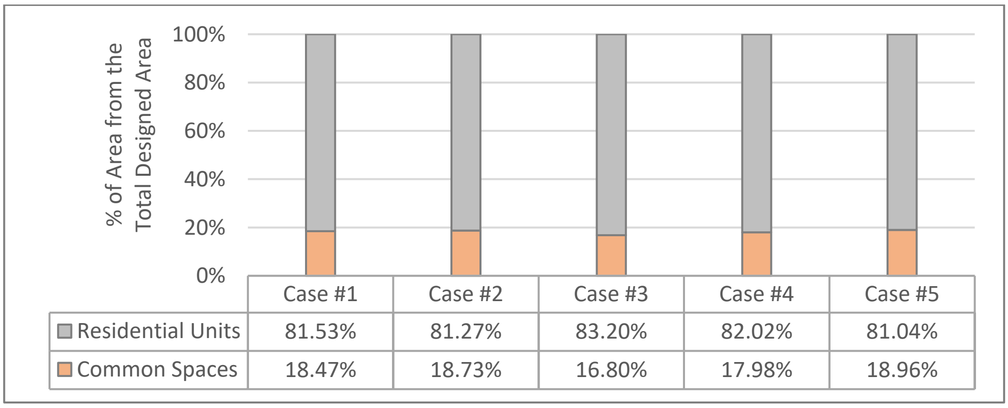


Figure 5.113: Percentages of common spaces and residential units from the total designed area

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).

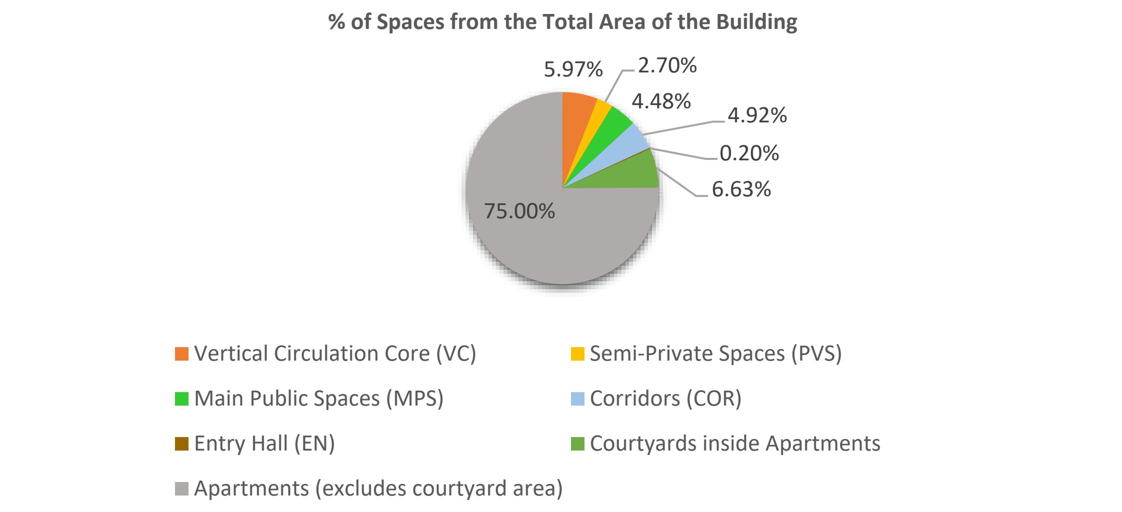
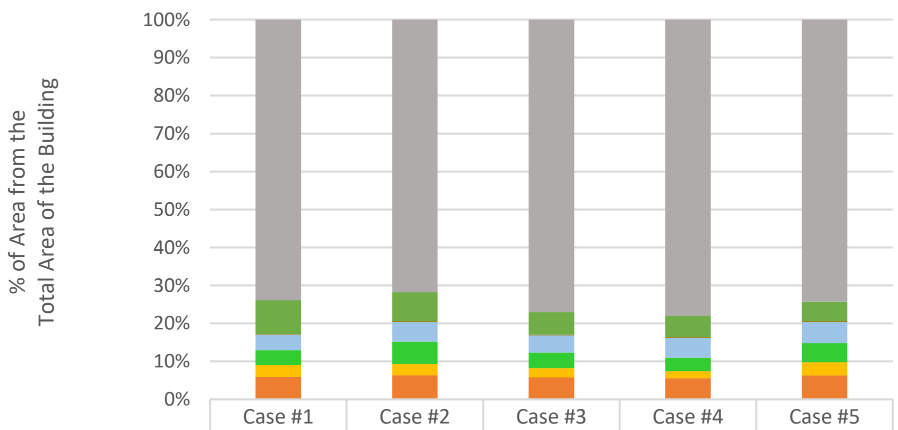


Figure 5.114: Average percentages of different spaces for all cases

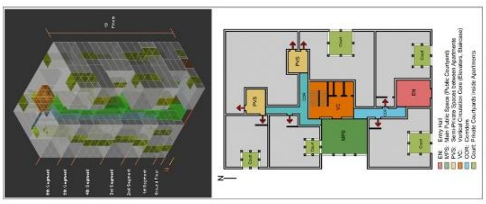


	Case #1	Case #2	Case #3	Case #4	Case #5
Apartments (excludes courtyard area)	73.95%	71.79%	77.01%	78.03%	74.27%
Courtyards inside Apartments	8.83%	7.64%	5.95%	5.58%	5.15%
Entry Hall (EN)	0.20%	0.22%	0.20%	0.19%	0.21%
Corridors (COR)	4.09%	5.18%	4.54%	5.24%	5.53%
Main Public Spaces (MPS)	3.88%	5.86%	4.06%	3.55%	5.05%
Semi-Private Spaces (PVS)	3.17%	2.97%	2.48%	1.83%	3.49%
Vertical Circulation Core (VC)	5.88%	6.34%	5.76%	5.58%	6.30%

Figure 5.115: Percentages of different spaces from the total designed areas

Case No. 1

Spatial Calculations



Ground Floor Plan

Overall Calculations for the Building

Total Number of Floors: 18

Total Height of the Building (meter): 70.4

Total Allowable Area for the Building (m2): 24300.0

Total Designed Area for the Building (m2): 22517.51

Total Area of Common Spaces on All Floors (m2): 4158.49 = 18.47 % of the Total Designed Area

Total Area of Residential Apartments on All Floors (m2): 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 (m2)	Total Designed Area for All Floors on Each Segment (m2)	% 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 %
TOTAL	18	94			22517.51	

Detailed Calculations for Residential Apartments

	Private Courtyards inside Apartments					Area of Apartments (including Courtyards)			
	Area on Each Floor (m2)	% 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 (m2)	% 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	74.73 %	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 = 10.82 % from the Total Area of Apartments	8.83 %			18359.02	81.53 %

Detailed Calculations for Common Spaces inside the Building

	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
Ground Floor	79.28	6.02 %	79.28	0.35 %	39.64	3.01 %	39.64	0.18 %
1st Segment	79.28	6.82 %	237.84	1.06 %	39.64	3.41 %	118.92	0.53 %
2nd Segment	30.09	2.28 %	60.18	0.27 %	39.61	3.01 %	79.22	0.35 %
3rd Segment	49.74	3.77 %	149.22	0.66 %	39.64	3.01 %	118.92	0.53 %
4th Segment	38.49	3.39 %	153.96	0.68 %	39.61	3.49 %	158.44	0.7 %
5th Segment	31.8	2.41 %	63.6	0.28 %	39.64	3.01 %	79.28	0.35 %
6th Segment	43.84	3.33 %	131.52	0.58 %	39.61	3.01 %	118.83	0.53 %
TOTAL			875.6	3.88 %			713.25	3.17 %

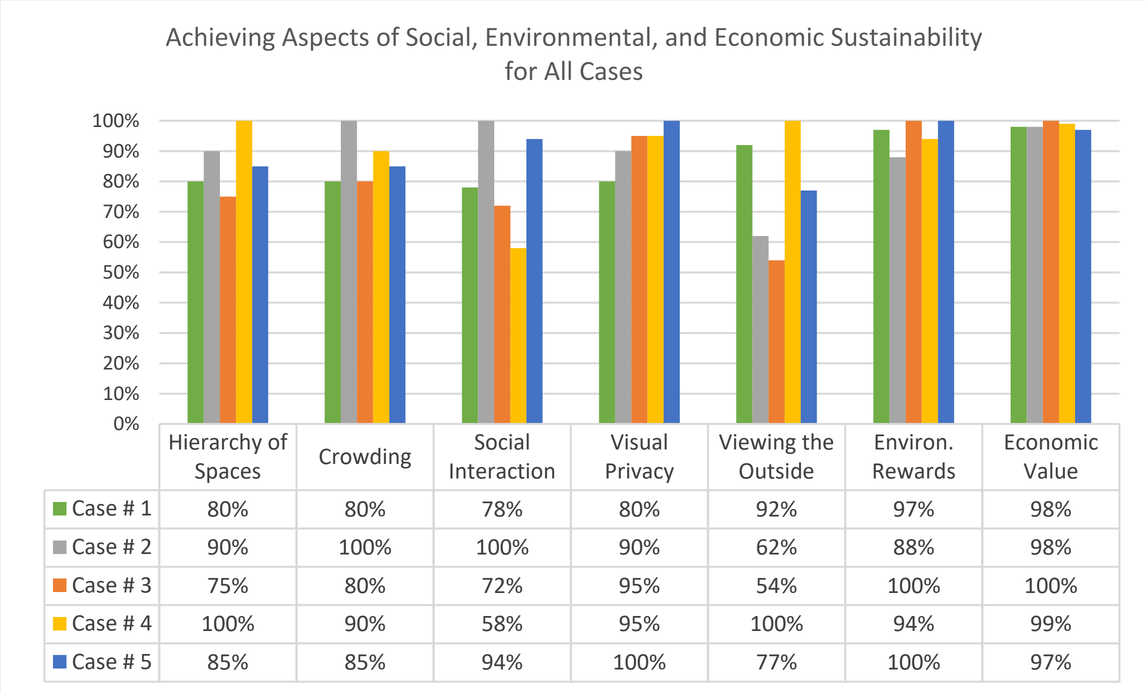
	Entry Hall (EN)			Corridors (COR)				Vertical Core (VC)			
	Area (m2)	% from the Area of the Floor	% from the Total Area of the Building	Area on Each Floor (m2)	% from the Area of Each Floor	Area on All Floors of the Segment	% from the Total Area of the Building	Area on Each Floor (m2)	% from the Area 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 %
TOTAL	45.0	3.41 %	0.2 %			920.38	4.09 %			1323.0	5.88 %

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.



	Hierarchy of Spaces	Crowding	Social Interaction	Visual Privacy	Viewing the Outside	Environ. Rewards	Economic Value
Case # 1	80%	80%	78%	80%	92%	97%	98%
Case # 2	90%	100%	100%	90%	62%	88%	98%
Case # 3	75%	80%	72%	95%	54%	100%	100%
Case # 4	100%	90%	58%	95%	100%	94%	99%
Case # 5	85%	85%	94%	100%	77%	100%	97%

Figure 5.117: Achieving aspects of social, environmental, and economic sustainability for all cases

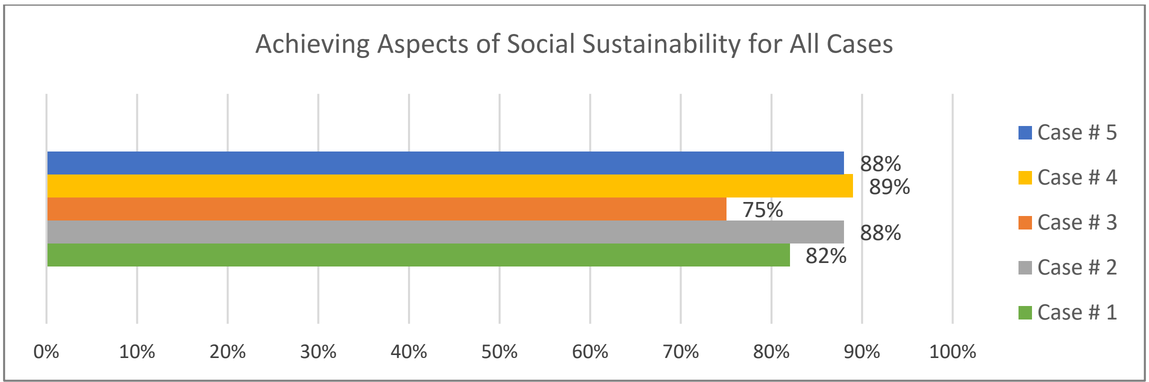


Figure 5.118: Achieving aspects of social sustainability for all cases

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 3rd-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[1] 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

[1] 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[2].

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.

[2] 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
	3rd-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^2.

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 Length = 25 m	Width = 30 m Length = 45 m	Width = 35 m Length = 30 m	Width = 30 m Length = 50 m
Area of the ground floor	1000 m^2	1350 m^2	1050 m^2	1500 m^2
Number of floors	7 floors	12 floors	16 floors	9 floors
Number of designed segments	GF + 3 segments	GF + 6 segments	GF + 5 segments	GF + 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 apartments	58 apartments	94 apartments	68 apartments

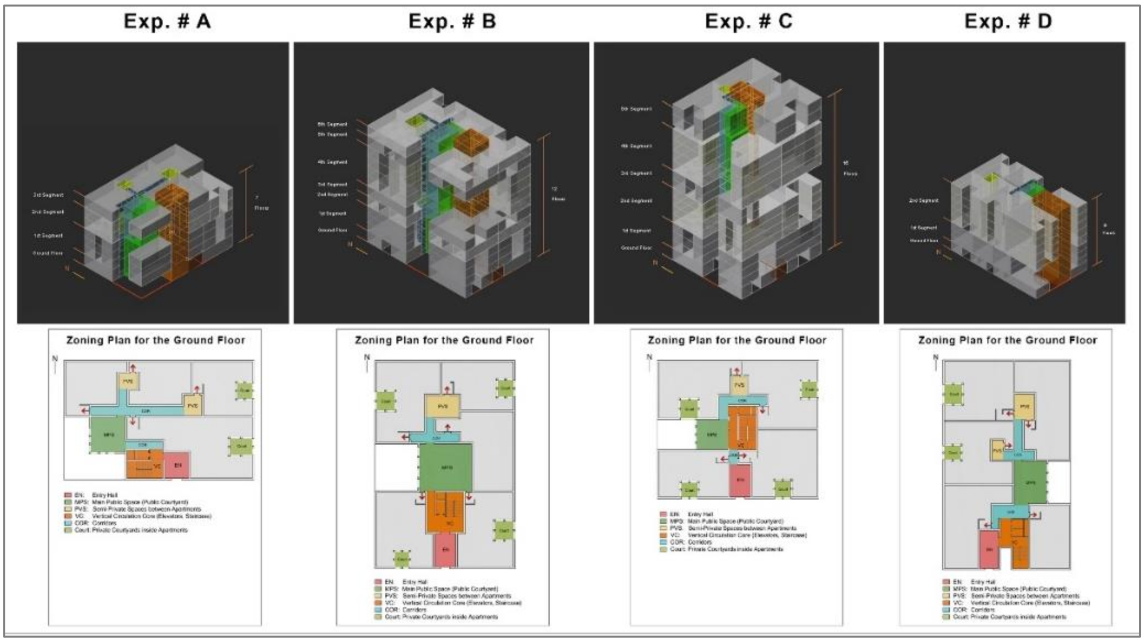


Figure 5.120: Solutions produced by participants: (A + B) by professionals, (C + D) by students

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.

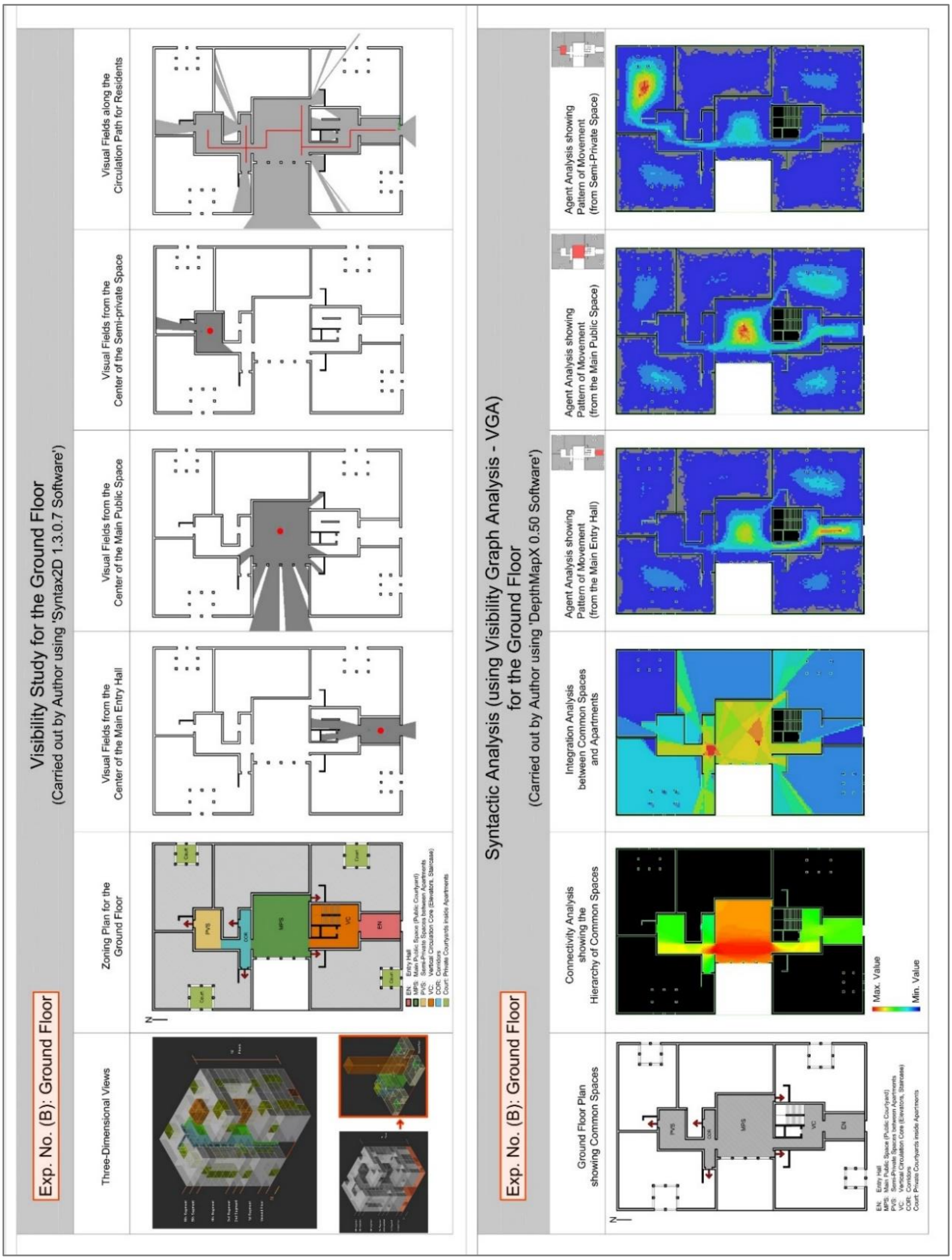


Figure 5.121: Visibility study and syntactic analysis for the ground floor - Experiment #B

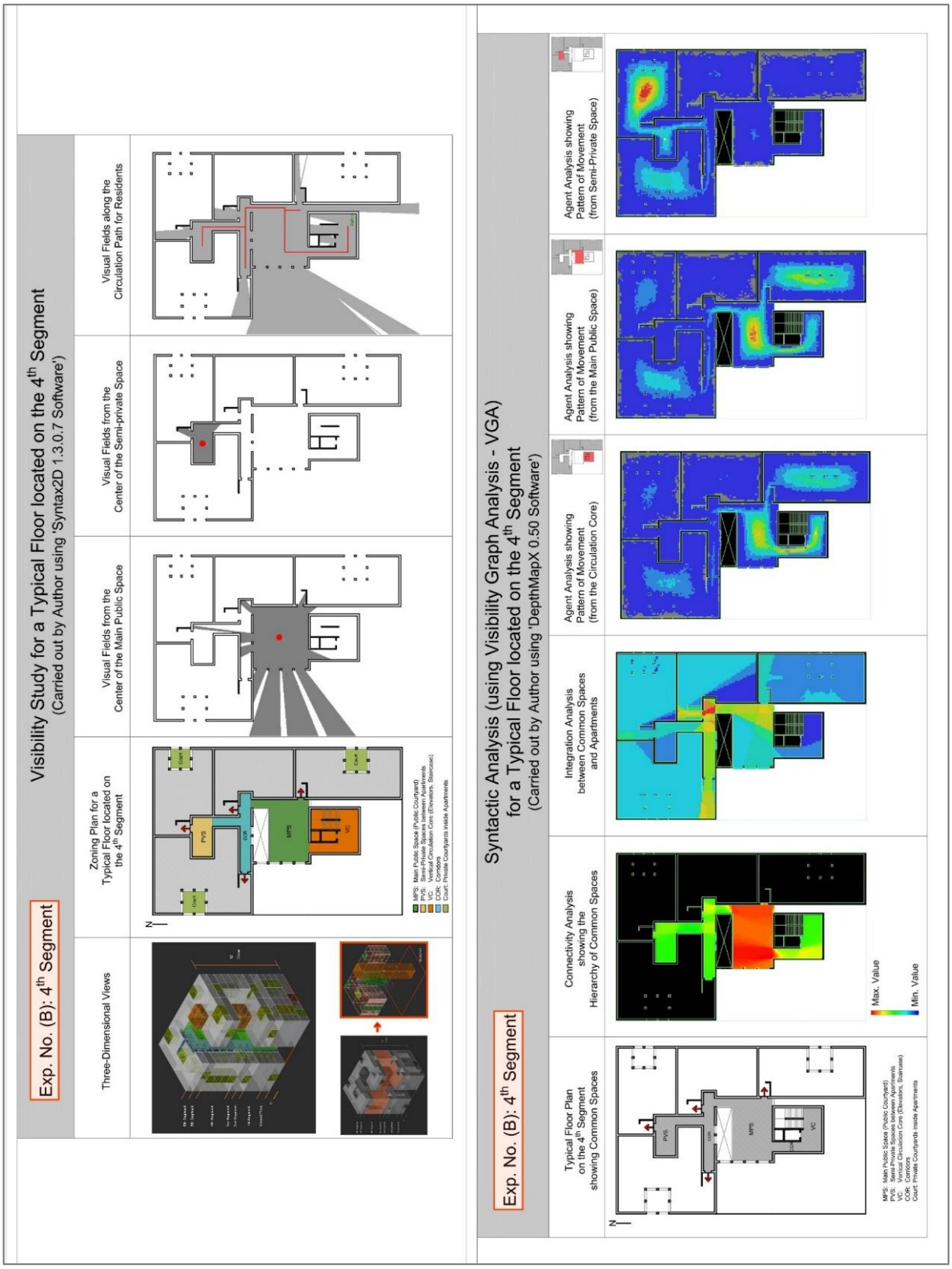


Figure 5.122: Visibility study and syntactic analysis for the 4th segment - Experiment #B

- *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.

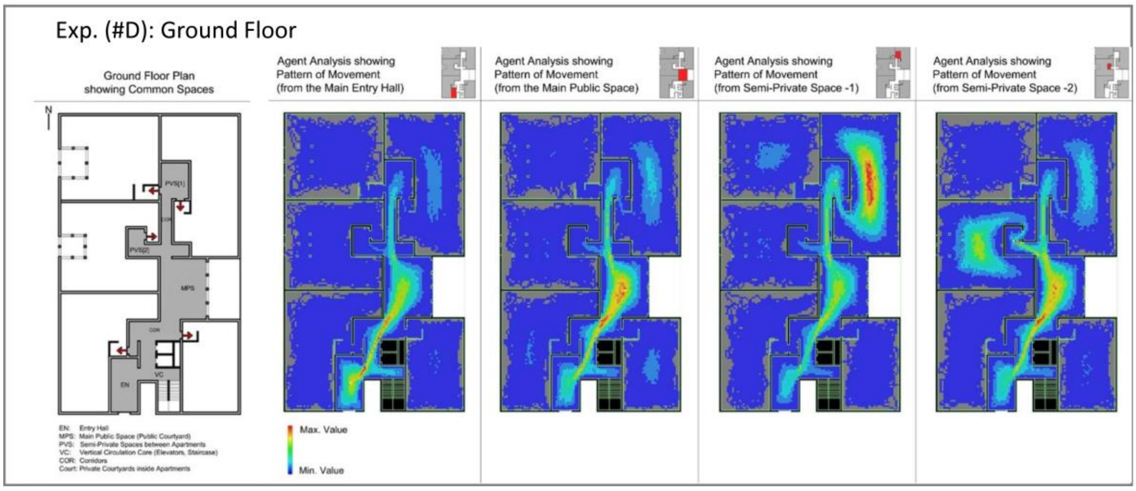


Figure 5.123: Agent analysis from the centre of each common space on the ground floor for Experiment #D

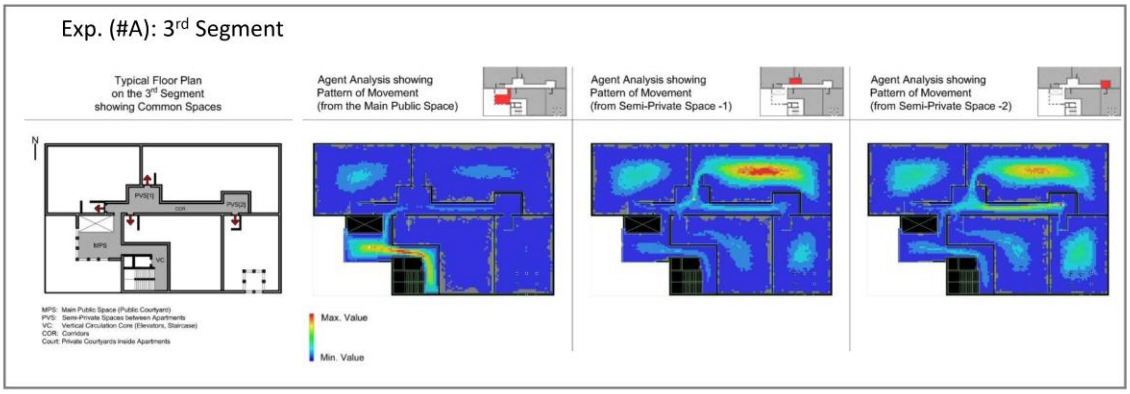


Figure 5.124: Agent analysis from the centre of each common space on the 3rd segment for Experiment #A

- *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 .
	3rd Segment	MPS > PVS-2. > PVS-1. > VC .
Exp. # B	Ground Floor	MPS > VC > EN > PVS-1.
	4th Segment	MPS > VC > PVS-1.
Exp. # C	Ground Floor	VC > MPS > EN > PVS-1.
	4th Segment	VC > MPS > PVS-2. > PVS-1.
Exp. # D	Ground Floor	MPS > VC > EN > PVS-1. > PVS-2.
	2nd 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)

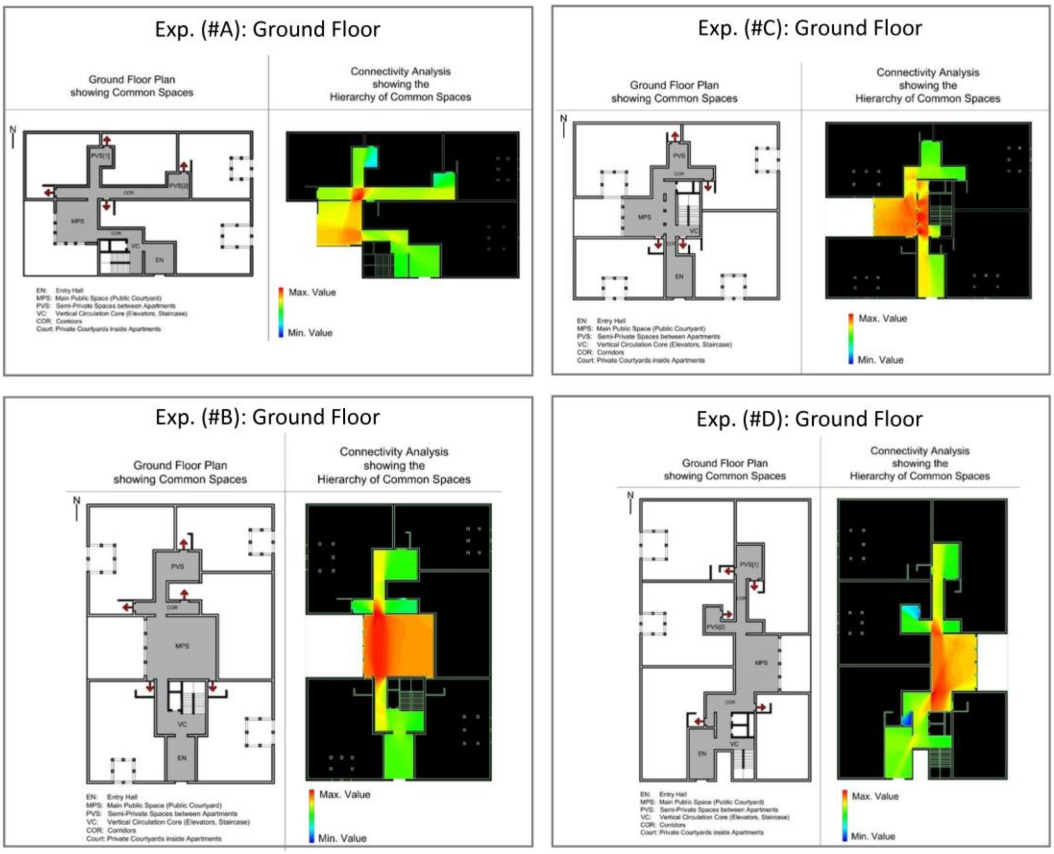


Figure 5.125: Hierarchy of common spaces according to connectivity values on the ground floor of the selected experiments

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
	3rd Segment	5.50	2.15	-	3.91	5.20
Exp. # B	Ground Floor	14.13	6.74	5.73	4.12	-
	4th Segment	9.91	3.45	-	3.10	-
Exp. # C	Ground Floor	7.86	8.75	4.79	2.94	-
	4th Segment	6.73	7.30	-	1.43	4.44
Exp. # D	Ground Floor	12.60	8.10	5.90	4.22	4.01
	2nd 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.

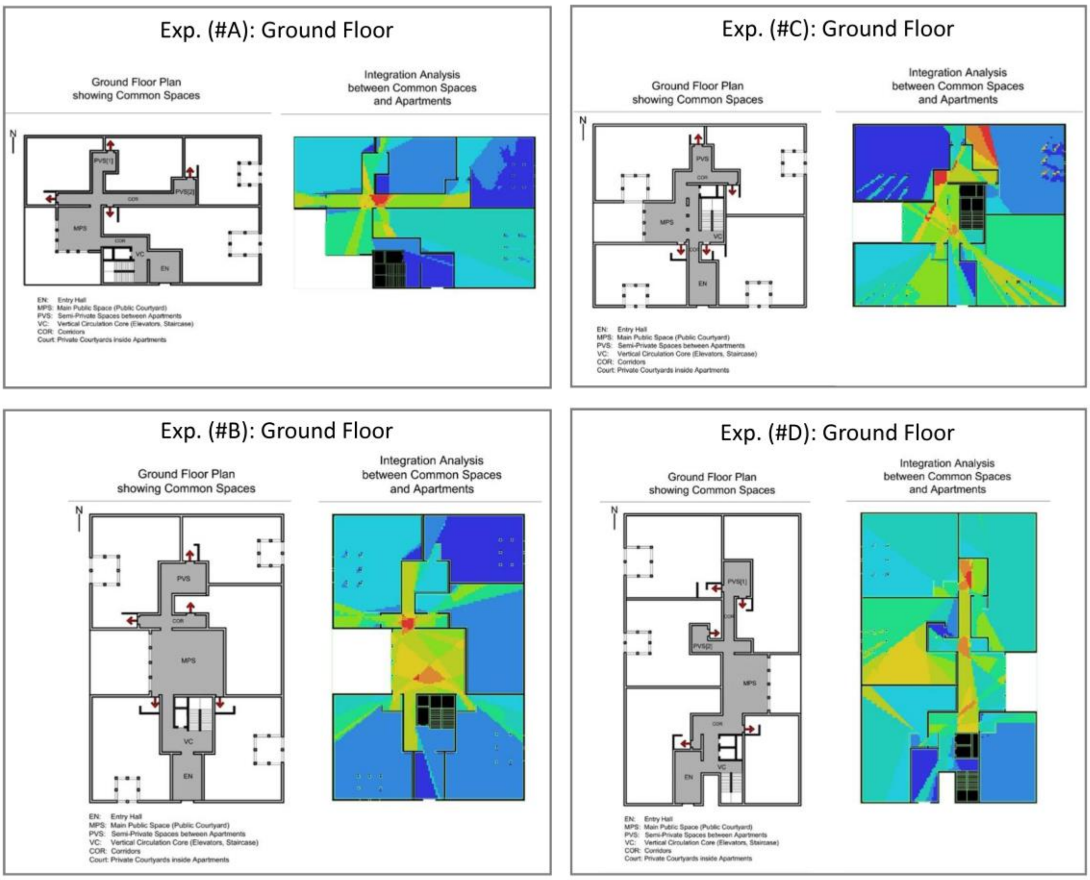


Figure 5.124: Integration analysis for the ground floor of the selected experiments

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 . 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 . 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 . 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 . 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 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 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 . 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 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.

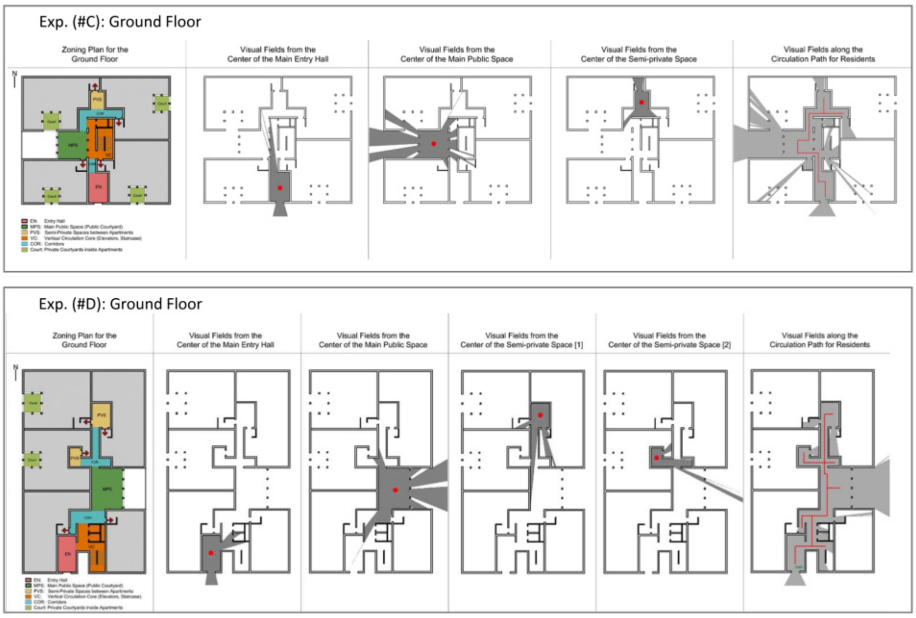


Figure 5.127: Isovist analysis from the centre of each common space on the ground floor Experiments #C and #D

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^2)**	**Total Area of Designed Spaces (m^2)**	**% 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^2)**
Exp. #A	7000 m^2	6067 m^2	86.7 %	16.3 %	83.7 %	51	100 m^2
Exp. #B	16200 m^2	13620 m^2	84.1 %	21.7 %	78.3 %	58	184 m^2
Exp. #C	16800 m^2	14704 m^2	87.5 %	16.1 %	83.9 %	94	131 m^2
Exp. #D	13500 m^2	11605 m^2	86.0 %	20.0 %	80.0 %	68	136 m^2
Average				**18.5 %**	**81.5 %**		

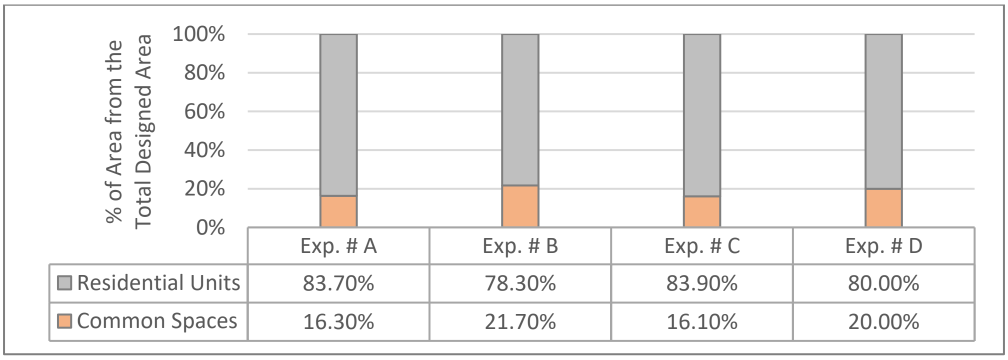


Figure 5.128: Percentages of common spaces and residential units from the total designed area

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)).

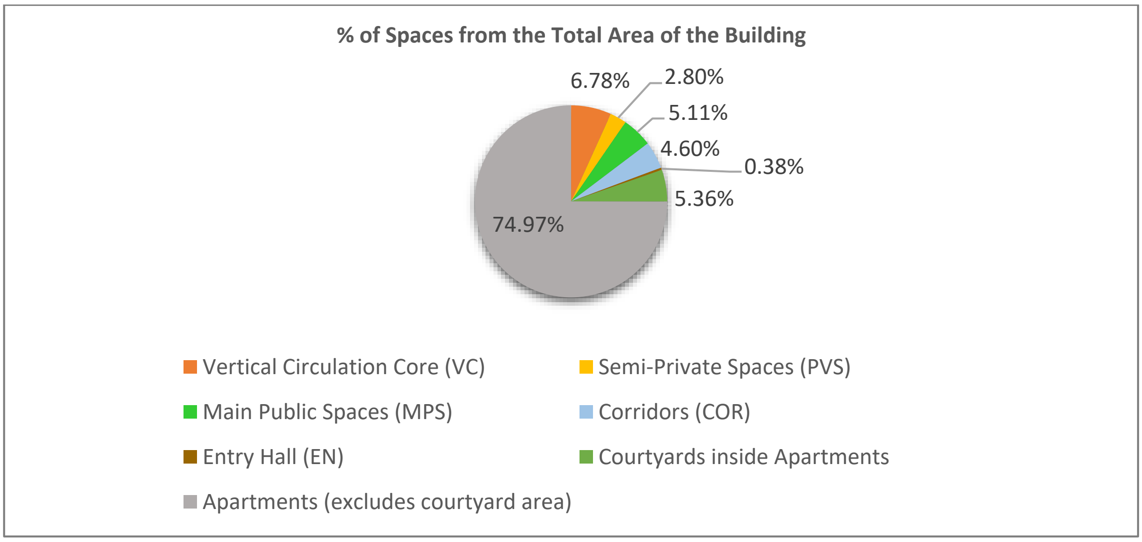
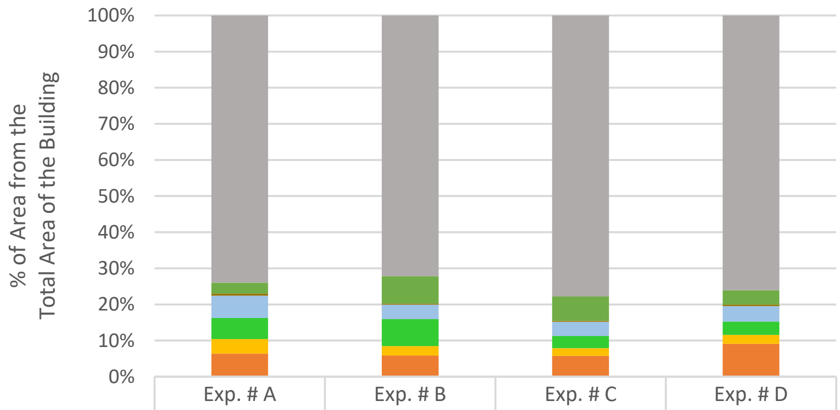


Figure 5.129: Average percentages of different spaces for the selected experiments



	Exp. # A	Exp. # B	Exp. # C	Exp. # D
Apartments (excludes courtyard area)	72.70%	73.63%	77.25%	76.44%
Courtyards inside Apartments	2.98%	7.76%	6.70%	4.01%
Entry Hall (EN)	0.55%	0.30%	0.24%	0.41%
Corridors (COR)	6.05%	4.06%	3.94%	4.33%
Main Public Spaces (MPS)	5.78%	7.63%	3.32%	3.71%
Semi-Private Spaces (PVS)	3.94%	2.66%	2.14%	2.46%
Vertical Circulation Core (VC)	6.28%	5.97%	5.71%	9.15%

Figure 5.130: Percentages of different spaces from the total designed areas for the selected experiments

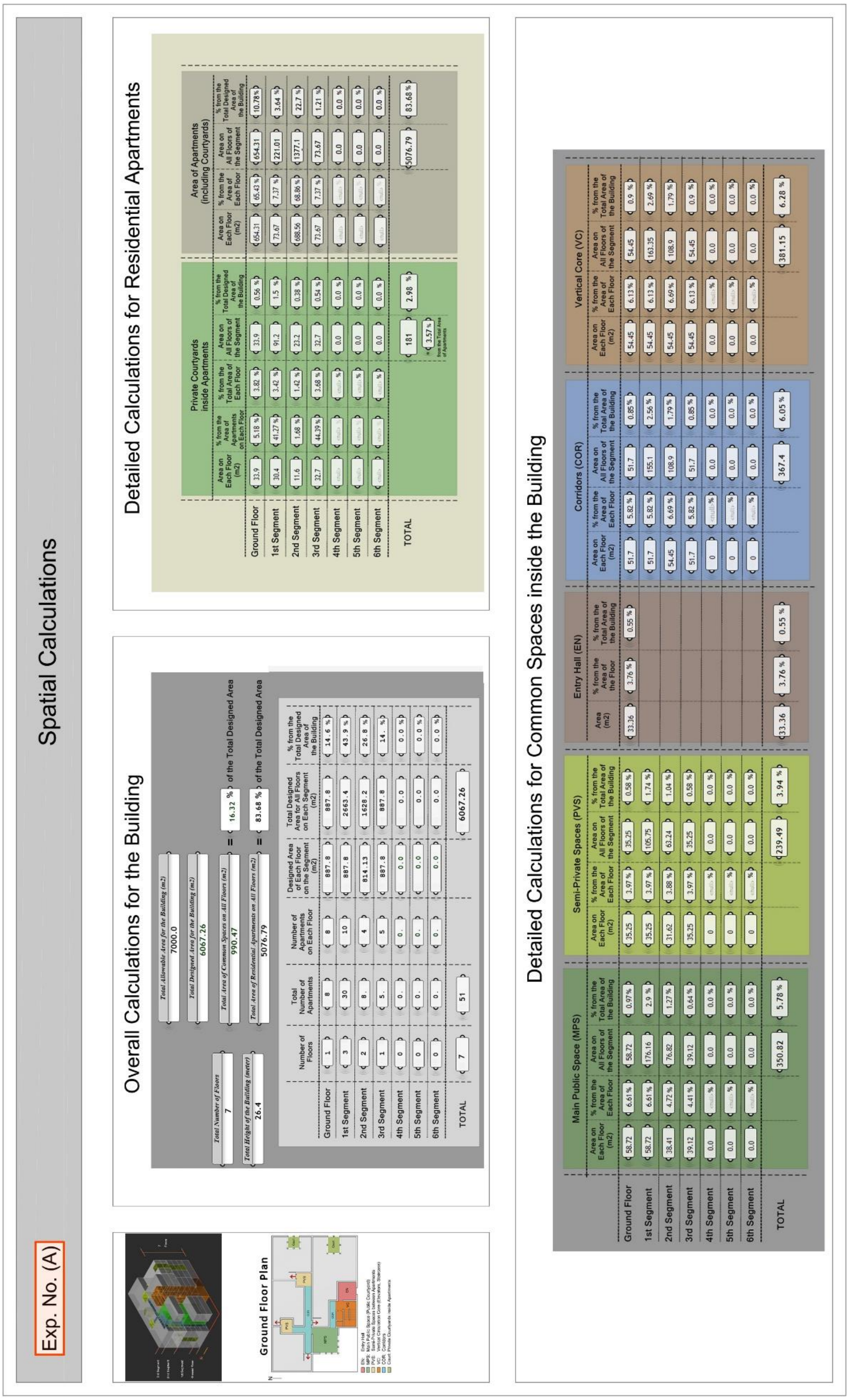
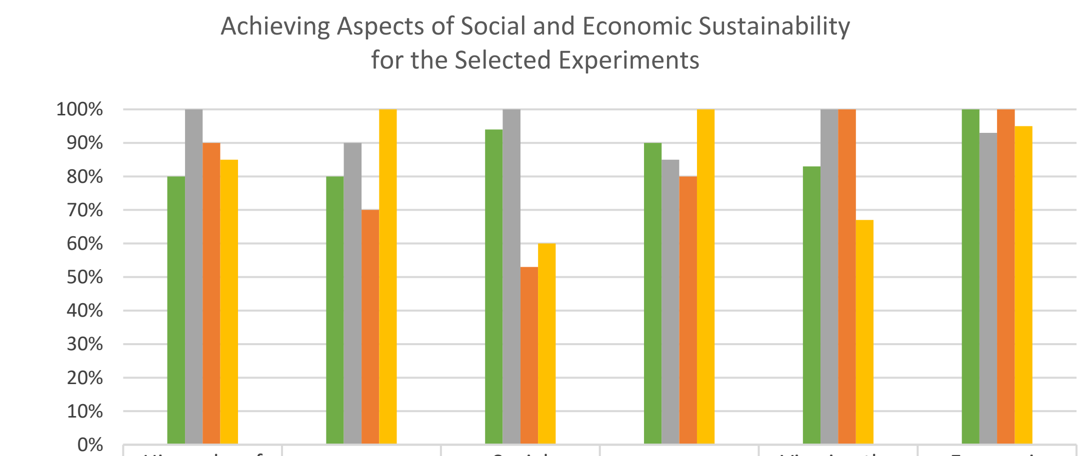


Figure 5.131: Detailed calculations for the different spaces for Experiment #A

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.



	Hierarchy of Spaces	Crowding	Social Interaction	Visual Privacy	Viewing the Outside	Economic Value
Exp. # A	80%	80%	94%	90%	83%	100%
Exp. # B	100%	90%	100%	85%	100%	93%
Exp. # C	90%	70%	53%	80%	100%	100%
Exp. # D	85%	100%	60%	100%	67%	95%

Figure 5.132: Achieving aspects of social and economic sustainability for the selected experiments

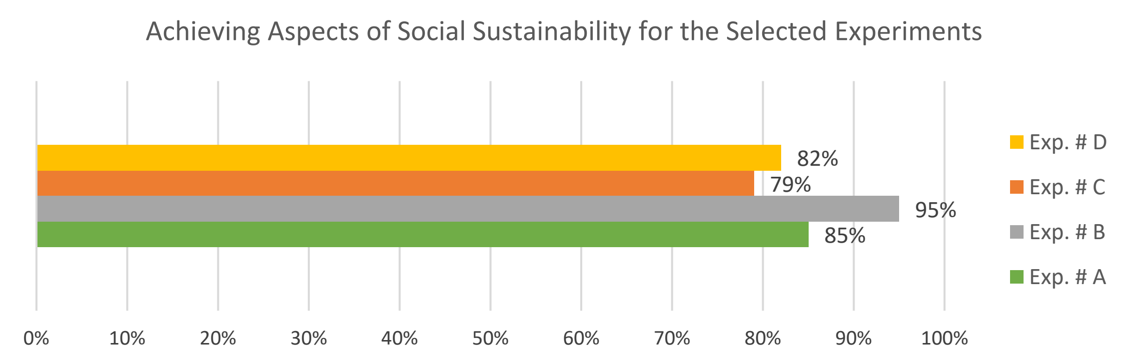


Figure 5.133: Achieving aspects of social sustainability for the selected experiments

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.

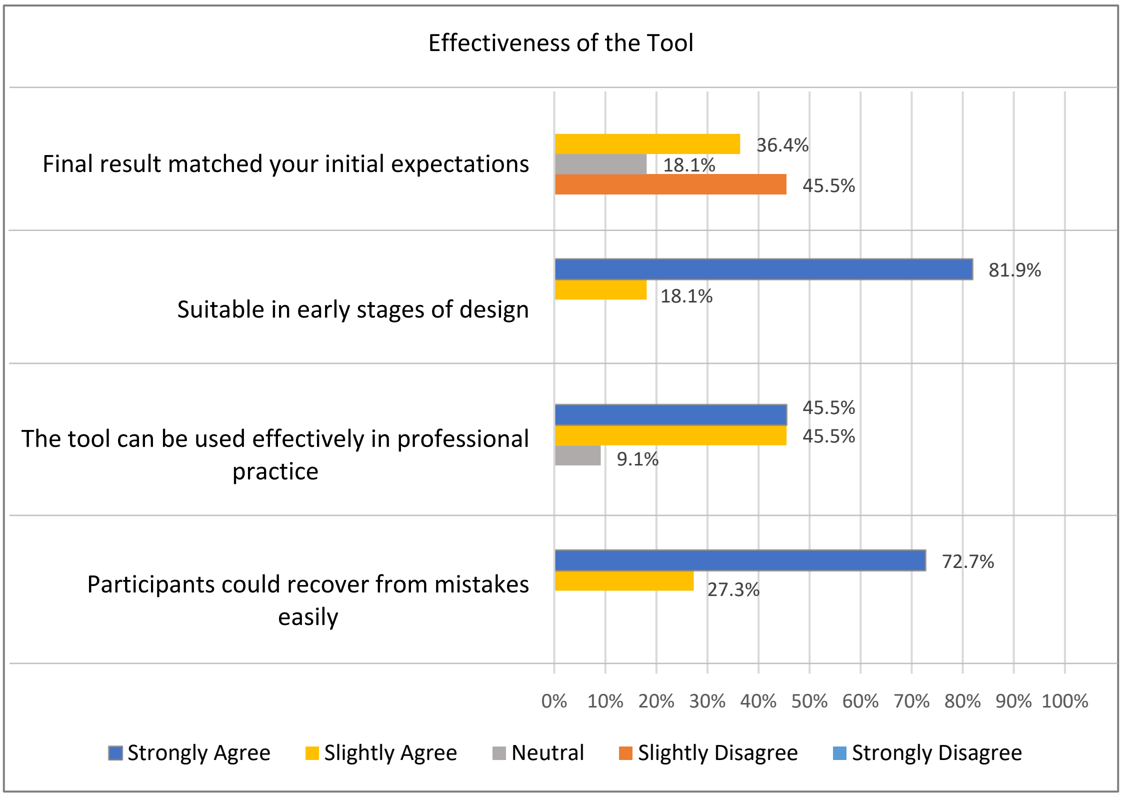


Figure 5.134: Results of the questionnaire regarding the effectiveness of the tool

- 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.

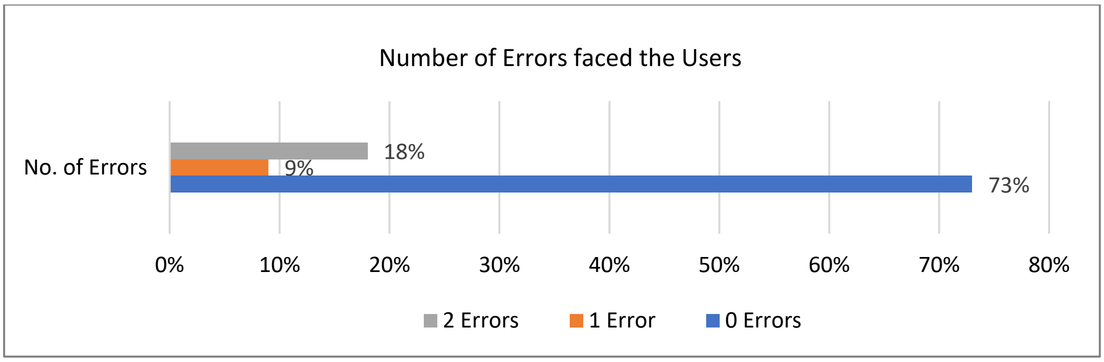


Figure 5.135: Number of errors faced the users during the implementation process

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.

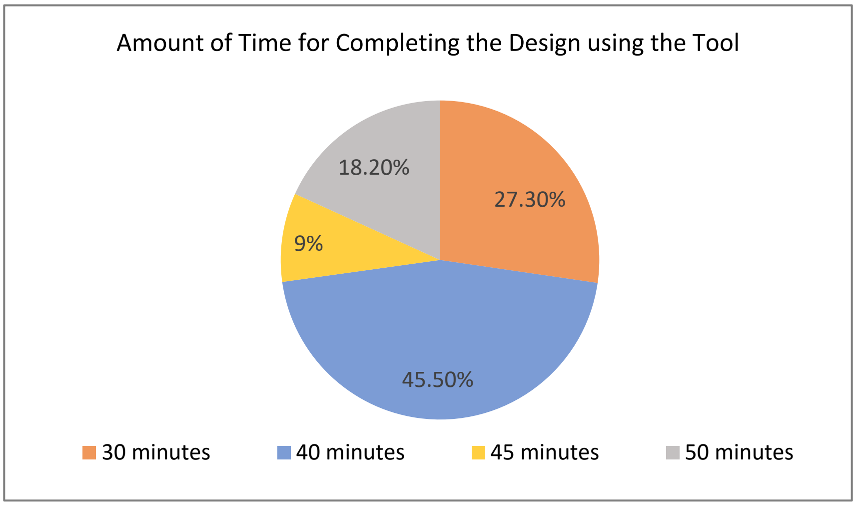


Figure 5.136: Amount of time for completing the task using the tool

- 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.

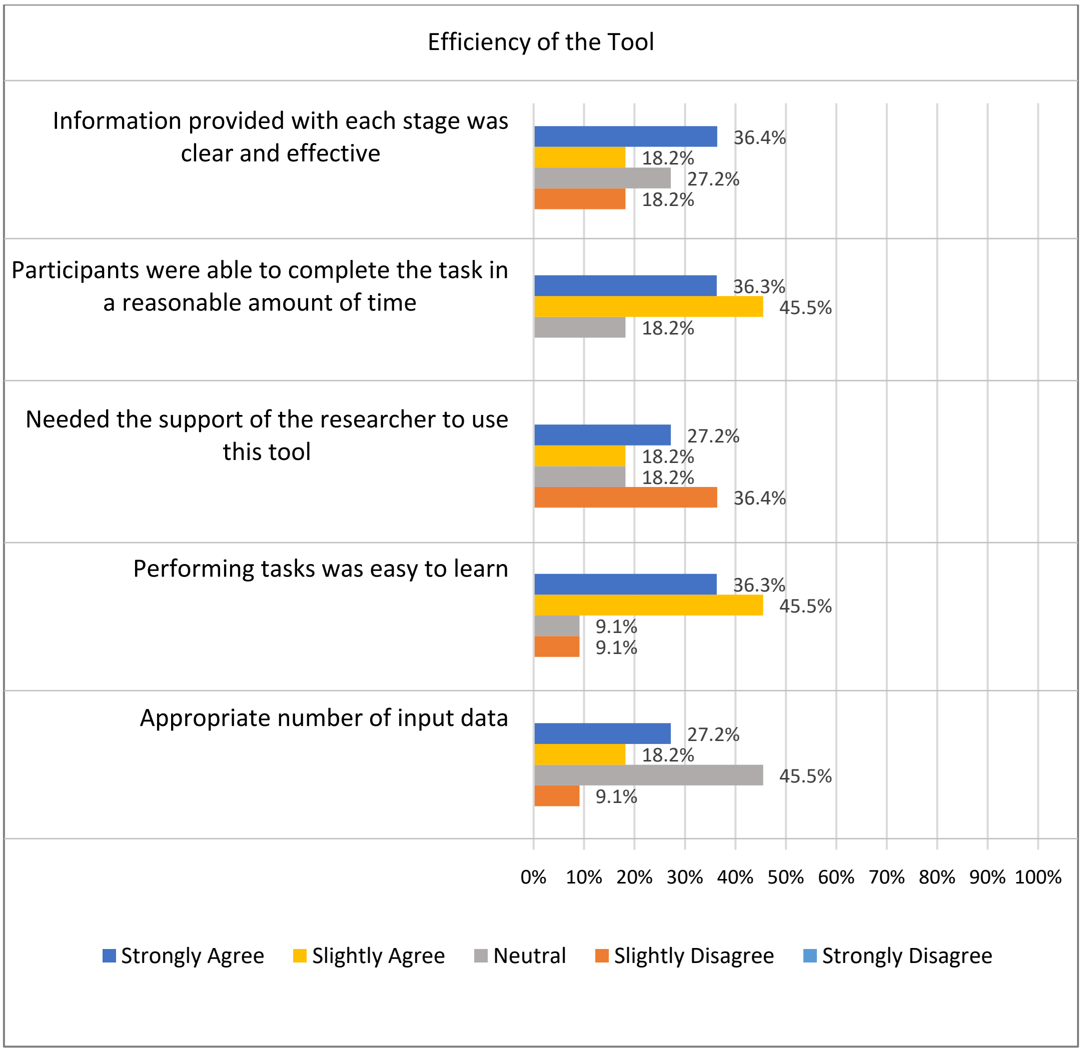


Figure 5.137: Results of the questionnaire regarding the efficiency of the tool

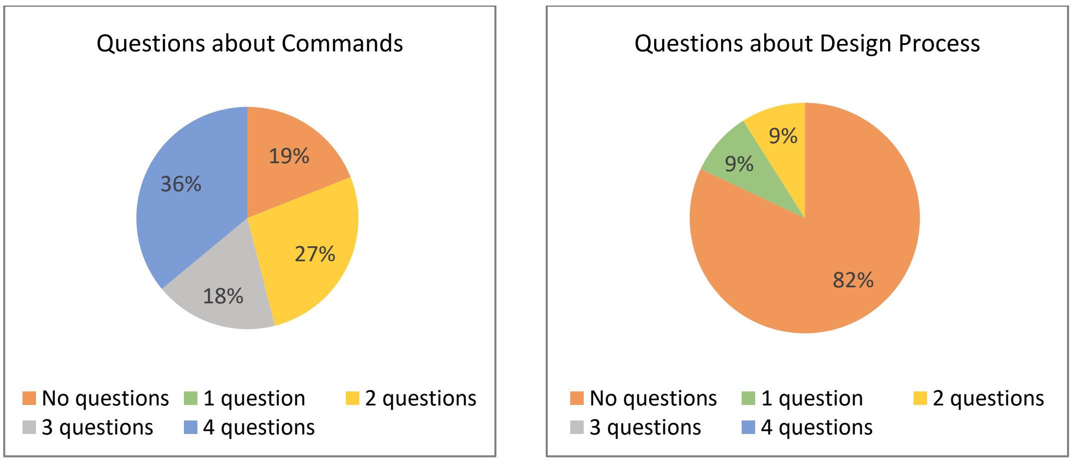


Figure 5.138: Number of questions by participants about commands and design process

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.

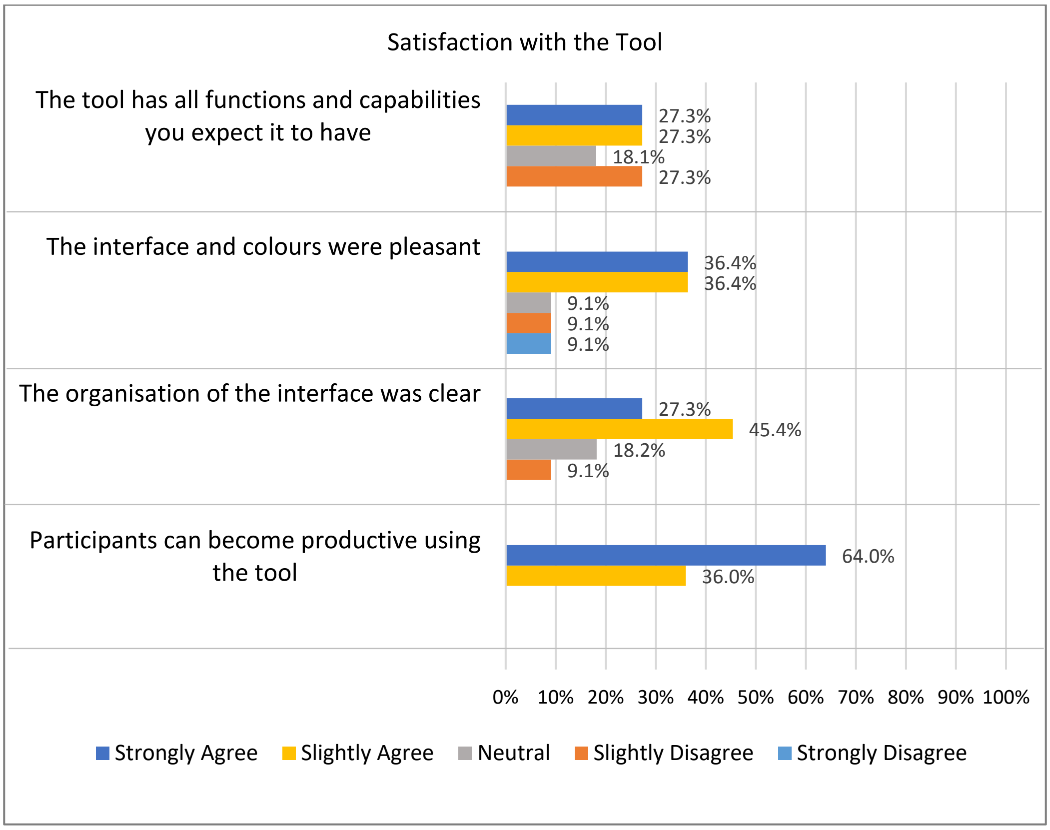


Figure 5.139: Results of the questionnaire regarding level of satisfaction with the tool

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

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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

Appendices

(Volume 2 of 2)

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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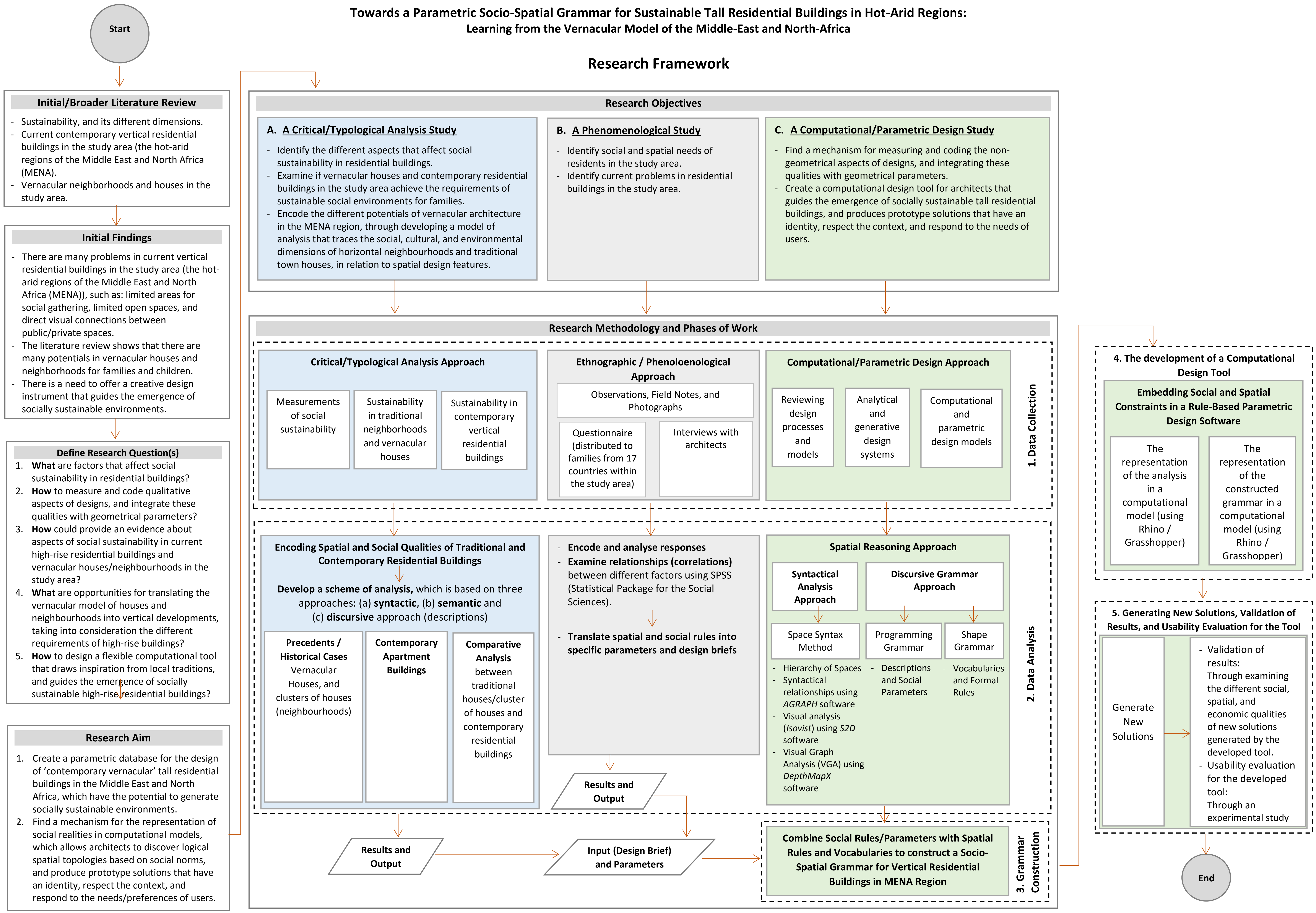
Appendix (1 - 1)

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

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYD

Welsh School of Architecture
Cardiff University
Bute Building
King Edward VII Avenue
Cardiff, CF10 3NB
Wales, UK
Tel: +44 (0)29 087 4430
Fax: +44 (0)29 2087 4623

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**

Supervisors: **Dr. Wassim Jabi - Dr. Oriel Prizeman**

For correspondence:
Email: Al-JokhadarA@cardiff.ac.uk
Tel (UK): 0044-74 247 60 703
Tel (Jordan) 00962-79 597 27 14

Name of Architect: ....
Date of Interview: ....

1. Traditional Houses in the Middle-East and North-Africa

1.1. How would you describe the traditional house in the Middle-East and North-Africa Region? What are its key features you visualize?

....
....
....
....
....
....
....
....
....
....
....
....

1.2. Can you please draw a sketch for a traditional house with all distinctive features?

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

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?

....

....

....

....

....

....

....

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....

....

....

....

....

2.2. What are the key features that developers want in these developments?

....

....

....

....

....

....

....

....

....

2.3. What are problems facing the design of a contemporary high-rise building?

....

....

....

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....

....

....

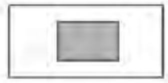
....

....

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 od 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?
....
....
....
....
....
....
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....

Finally, if you have any comments, clarifications or opinions that you would like to share us with, please do not hesitate to write these down.

....
....
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....
....
....
....
....
....
....
....

End of Interview
Thank you for your kind effort

Appendix (4-A-2)

The Questionnaire Form
(In both languages: Arabic and English)

Questionnaire Form

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

Welsh School of Architecture
Cardiff University
Bute Building
King Edward VII Avenue
Cardiff, CF10 3NB
Wales, UK
Tel: +44 (0)29 087 4430
Fax: +44 (0)29 2087 4623

Investigating Social and Spatial Needs in Residential Buildings in The Middle-East and North-Africa

---

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.

Researcher: **Amer Al-Jokhadar**

Supervisors: **Dr. Wassim Jabi - Dr. Oriel Prizeman**

<u>For correspondence:</u>
Email: Al-JokhadarA@cardiff.ac.uk
Tel (UK): 0044-74 247 60 703
Tel (Jordan) 00962-79 597 27 14

Ref. No.		Region					
		1	Gulf Region & Yemen	3	Egypt	5	*Bilad Al-Sham*
		2	*Al-Maghreb*	4	Iraq	6	Turkey

1. Information about Your House and the Household Structure

1.1. In which country do you live today?

- ☐ Saudi Arabia
- ☐ Kuwait
- ☐ United Arab Emirate
- ☐ Bahrain
- ☐ Qatar
- ☐ Oman
- ☐ Jordan
- ☐ Syria
- ☐ Lebanon
- ☐ Palestine
- ☐ Egypt
- ☐ Iraq
- ☐ Turkey
- ☐ Morocco
- ☐ Tunis
- ☐ Algeria
- ☐ 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:

- ☐ Single
- ☐ Couple
- ☐ Couple with children
- ☐ Single with children
- ☐ Extended family
- ☐ 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:

- ☐ Less than 100 m^2
- ☐ 100 – 140 m^2
- ☐ 141 – 180 m^2
- ☐ 181 – 250 m^2
- ☐ More than 250 m^2

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^2

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

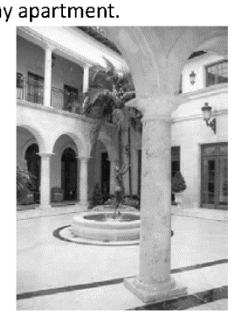
If your answer is (yes), please answer the following questions:

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
e. I would prefer to have a courtyard inside my apartment. 	1	2	3	4	5
f. I would prefer to have an *'iwan'* (a sheltered living space with one open-side connected directly with the courtyard) inside my apartment. 	1	2	3	4	5
g. I would prefer to have a *'gallery'* (a sheltered space with columns around the courtyard) inside my apartment. 	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? .... cm

4.5. What is the most appropriate height of ceiling would you prefer if you move to another house?

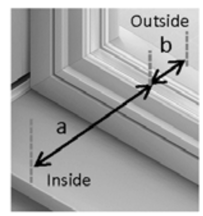
☐ 280 cm ☐ between 290 cm and 350 cm ☐ above 350 cm

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 inside 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).

- ☐ Noise from neighbours
- ☐ Lack of common gathering spaces
- ☐ Lack of social interaction between neighbors
- ☐ Lack of privacy due to the huge number of windows
- ☐ Lack of security and safety issues for children
- ☐ 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).

- ☐ High walls between neighbours
- ☐ High roof parapet
- ☐ Curtains
- ☐ No openings overlooking my neighbours
- ☐ The use of screens (*mashrabiyyah*) and louvers
- ☐ 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).

- ☐ At the entrance of the building
- ☐ At the outside garden of the building
- ☐ At the entrance of your apartment
- ☐ 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

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نمـــــوذج استبيـــــان

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

Welsh School of Architecture
Cardiff University
Bute Building
King Edward VII Avenue
Cardiff, CF10 3NB
Wales, UK
Tel: +44 (0)29 087 4430
Fax: +44 (0)29 2087 4623

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 الدكتوراة في هندسة العمارة من جامعة كاردف 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 اراءكم 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 ومشاركتكم

الباحث: **م. عامر الجوخدار**

المشرفون: **د. وسيم جابي** ، **د. أوريل برايزمان**

للمراسلة:
البريد الالكتروني: Al-JokhadarA@cardiff.ac.uk
هاتف (الأردن): 00962-79 597 27 14
هاتف (بريطانيا): 0044-74 247 60 703

الرقم المرجعي		المنطقة					
		1	الخليج العربي واليمن	3	مصر	5	بلاد الشام
		2	المغرب العربي	4	العراق	6	تركيا

1. معلومات حول السكن والأسرة

1.1. في أي بلد تعيش حالياً ؟

- ☐ المملكة العربية السعودية
- ☐ الكويت
- ☐ الإمارات العربية المتحدة
- ☐ البحرين
- ☐ قطر
- ☐ سلطنة عمان
- ☐ الأردن
- ☐ سوريا
- ☐ لبنان
- ☐ فلسطين
- ☐ مصر
- ☐ العراق
- ☐ تركيا
- ☐ المغرب
- ☐ تونس
- ☐ الجزائر
- ☐ 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 فاكثر

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. مواصفـــات المنـــزل

1.2. المساحة الإجمالية لمنزلك:

- ☐ أقل من 100 م²
- ☐ 100 – 140 م²
- ☐ 141 – 180 م²
- ☐ 181 – 250 م²
- ☐ أكبر من 250 م²

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 الضيوف (تستخدم فقط للرجال)			
ج. غرفة الضيوف (تستخدم فقط للنساء)			
د. غرفة الضيوف (تستخدم للرجال وللنساء)			
ه. غرفة الطعام			
و. غرفة المعيشة			
ز. قاعة متعددة الاستخدامات			
ح. غرفة مكتب / غرفة دراسة			
ط. غرفة نوم رئيسية (مع حمام)			
ي. غرفة نوم للأولاد			
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			
ه. 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 المنـزل

1.3. إذا كنت بحاجة إلى مساحات إضافية في منزلك، ما هي هذه المساحات ؟

....

2.3. 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)

	غير موافق بشدة	غير موافق إلى حد ما	محايد	موافق إلى حد ما	موافق بشدة
أ. فراغات المعيشة العائلية في منزلي صغيرة ولا تلبي احتياجات الأسرة.	1	2	3	4	5
ب. مساحة غرفة الضيوف كبيرة جداً مقارنة بمساحة غرف المعيشة الخاصة بالأسرة في منزلي.	1	2	3	4	5
ج. لا يوجد هناك اتصال بصري بين (غرف الضيوف والطعام) وبين (الغرف الخاصة بالعائلة مثل غرفة المعيشة) في منزلي.	1	2	3	4	5
د. يوجد اتصال بصري مباشر بين (المدخل الرئيسي) وبين (غرفة المعيشة) في منزلي.	1	2	3	4	5
ه. عدد الممرات والموزع بين الغرف كثيرة في منزلي.	1	2	3	4	5
و. أستطيع التنقل بسهولة بين الغرف دون أية عوائق (مثل الأدراج) في منزلي.	1	2	3	4	5
ز. غرف النوم في منزلي هادئة ومعزولة عن غرف المعيشة.	1	2	3	4	5
ح. لا يوجد مساحات خارجية خاصة للعب الأطفال داخل منزلي.	1	2	3	4	5
ط. لا أستطيع رؤية المناظر الخارجية من داخل منزلي.	1	2	3	4	5
ي. موقع وتوجيه المطبخ في منزلي يمنع روائح الطبخ من انتقالها إلى الغرف الأخرى. (يرجى ذكر الجهـــة التي يقع فيها شباك المطبخ)	1	2	3	4	5

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

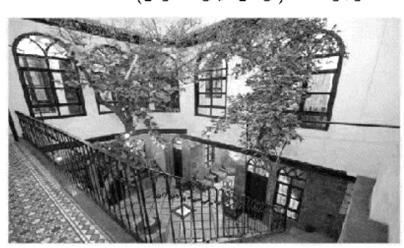
إذا كانت إجابتك (نعم)، الرجاء الإجابة على الأسئلة التالية:

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
أ. أفضّل وجود تراسات خارجية وبرندات في الشقة.	1	2	3	4	5
ب. أفضّل وجود محلات تجارية في الطابق الأرضي من المبنى.	1	2	3	4	5
ج. أفضّل وجود مساحات لتجمع الجيران (مثل فناء/أرض ديار في منتصف المبنى، حدائق داخلية) داخل المبنى.	1	2	3	4	5
د. أفضّل أن تكون الشقة من طابقين: الطابق الأول لغرف الضيوف والمعيشة، والطابق الثاني لغرف النوم. 	1	2	3	4	5
ه. أفضّل وجود فناء (أرض ديار / حوش) داخل الشقة. 	1	2	3	4	5

صفحة 4 من 7

و. أفضّل وجود إيوان (غرفة معيشة مسقوفة ومكشوفة من جهة واحدة على الفناء (الحوش)) داخل الشقة. 	1	2	3	4	5
ز. أفضل وجود رواق (فراغ خارجي مسقوف ومحاط بأعمدة) حول الفناء (الحوش) داخل الشقة. 	1	2	3	4	5

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 البيئية داخل المنـزل

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 / المسلحات؟ ....

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 / المسلحات؟ ....

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 ؟

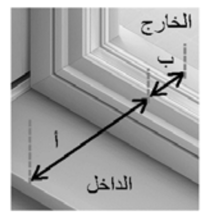
☐ نعم ☐ لا

4.4 ما هو ارتفاع السقف داخل منزلك ؟ .... سم

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).



المسافـــة (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).

- ☐ الإزعاج من الجيران
- ☐ قلة الخصوصية بسبب كثرة الشبابيك
- ☐ قلة أماكن التجمع مع الجيران
- ☐ قلة الشعور بالأمان والأمور الخاصة بسلامة الأطفال
- ☐ قلة التواصل الاجتماعي مع الجيران
- ☐ لا أستطيع استعمال المساحات الخارجية والتراسات لأنها مكشوفة من الجيران

3.5. ما هي المعالجات المختلفة في منزلك والتي تساعد في توفير الخصوصية لك ولعائلتك ؟ (يرجى وضع علامة أمام جميع ما ينطبق).

- ☐ أسوار عالية بين الجيران
- ☐ عدم وجود شبابيك تطل مباشرة على الجيران
- ☐ استخدام تصوينة عالية على سطح المنزل
- ☐ استخدام عناصر خشبية/معدنية على الشبابيك تمنع الجيران من رؤية داخل المنزل
- ☐ استخدام الستائر
- ☐ معالجات أخرى (أذكرها) ....

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)

- ☐ عند مدخل العمارة
- ☐ في الممرات الداخلية عند مدخل الشقة
- ☐ في الحديقة الخارجية للمبنى
- ☐ 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

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 Rooms 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. Family spaces	Family living room
12-A		Multi-purpose hall
12-B		Office / Study area
12-C		Other (please specify)
13	2.3.c. 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. 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. Outdoor 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 m2) 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.	a. Features in the apartment
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. Information about the 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

WSA

Tick one box:	☐ STAFF ■ 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:	14th 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 (http://www.cardiff.ac.uk/archi/ethics_committee.php)				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)[1]	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? (http://www.cf.ac.uk/osheu/index.html)	x		

Research Governance	YES	NO	N/A
Does your study include the use of a drug? You need to contact Research Governance before submission (resgov@cf.ac.uk)		x	
Does the study involve the collection or use of human tissue? You need to contact the Human Tissue Act team before submission (hta@cf.ac.uk)		x	

[1] 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*).	x
• I consider this project research to have **some ethical implications**.	
• I consider this project to have **significant ethical implications**	

PhD student:

Signature	**Name**	**Date**
[signature]	**Amer Al-Jokhadar**	**14.06.2016**

Supervisor:

Signature	**Name**	**Date**
[signature]	**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

Juliet Davis — **Signature**

Name JULIET DAVIS

28.06.16 **Date**

Chair, School Research Ethics Committee

Welsh School of Architecture
Ysgol Bensaernïaeth Cymru
Head of School, Pennaeth yr Ysgol
Professor, Yr Athro Chris Tweed BSc BArch PhD FHEA

Cardiff University
Bute Building
King Edward VII Avenue
Cardiff CF10 3NB
Wales UK

Tel +44(0)29 2087 4430
www.cardiff.ac.uk/architecture

Prifysgol Caerdydd
Adeilad Bute
Rhodfa'r Brenin Edward VII
Caerdydd CF10 3NB
Cymru, Y Deyrnas Unedig

Ffôn +44(0)29 2087 4430
www.caerdydd.ac.uk/architecture

10th 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,

K Lewis

Katrina Lewis
Research Executive Officer

Email: lewisk2@ccf.ac.uk
Direct line: +44 (0)2920 876251

The Queen's Anniversary Prizes For Higher and Further Education 2013
INVESTORS IN PEOPLE
Athena SWAN Bronze Award
QAA Cymru UK Quality Assured Sicrwydd Ansawdd y DU

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 needs 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:
    - 180 – 240 m^2 (three bedrooms): two apartments in each floor.
    - 60 – 80 m^2: 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

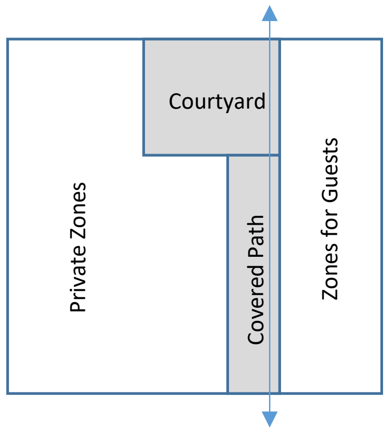
- One of the most important characteristics of traditional houses in the region is that the outside walls of the house are located on the boundary of plot, and opened to the inside through using courtyards. Gardens are inside the house and not on the sides of the house.
- The use of *mashrabiyyah* in 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-Ghouri 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^2.
- 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):
    - Modon Project, Dubai, UAE
    - Apartment Buildings, Senegal
    - Apartment Buildings, Mecca, KSA
    - Wadi Abu Jamil, Beirut, Lebanon
    - 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

BUILDING TYPE -3

DAR AL-OMRAN
Planners - Architects - Engineers

SIGNATURE APARTMENT BUILDINGS
SECTOR - C
STAGE II - CONCEPT DESIGN

mace
DUBAI PROPERTIES

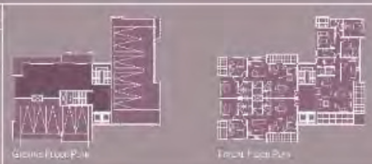
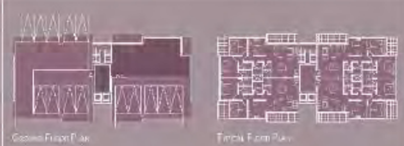
Residential - Building Apartments

Building Apartments

155 Apartment buildigs are disributed in the site in 23 groups

Each group of buildings gathered arround a grren garden and children playing area

Apartment Buildings

Building	Quant.	Plans
B1	23	
B2	70	
B3	8	
B4	29	
B5	21	
B6	4	

Apartment Buildings

Main lobby , car parking and building utility at ground floor level

Upeer 4 floors for apartments, the fifth and sixth floors for appartments and duplexes with roof garden


Type A
Three Bedrooms
Gross Area = 156 m²
Terrace = 40 m²
No. = 92
Type B
Two Bedrooms
Gross Area = 114 m²
Terrace = 18.5 m²
No. = 720


Type C
Three Bedrooms - Duplex
Gross Area = 185 m²
Terrace = 94 m²
No. = 23
Maid Room
Bath
Bedroom
Bedroom
Kitchen
Upper Floor Plan
Lower Floor Plan

Type D

Three Bedrooms
Gross Area = 158 m²
Terrace = 70 m²
No. = 142

Type E

Two Bedrooms
Gross Area = 120 m²
Terrace = 20 m²
No. = 280

Type F

Three Bedrooms - Duplex
Gross Area = 168 m²
Terrace = 58 m²
No. = 70

Upper Floor Plan

Lower Floor Plan

Type G

Three Bedrooms

Gross Area = 134.5 m²
Terrace = 16.8 m²
No. = 700

Type H

Three Bedrooms

Gross Area = 152 m²
Terrace = 34 m²
No. = 116

Type I

Three Bedrooms - Duplex

Gross Area = 198 m²
Terrace = 130 m²
No. = 29

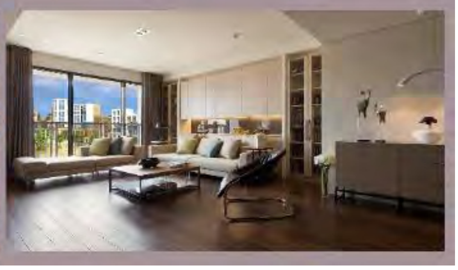
Upper Floor Plan

Lower Floor Plan

Type J

Two Bedrooms

Gross Area = 112 m²
Terrace = 15 m²
No. = 168



Type L

Three Bedrooms - Duplex

Gross Area = 149 m²

Terrace = 48 m²

No. = 42

Upper Floor Plan

Lower Floor Plan

Type K

Two Bedrooms

Gross Area = 112 m²

Terrace = 12 m²

No. = 84

Type M

Lower Floor Plan

Upper Floor Plan

Three Bedrooms - Duplex

Gross Area = 170 m²

Terrace = 53 m²

No. = 21

Type N

Two Bdrooms

Gross Area = 122 m²

Terrace = 34 m²

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 البنيان". 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 for the characteristics of traditional building is the German Jordanian University in Amman, Jordan (Design by Dar Al-Omran, Architect Rasem Badran).
    - All classes are oriented to the north-south axis.
    - Classes are parallel to circulation paths.
    - The use of louvers on the south facade.
- The use of sackcloth on skylights is a good solution for preventing the sun to be entered directly.
- When we design the house, we should allow the residents to adapt their houses with 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

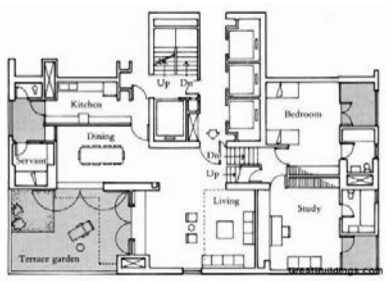
Interview # 5 - Architect Wael Al-Masri
Date of Interview: 03/08/2016 (17:00 pm – 18:30 pm)

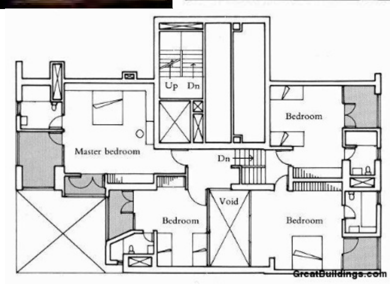
1. Traditional Houses in the Middle-East and North-Africa

- 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)



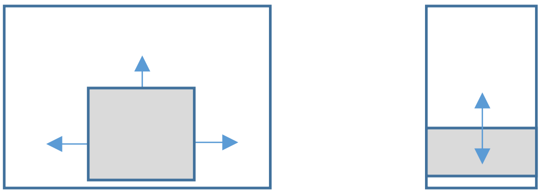


- A main problem in apartment buildings is that the residents do not care with public spaces and plazas inside the building. Therefore, developers do not prefer to include common spaces inside buildings, as it needs regular maintenance.

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.



Courtyard Terraces

- 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 see, and a green wall for plants.

تصاميم معاصرة و مستدامة من وحي التراث و الأصالة

وائل المصري
مخططون و معماريون
Wael Al-Masri
Planners & Architects

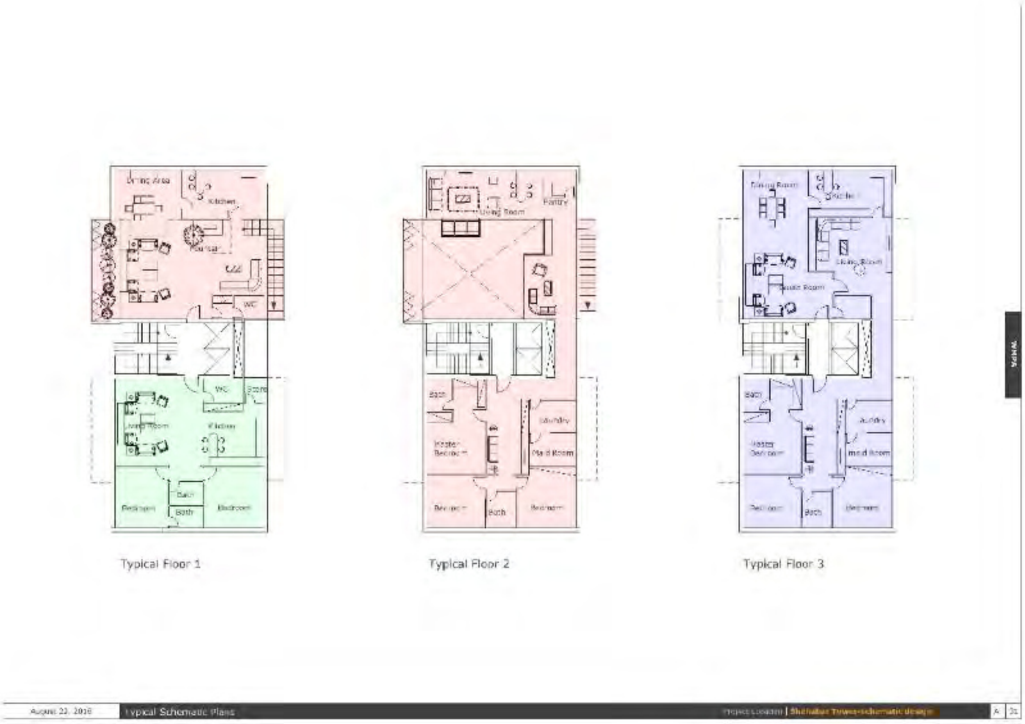
تركز الشركة على التصميم الشمولي المتكامل، بما في ذلك التخطيط الهيكلي والتصميم المعماري وتنسيق الموقع والتصميم الداخلي للمشاريع في العالم العربي بشكل عام ومنطقة الخليج بشكل خاص. وتركز الشركة على تطوير العمارة المعاصرة المستمدة من الثقافة العربية الإسلامية والتراث المعماري الأصيل لهذه المنطقة. ويستخدم فريق التصميم بالشركة المفاهيم الحديثة والتقنيات الرائدة إلى تحقيق المشاريع المستدامة بيئيا واقتصاديا وثقافيا.

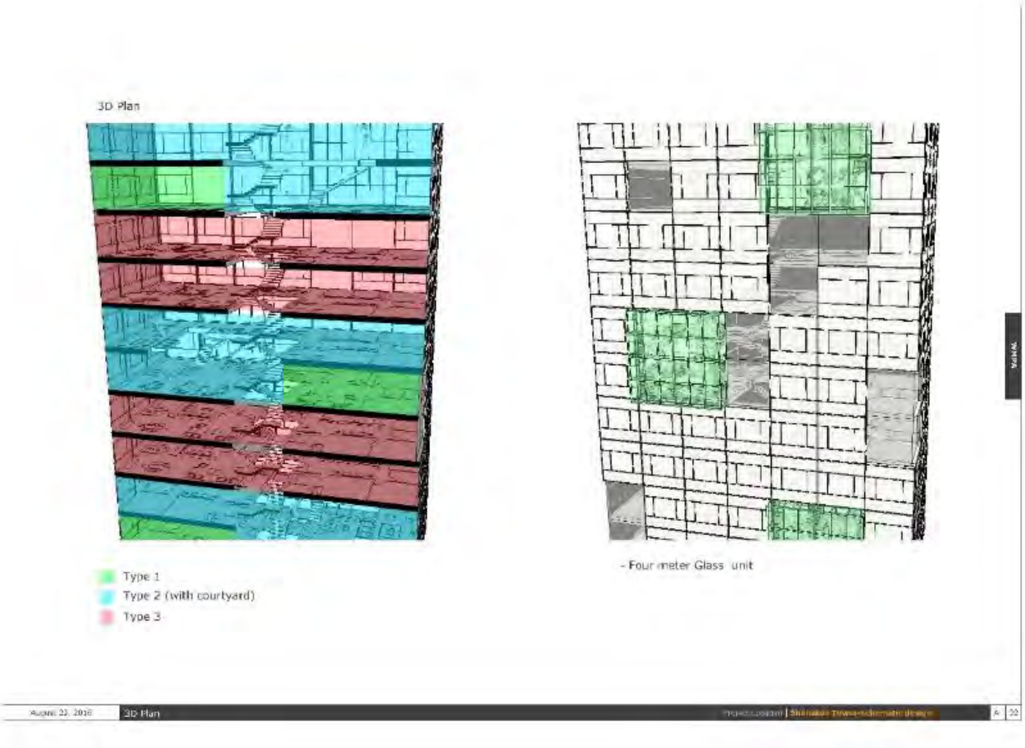
وتشمل مشاريع الشركة مبنى المقر الرئيسي للبنك الأهلي في مسقط، سلطنة عمان، الذي فازت به الشركة في مسابقة عالمية، والذي تم افتتاحه في شهر فبراير 2014. كما عملت الشركة على عدة مشاريع في المنطقة بما في ذلك المخطط الهيكلي لمشروع درب المشاعر المتعدد الاستخدامات في حي العزيزية في مكة المكرمة (800,000 متر مربع)، ومجمع سكني خاص في الطائف، وقصر خاص في الرياض، المملكة العربية السعودية، ومجموعة مساكن لعائلة ممتدة في الكويت، وقصر في الشارقة والقصر في العين، الإمارات العربية المتحدة، وفيلا في مسقط سلطنة عمان، وأبراج سكنية في الكويت، فضلا عن العديد من المشاريع السكنية في عمان، الأردن، ومسجد في مدينة الرشا ومركز اسلامي ومسجد في أمريكا، كما تم اختيار الشركة في مسابقة التصميم المعماري لفندق خمس نجوم مساحة 50،000 متر مربع، في الخبر بالسعودية.

عملت الشركة على عدة مشاريع في الشارقة، الإمارات العربية المتحدة، مع هيئة الشارقة للاستثمار والتطوير (شروق)، بما في ذلك تطوير المخطط الهيكلي لمنطقة قلب الشارقة التاريخية وإعداد المخطط الهيكلي والتصميم المعماري لحديقة المجاز في مدينة الشارقة (افتتحت للجمهور في مارس 2012)، والمرحلة الثانية من الحديقة، بما في ذلك تصميم 12 مطعما جديدا (تحت الإنشاء)، بالإضافة إلى تصميم مشروع كلباء للتنمية السياحة البيئية ويشمل مركز تسوق وفندق خمس نجوم، ومشروع دبا لتطوير تجارة التجزئة، ومخيم الذايد الصحراوي.

المعمار وائل المصري، حصل على اجازته العلمية من جامعة مانشستر، بالمملكة المتحدة (البكالوريوس)، ودرجة الماجستير من معهد ماساتشوستس للتكنولوجيا، كامبردج، ماساتشوستس بالولايات المتحدة الأمريكية، ولقد عمل بالعالم العربي على مدى الأربعة عقود الماضية، وساهم في تطوير المشهد المعماري بالمنطقة بتصاميمه وأبحاثه ومحاضراته. وقد حازت أعماله على العديد من الجوائز المحلية والاقليمية والدولية ومنها "جائزة المعماري العربي" من منظمة المدن العربية في دورتها التاسعة لعام 2008، و"جائزة أفضل مصمم العام" (2007 و 2008) من ريتيل سيتي، دبي، و"جائزة العمارة الإسلامية" سيتي سكيب دبي (2007)، و"جائزة التصميم والتطوير" عام 2007، من المجلس الدولي لمراكز التسوق (ICSC)، الولايات المتحدة الأمريكية، و"جائزة المعهد الملكي للمهندسين المعماريين البريطانيين" RIBA "جائزة التصميم المعماري (Napper) 1984".

August 22, 2016 | 3D Shots | Project Location | Shohabar Tower-schematic design | A | 39





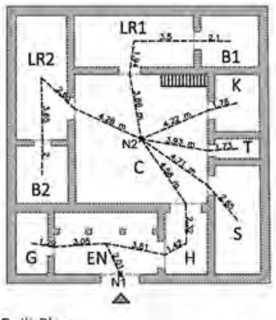
End of Interview

Appendix (4-B-1)

The Developed Model for carrying out Syntactic and Geometric Analyses

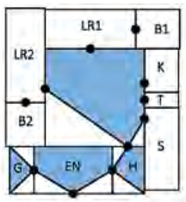
Region:	Location:	Case No.:
Maghrib	Tunis	M-1

The Developed Model for carrying out Syntactical and Spatial Analysis

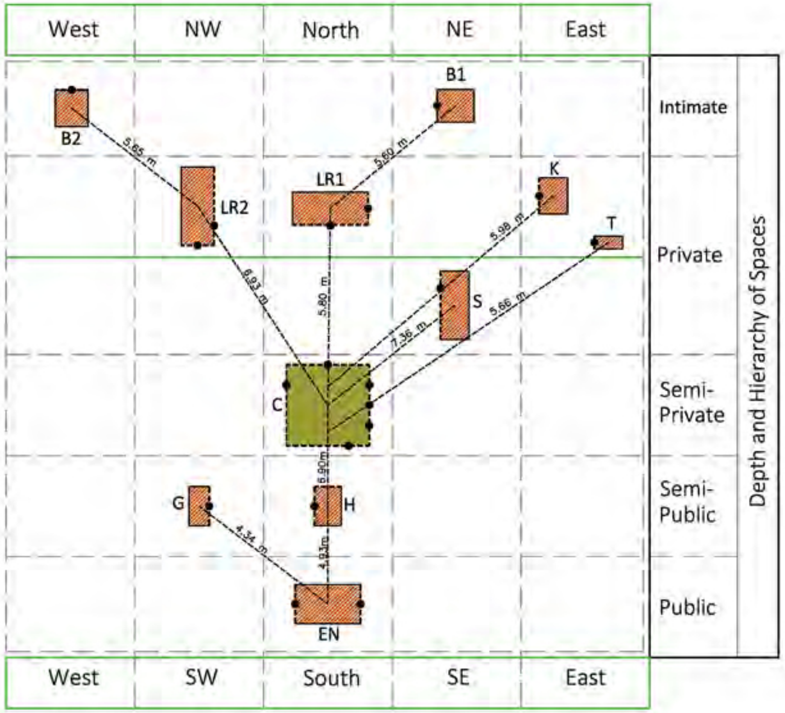


As-Built Plan
Source: Redrawn by Researcher from (Ragette 2003)
showing distances between spaces (in meters)

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



Indoor Space (closed from all sides) · Semi-Open Space · Outdoor Space · Entry Point to Space
4.93m Distance (in meters) between centers of spaces · Surface Interaction

Spatial and Geometric Relationships

Space	X:Y	%All	1:C	D1	D2	Users
B2	1 : 1.11	5.46 %	1 : 0.18	26.45	12.59	M+F
B1	1 : 1.2	5.48 %	1 : 0.18	25.23	11.39	M+F
LR2	1 : 2.45	8.52 %	1 : 0.37	20.79	6.94	M+F
LR1	1 : 2.30	8.89 %	1 : 0.36	19.63	5.77	M+F
K	1 : 3.1	4.70 %	1 : 0.15	19.71	5.98	F
T	1 : 2.2	1.65 %	1 : 0.05	19.49	5.63	M+F
S	1 : 2.45	8.94 %	1 : 0.29	21.23	7.36	M+F
C	1 : 1.03	30.37 %	1 : 1	13.83	0.00	M+F
G	1 : 1.90	3.62 %	1 : 0.12	6.32	16.16	M
H	1 : 1.45	4.79 %	1 : 0.16	6.93	6.89	M+F
EN	1 : 1.67	11.67 %	1 : 0.38	2.01	11.82	M+F

M : Predominant Male Users
F : Predominant Female Users
X:Y : 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

Space Syntax Analysis

Integration with Courtyard
(when the courtyard has the greatest control value)

Integration with Entrance
(when the entrance has the greatest control value)

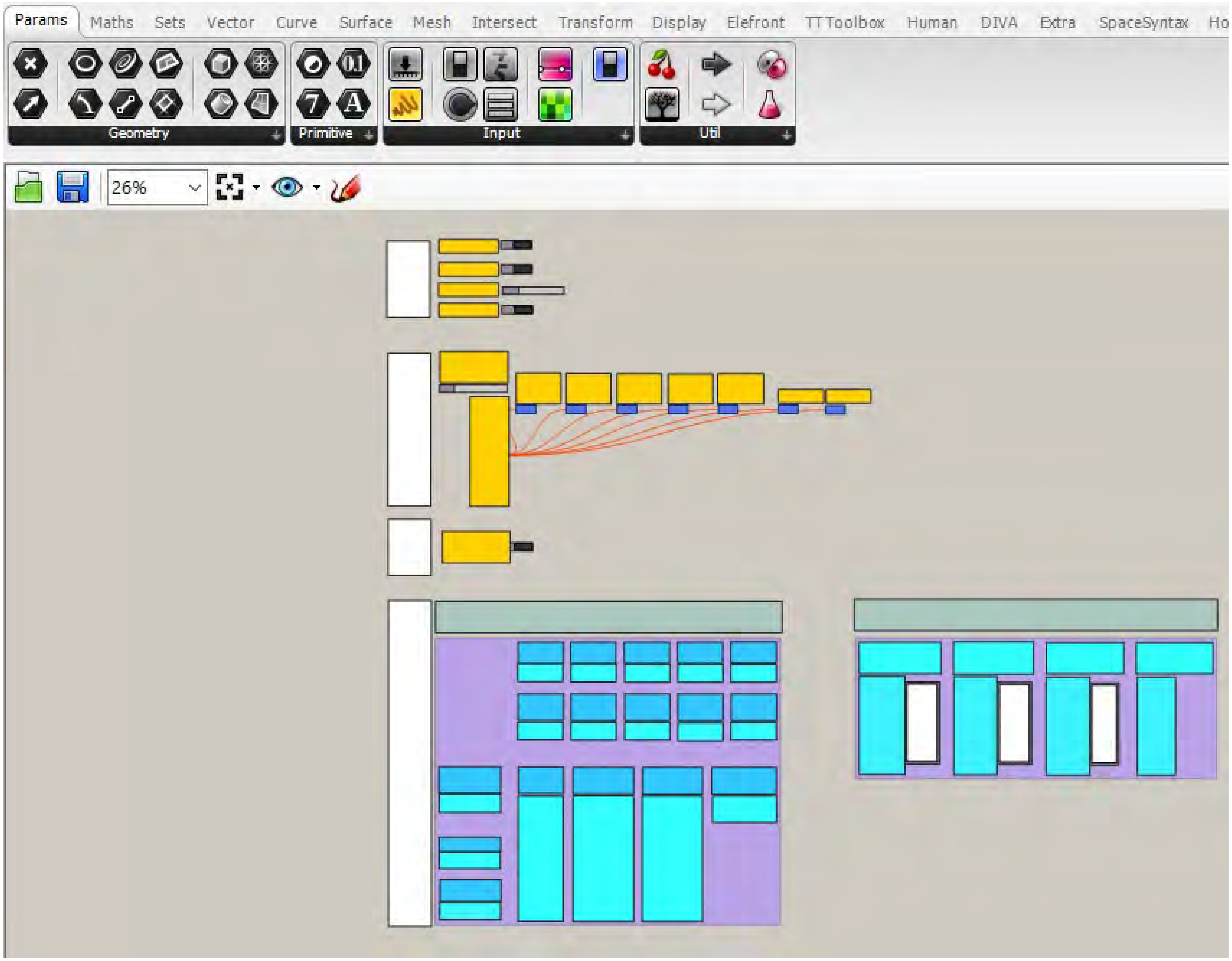
		TDn	MDn	RA	I	CV	NCn
0	Entrance	27	2.70	0.37	2.64	1.50	1.00
1	Guest Room	36	3.60	0.57	1.75	0.50	1.00
2	Hall	20	2.00	0.22	4.50	0.66	2.00
3	Courtyard	15	1.50	0.11	9.00	4.30	4.00
4	Living Space (1)	22	2.20	0.26	3.75	1.16	2.00
5	Living Space (2)	22	2.20	0.26	3.75	1.16	2.00
6	Bedroom (2)	31	3.10	0.46	2.14	0.50	1.00
7	Bedroom (2)	31	3.10	0.46	2.14	0.50	1.00
8	Kitchen	24	2.40	0.31	3.21	0.16	1.00
9	Toilet	24	2.40	0.31	3.21	0.16	1.00
10	Storage	24	2.40	0.31	3.21	0.16	1.00

TDn : Total Depth (TD) for actual node
MDn : Mean Depth (MD) for actual node = TD/(K-1)
RA : Relative Asymmetry = 2*(MD-1)/(K-2)
I : Integration Value = 1/RA
K : Number of Nodes
CV : Control Value
NCn : Number of Connections

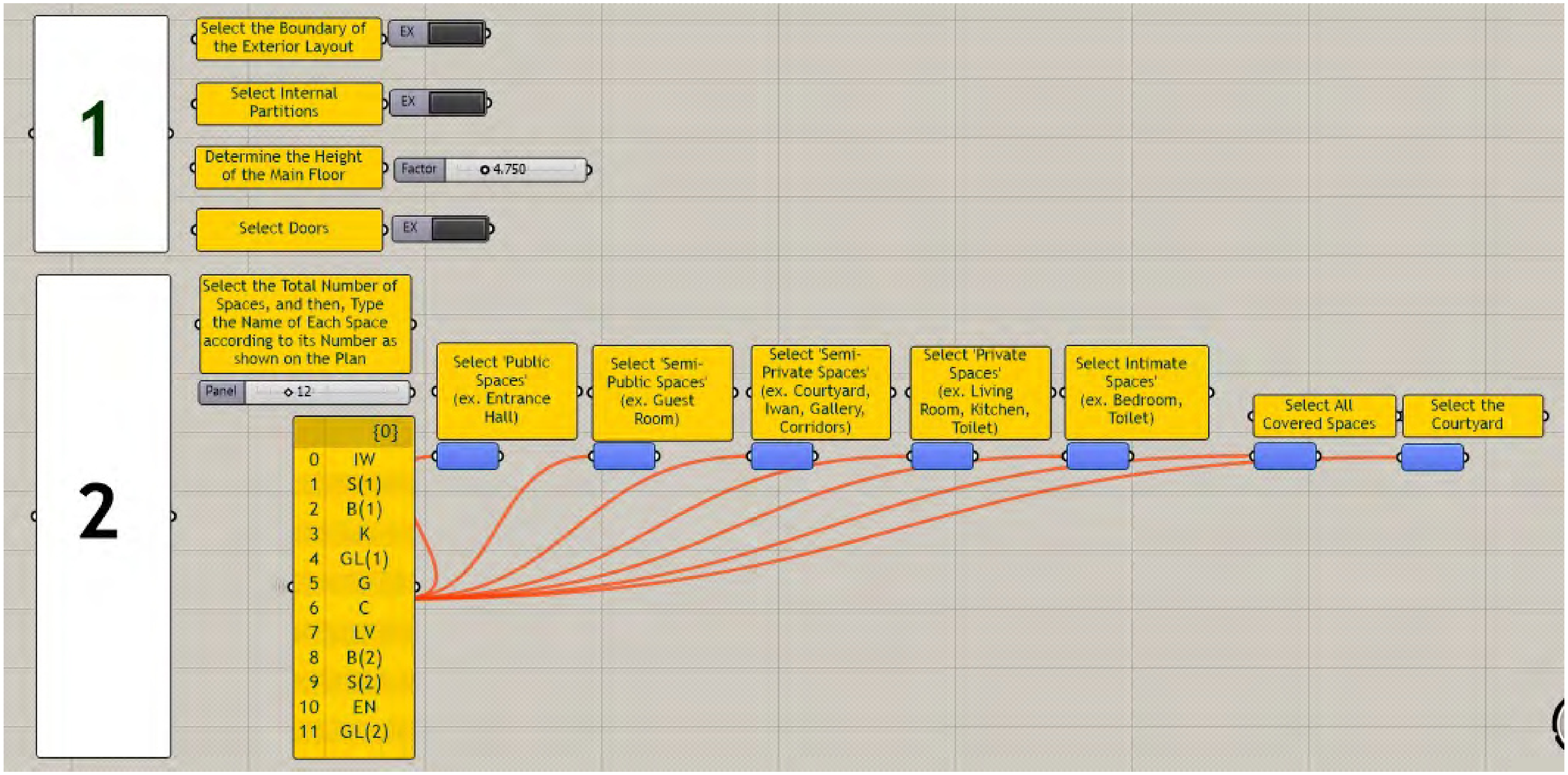
Diagrams and Calculation are produced by AGRAPH
(Online software, https://www.ntnu.no/ab/spacesyntax)

Appendix (4-B-2)

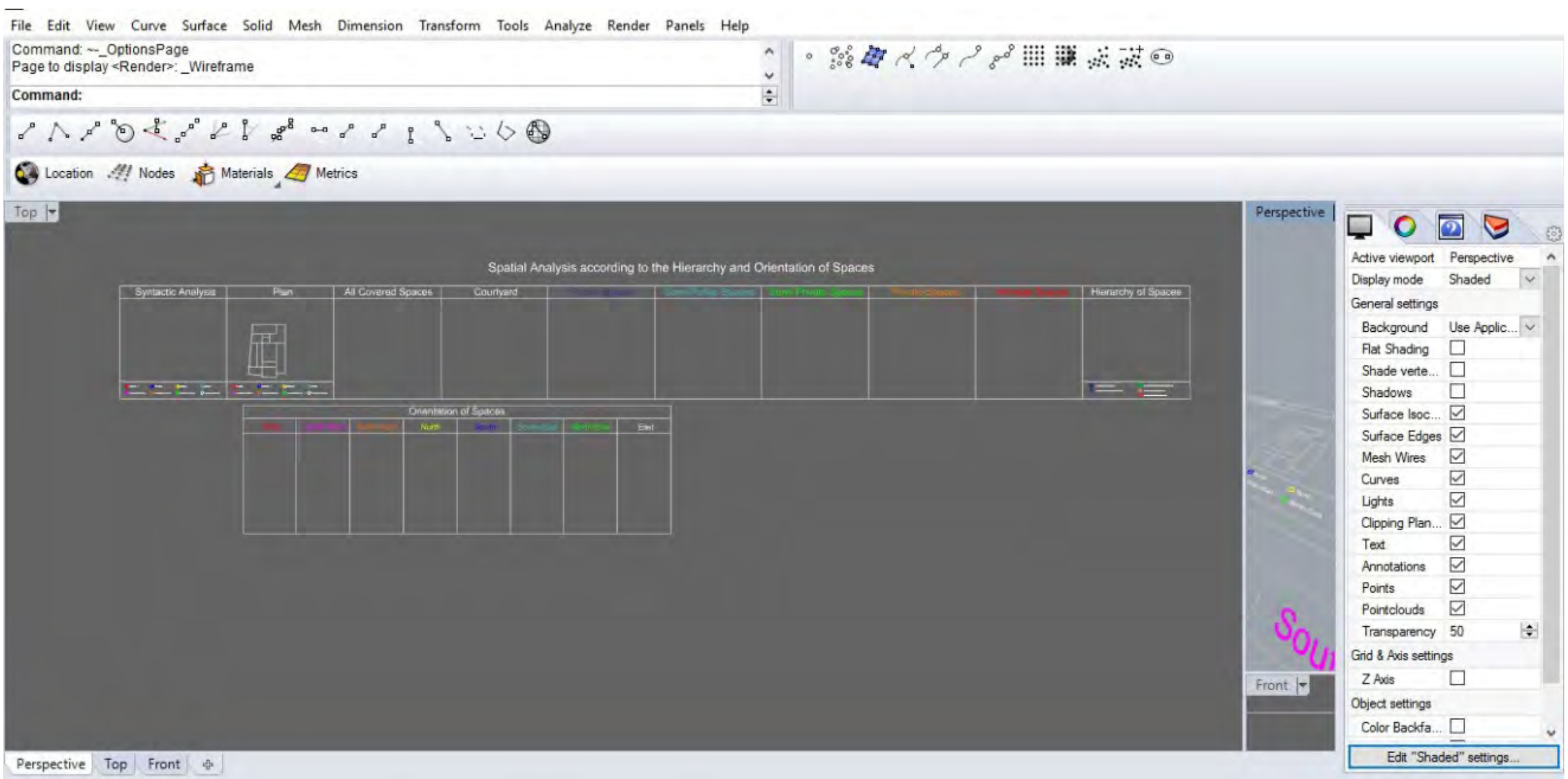
Screenshots for Components of the Computational Model for carrying out Syntactic and Geometric Analyses, using Rhino/Grasshopper



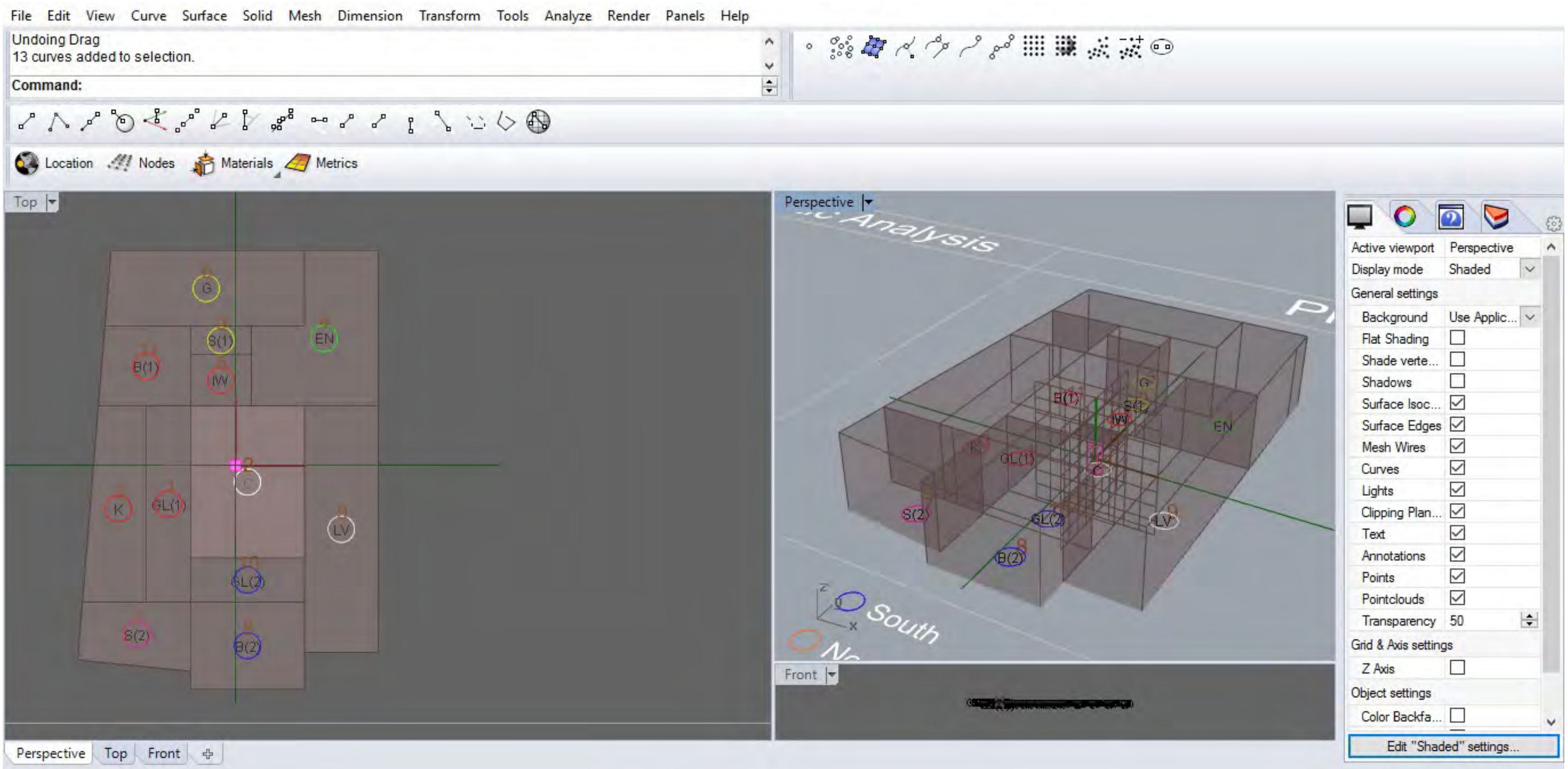
A screenshot showing the interface for the user



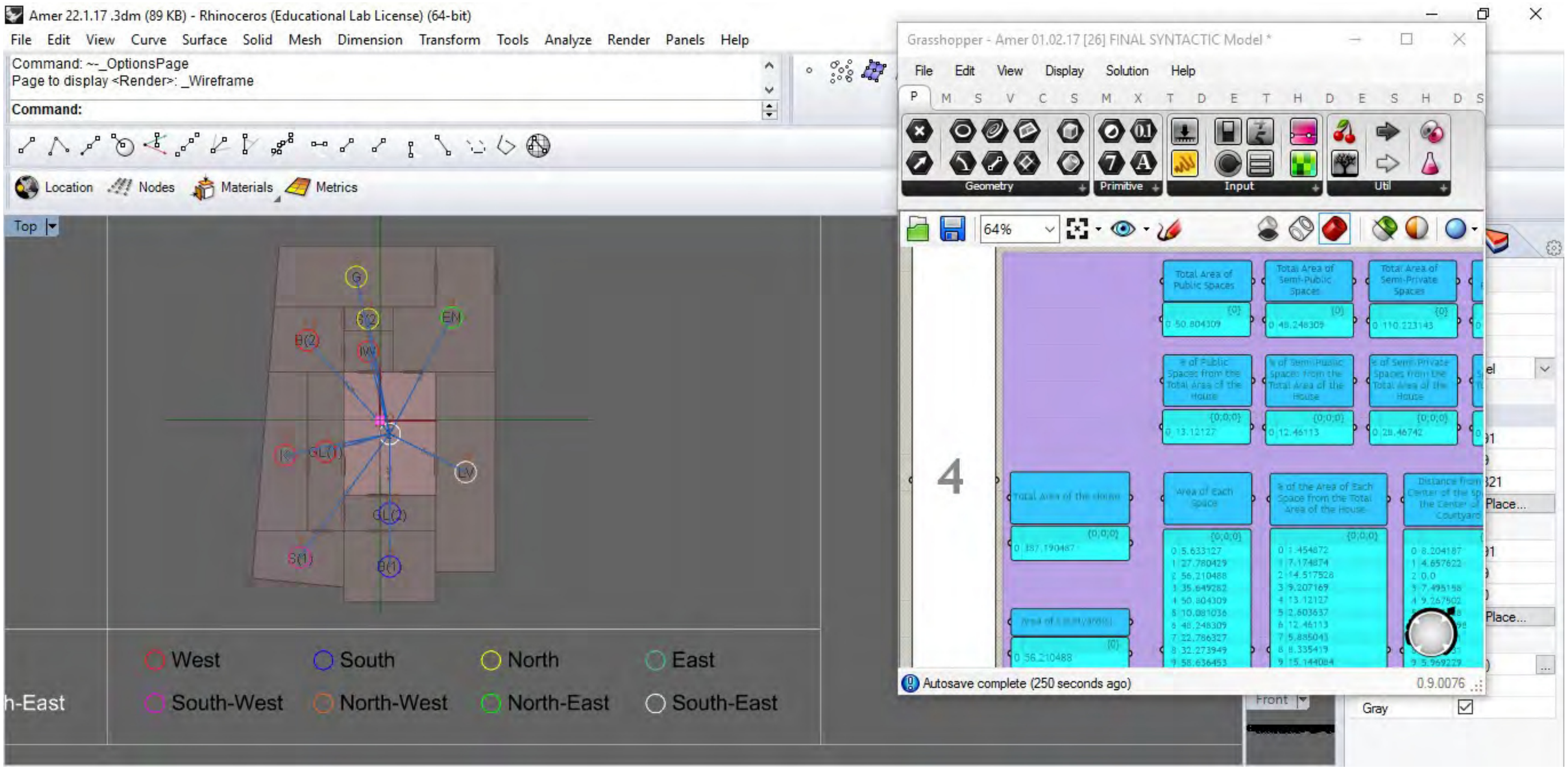
A screenshot showing stages 1 and 2 from the interface for the user
Stage (1): selecting the layout for the analysis, and
Stage (2): Selecting the different spaces according to the hierarchy of each space



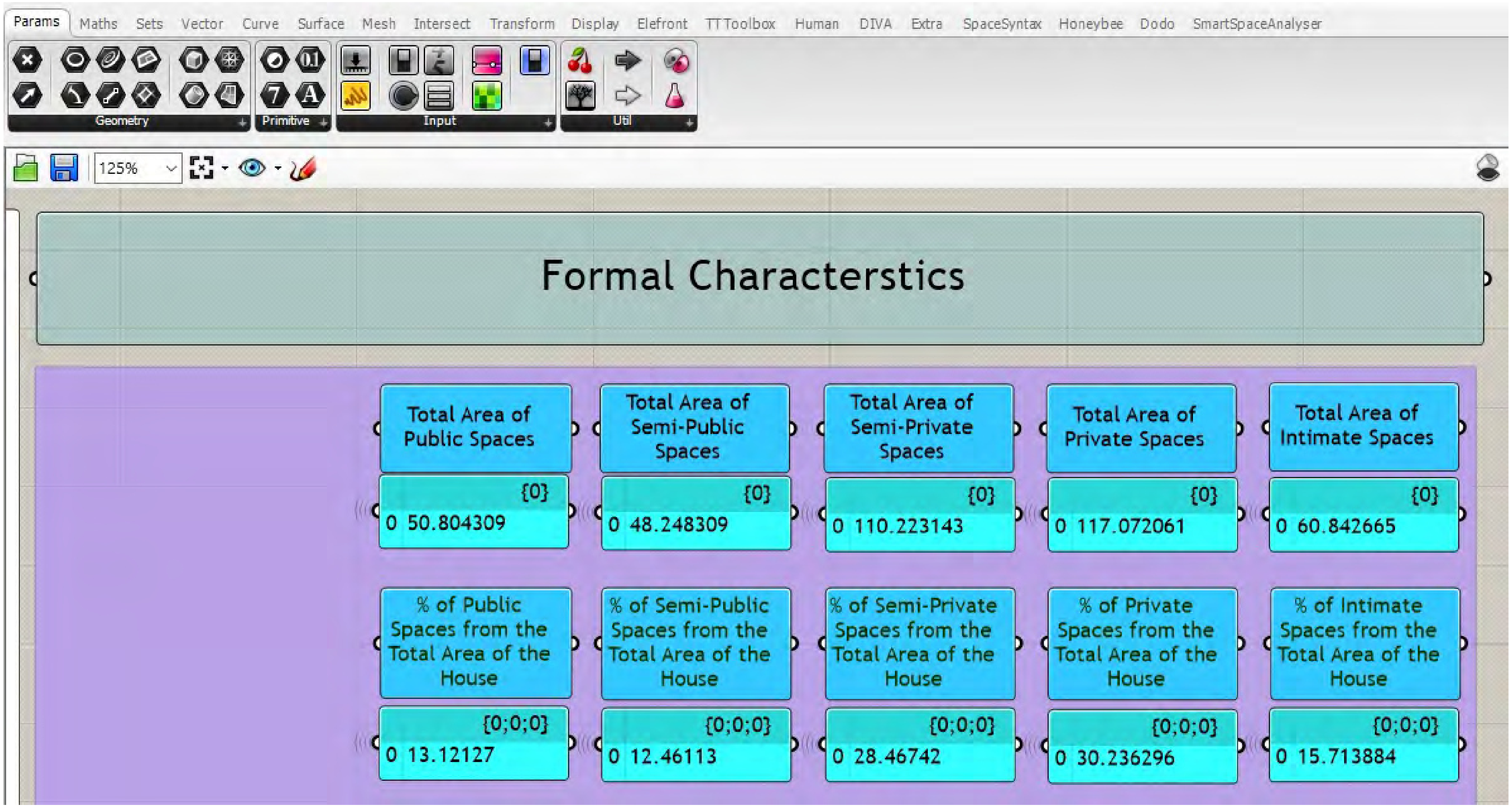
A screenshot showing the layout of the interface before carrying out the analysis



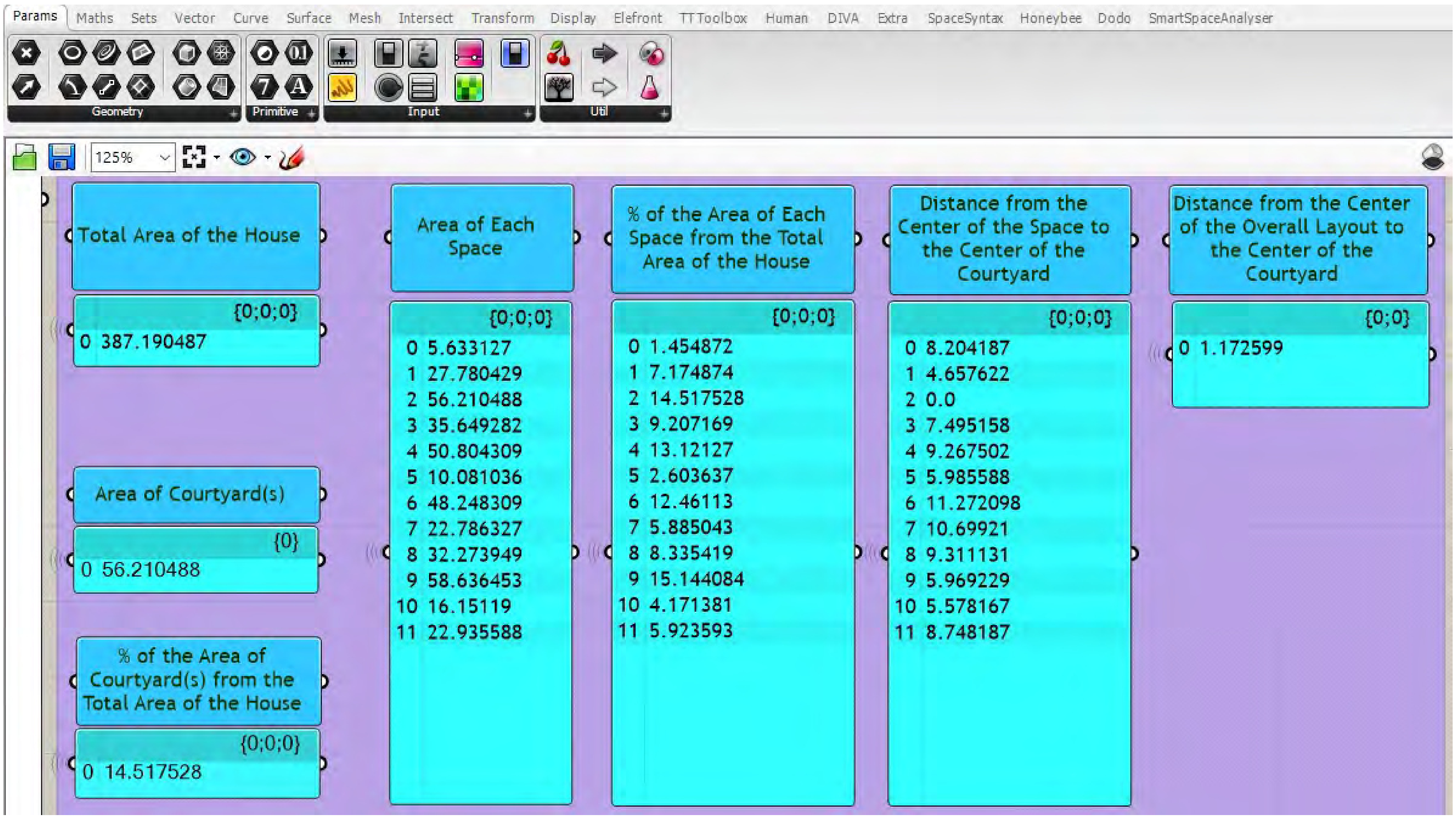
A screenshot showing the analytical diagrams carried out by the model



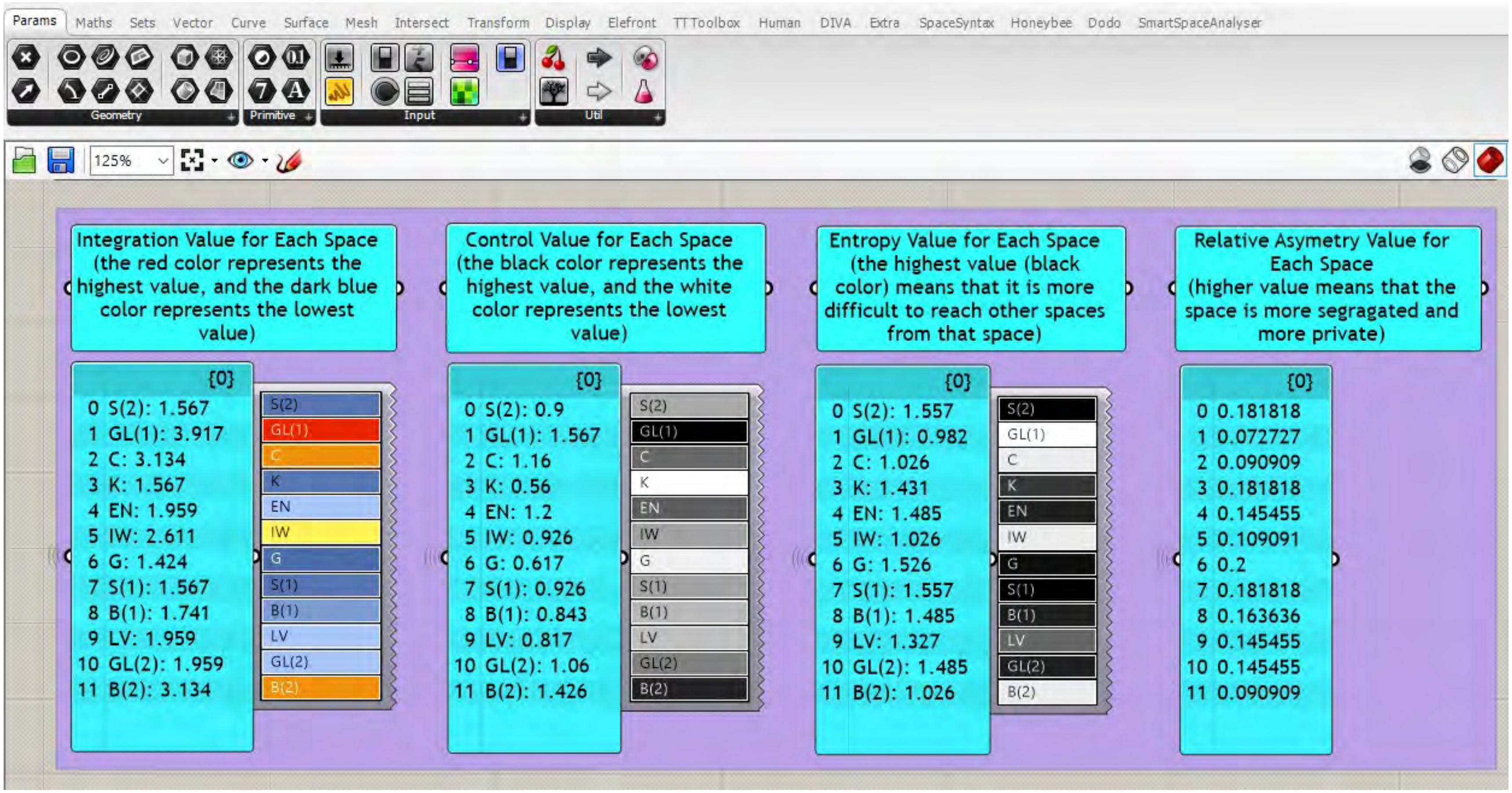
A screenshot showing the analytical diagrams and spatial calculations carried out by the model



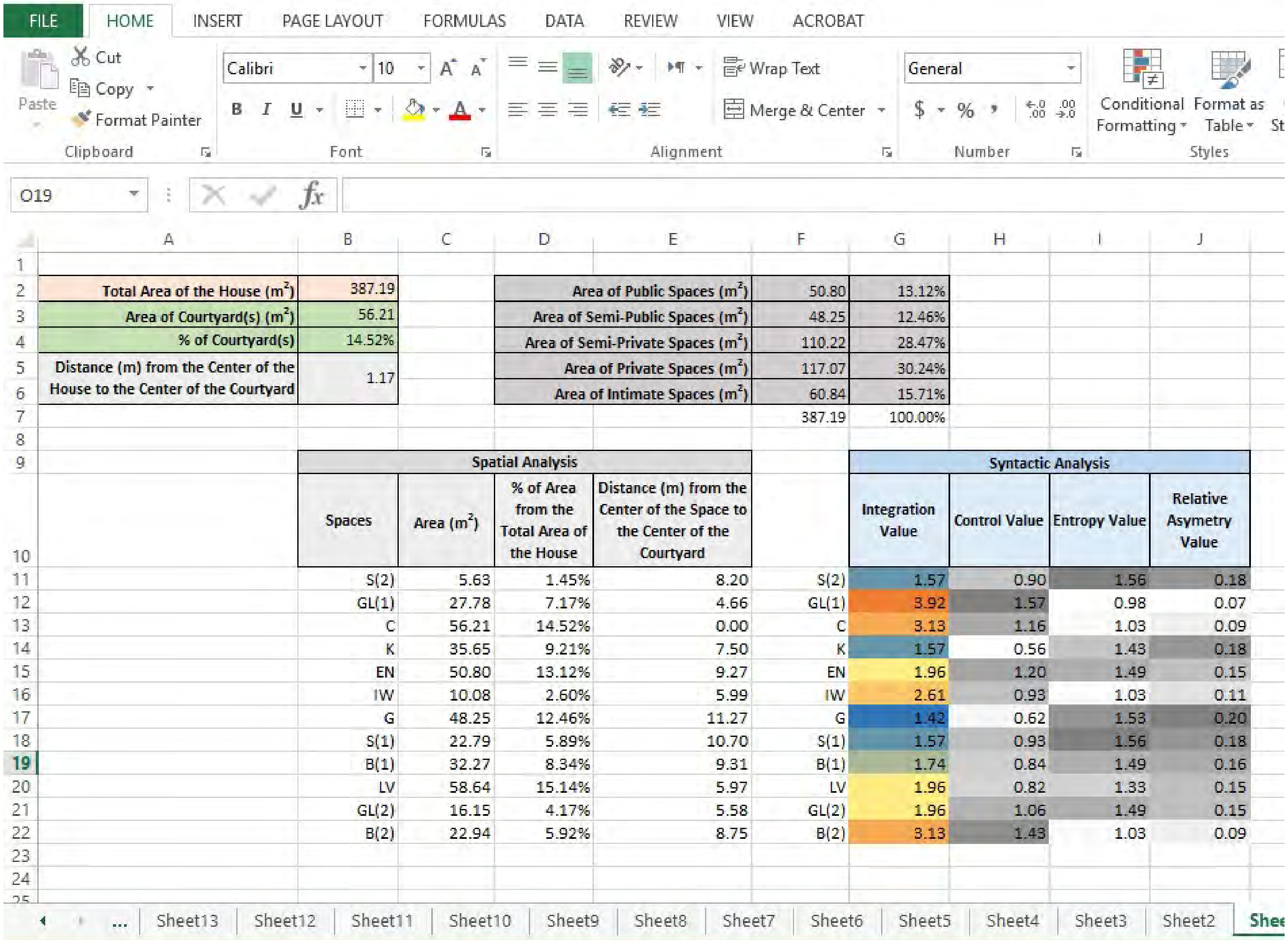
A screenshot showing spatial calculations carried out by the model



A screenshot showing spatial calculations carried out by the model



A screenshot showing syntactic calculations carried out by the model

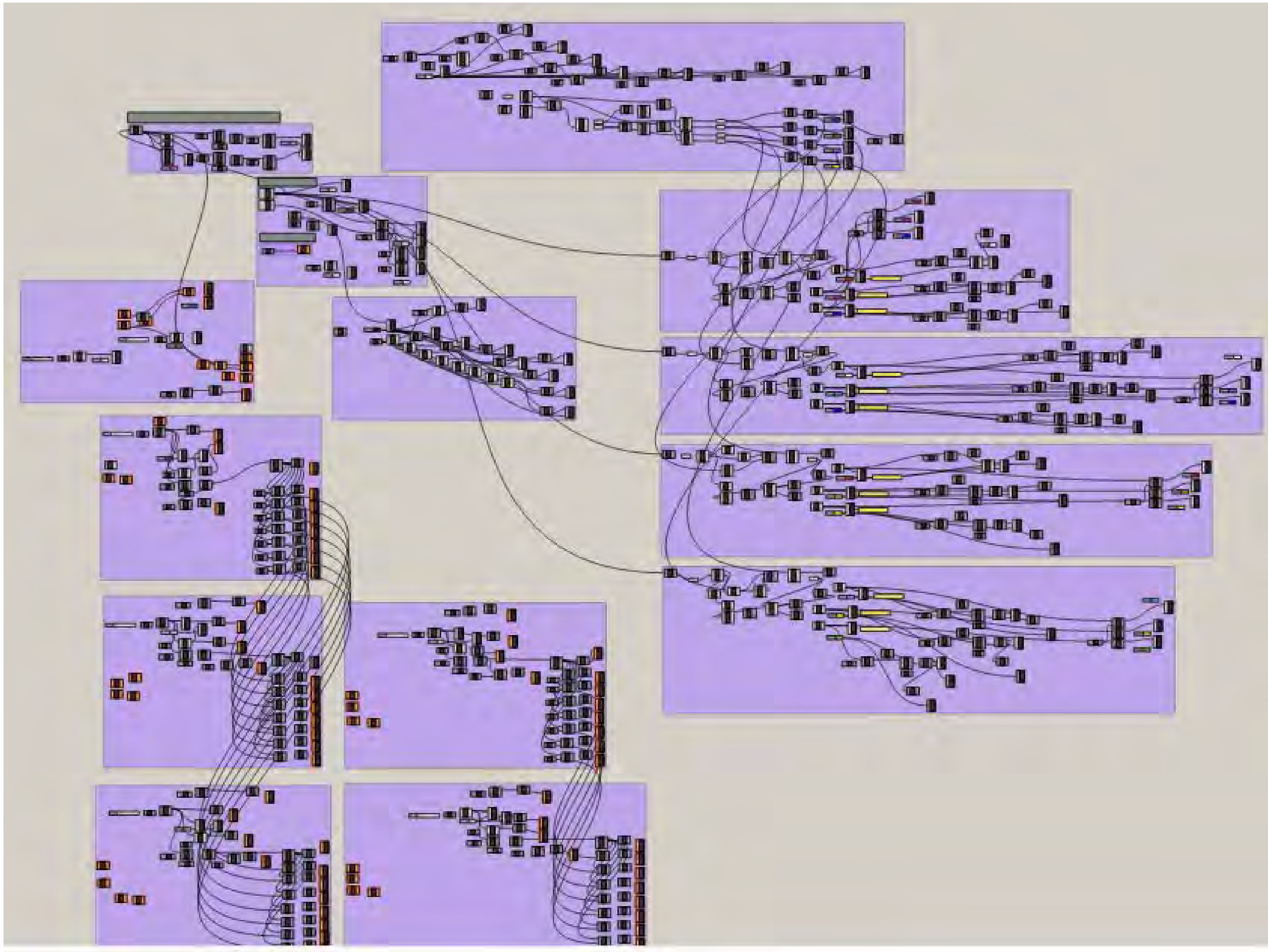


Total Area of the House (m^2)	387.19
Area of Courtyard(s) (m^2)	56.21
% of Courtyard(s)	14.52%
Distance (m) from the Center of the House to the Center of the Courtyard	1.17

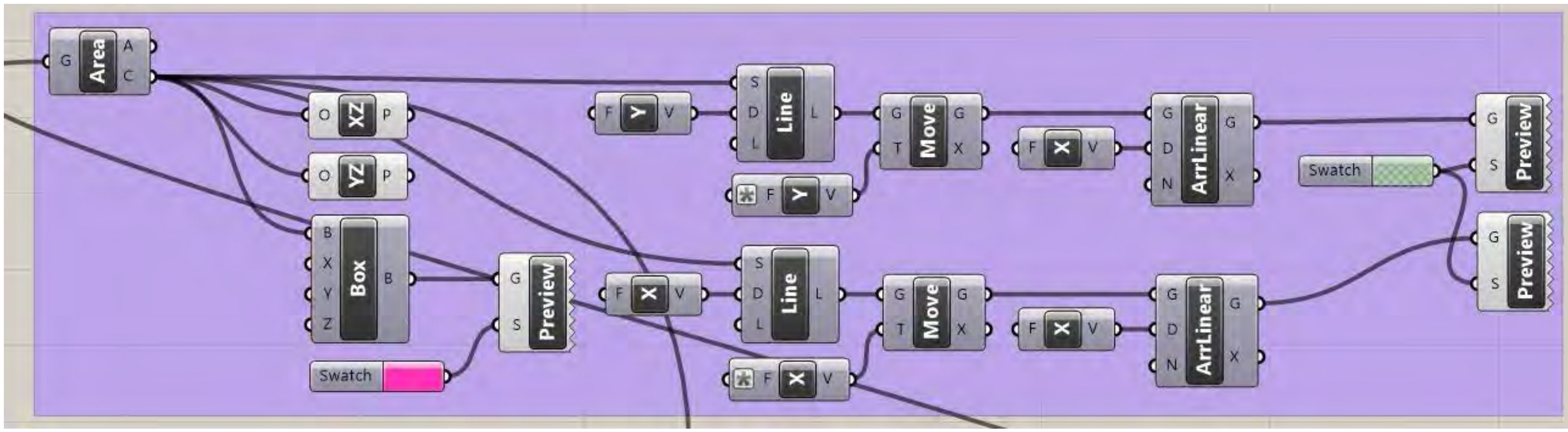
Area of Public Spaces (m^2)	50.80	13.12%
Area of Semi-Public Spaces (m^2)	48.25	12.46%
Area of Semi-Private Spaces (m^2)	110.22	28.47%
Area of Private Spaces (m^2)	117.07	30.24%
Area of Intimate Spaces (m^2)	60.84	15.71%
	387.19	100.00%

Spatial Analysis					Syntactic Analysis			
Spaces	Area (m^2)	% 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 Asymetry Value
S(2)	5.63	1.45%	8.20	S(2)	1.57	0.90	1.56	0.18
GL(1)	27.78	7.17%	4.66	GL(1)	3.92	1.57	0.98	0.07
C	56.21	14.52%	0.00	C	3.13	1.16	1.03	0.09
K	35.65	9.21%	7.50	K	1.57	0.56	1.43	0.18
EN	50.80	13.12%	9.27	EN	1.96	1.20	1.49	0.15
IW	10.08	2.60%	5.99	IW	2.61	0.93	1.03	0.11
G	48.25	12.46%	11.27	G	1.42	0.62	1.53	0.20
S(1)	22.79	5.89%	10.70	S(1)	1.57	0.93	1.56	0.18
B(1)	32.27	8.34%	9.31	B(1)	1.74	0.84	1.49	0.16
LV	58.64	15.14%	5.97	LV	1.96	0.82	1.33	0.15
GL(2)	16.15	4.17%	5.58	GL(2)	1.96	1.06	1.49	0.15
B(2)	22.94	5.92%	8.75	B(2)	3.13	1.43	1.03	0.09

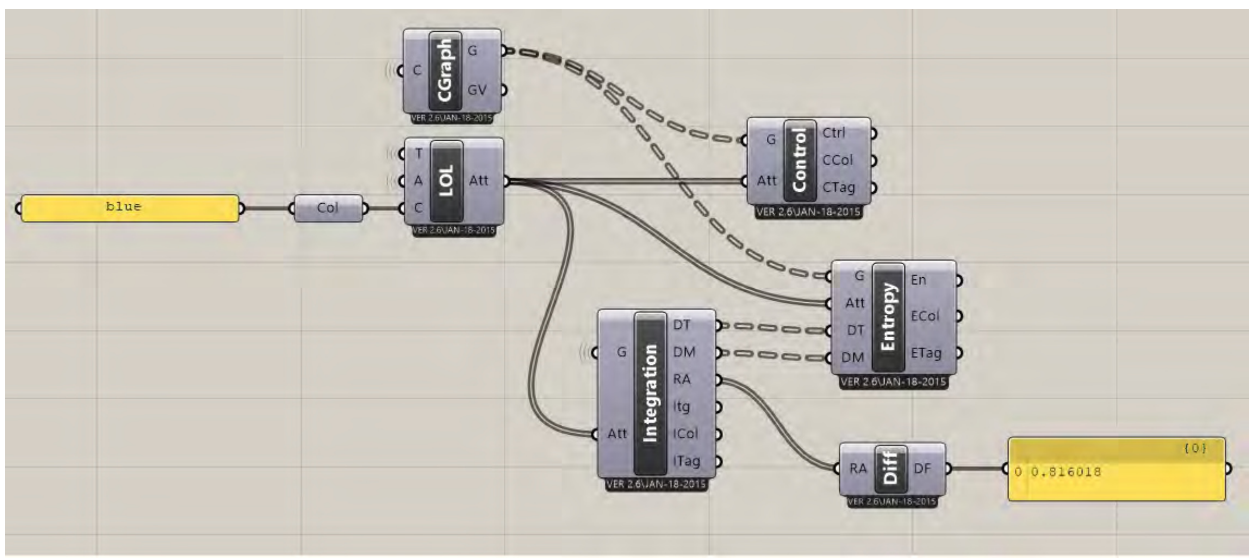
A screenshot showing syntactic calculations carried out by the model



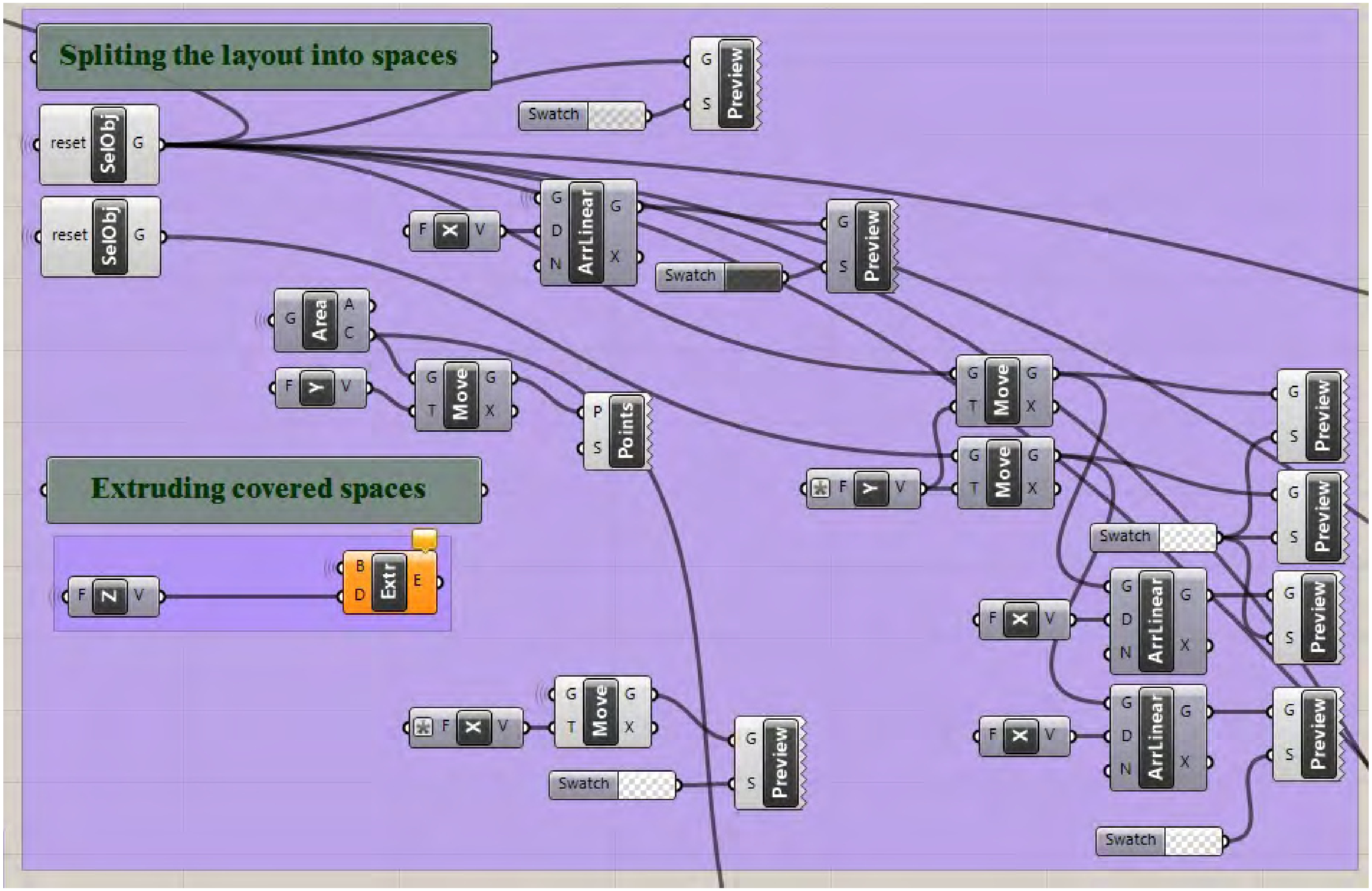
A screenshot showing all components for carrying out spatial and syntactical analysis



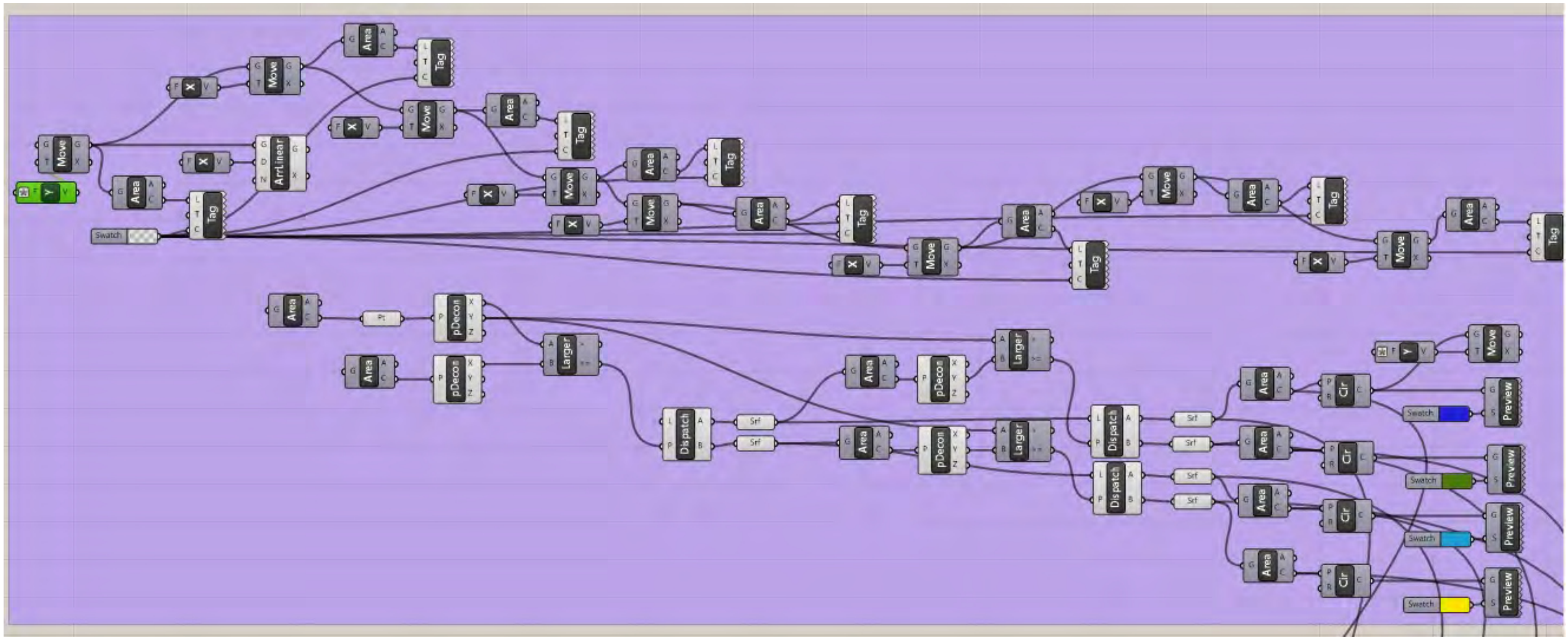
A screenshot showing components for drawing centre lines for the overall layout



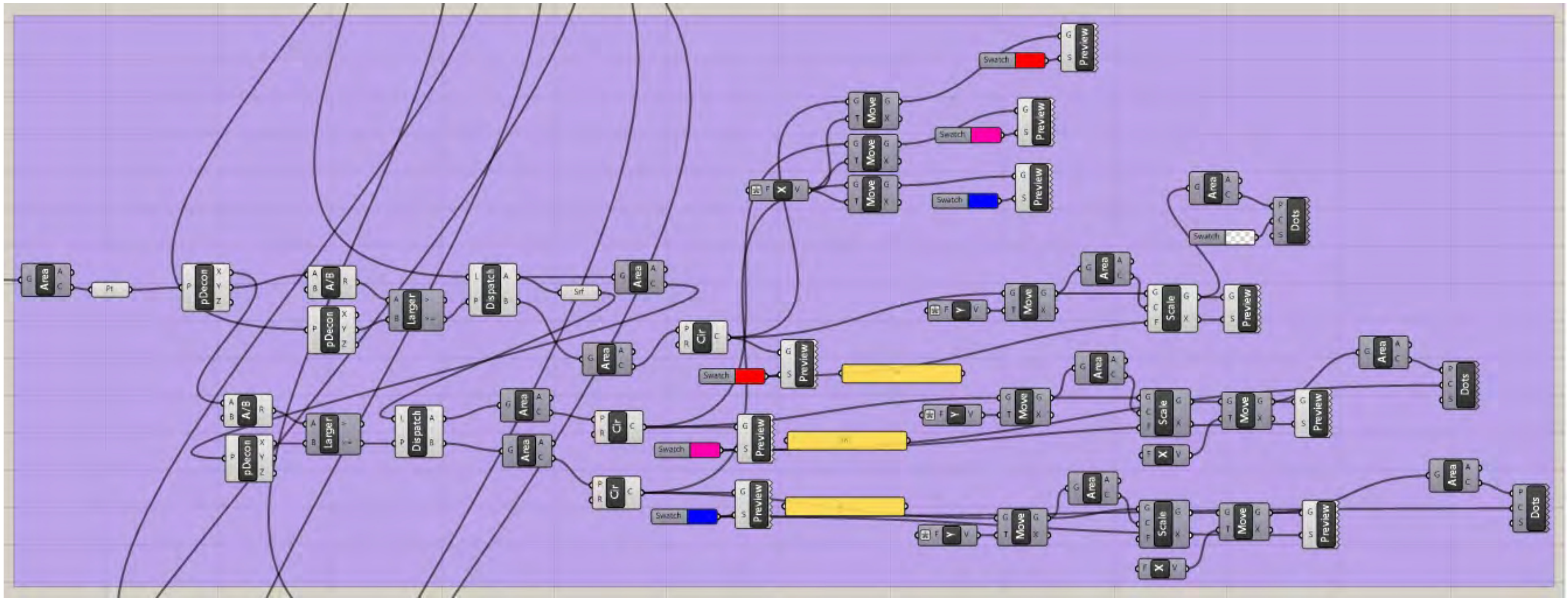
A screenshot showing components for carrying out syntactic calculations



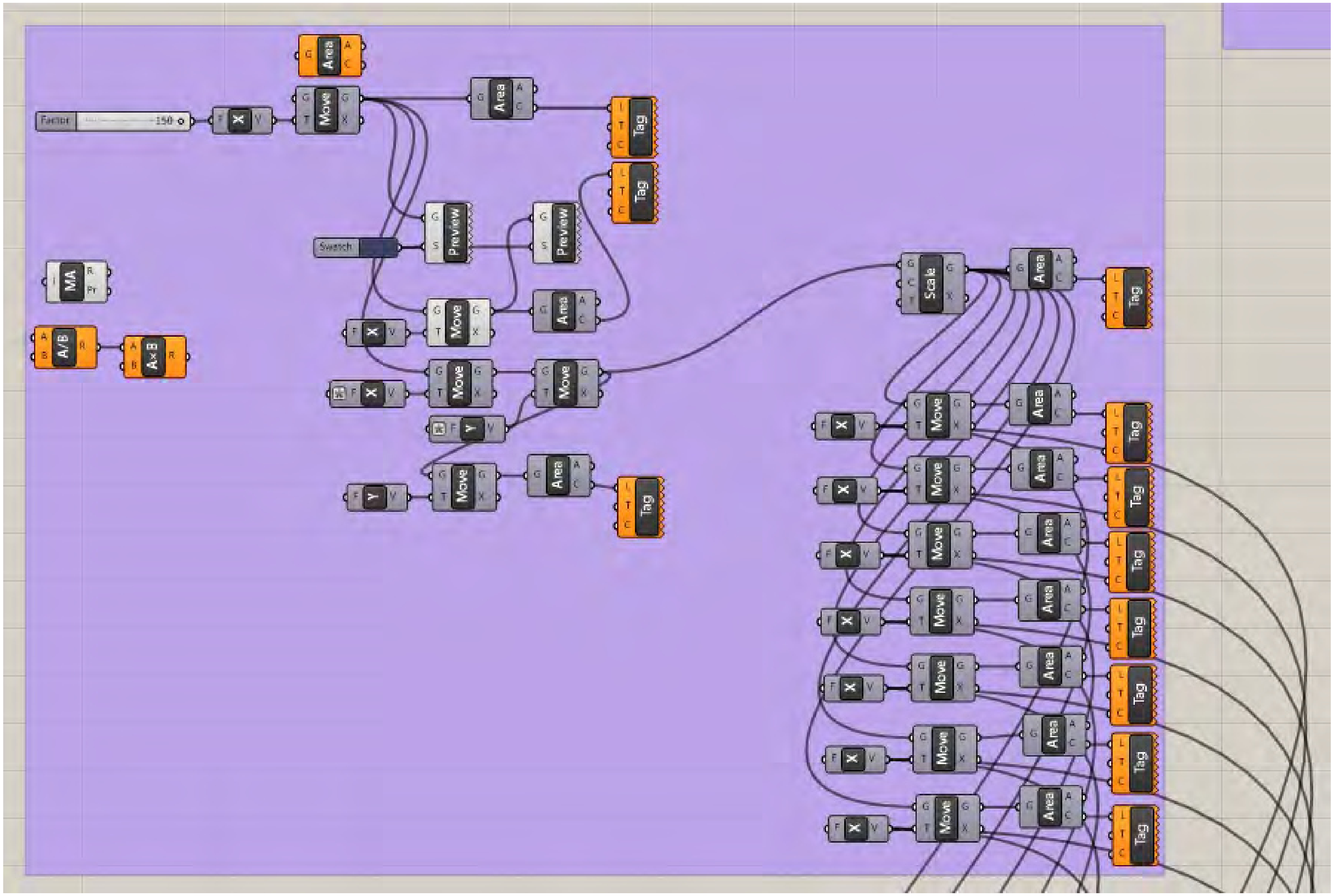
A screenshot showing components for splitting the layout into spaces, and extruding covered spaces



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

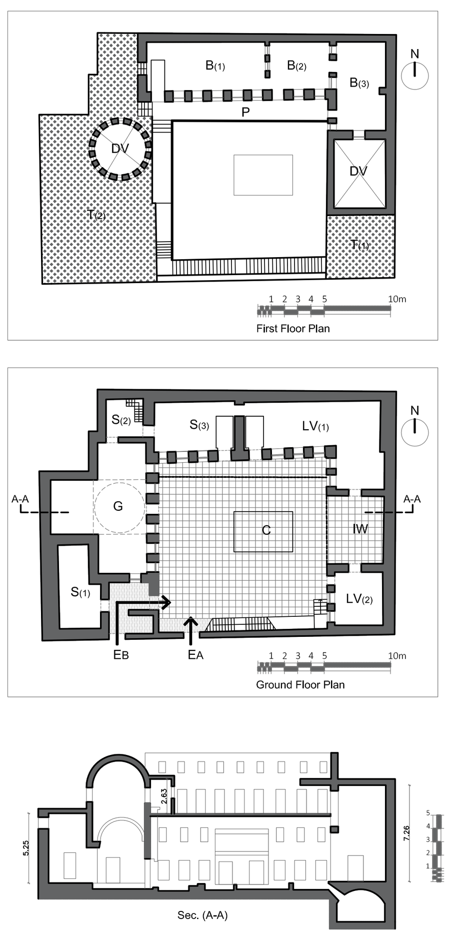
Appendix (4-B-3)

As-built Drawings for the Selected Vernacular Houses

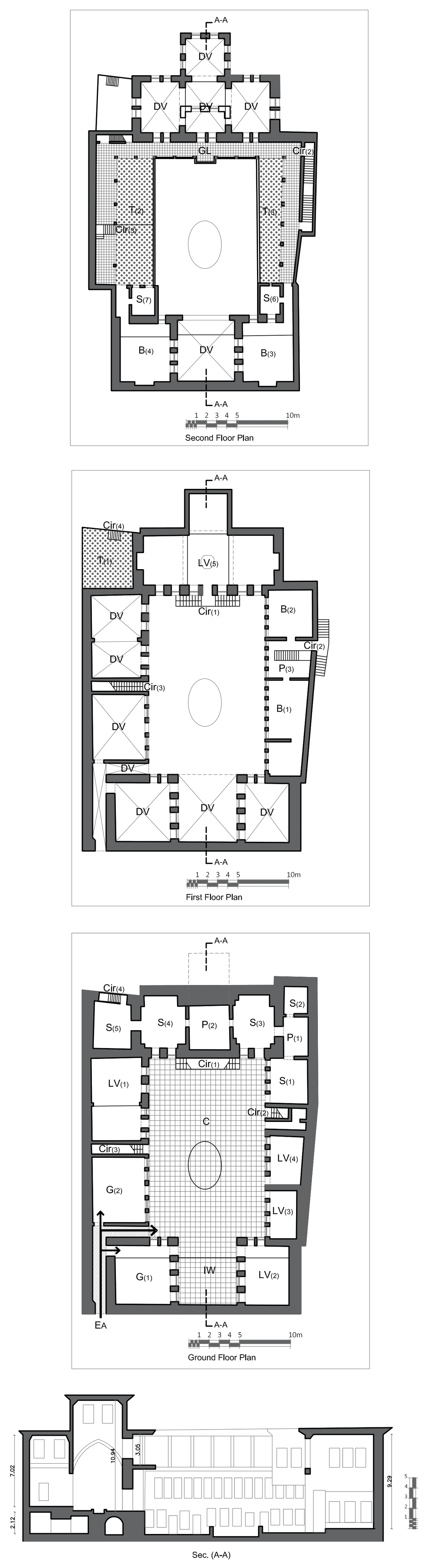
As-Built Plans - The Middle East (17 cases)

SYRIA

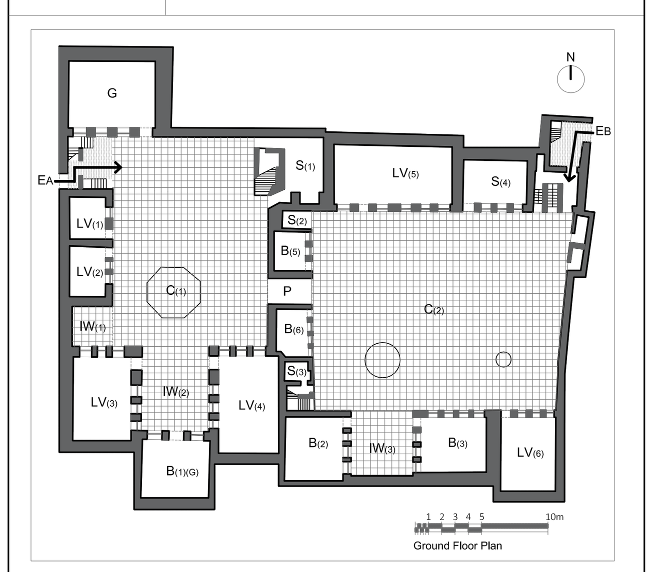
SYR-1 A courtyard house, Aleppo, Syria (redrawn by the author, after Ragette, 2016, 157)



SYR-2 A courtyard house, Damascus, Syria (redrawn by the author, after Ragette, 2016, 158)

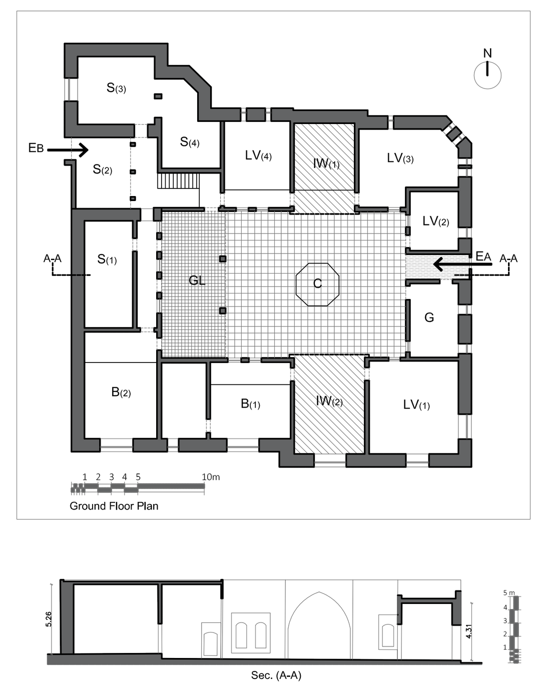


SYR-3 A courtyard house, Damascus, Syria (redrawn by the author, after Ragette, 2016, 159)

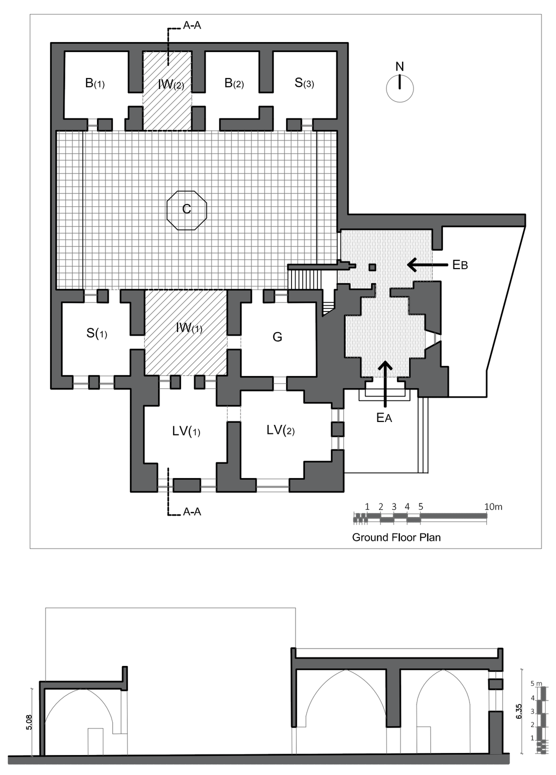


LEBANON

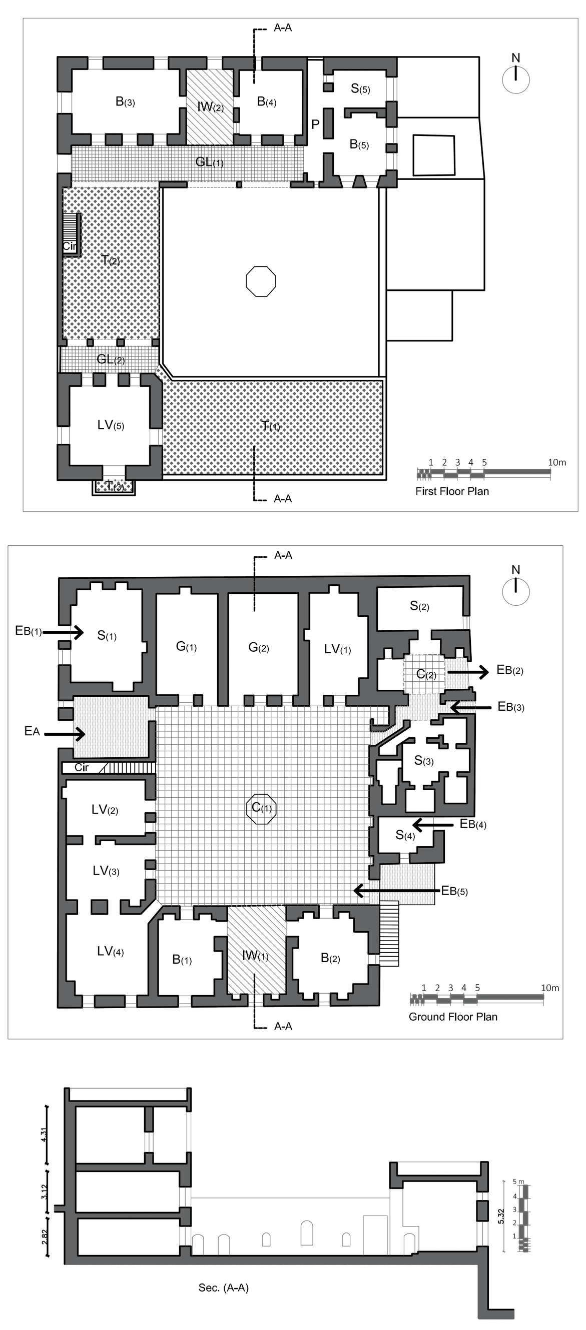
LBN-1 A courtyard house, Deir Al-Qamar, Lebanon (redrawn by the author, after Ragette, 2016, 171)



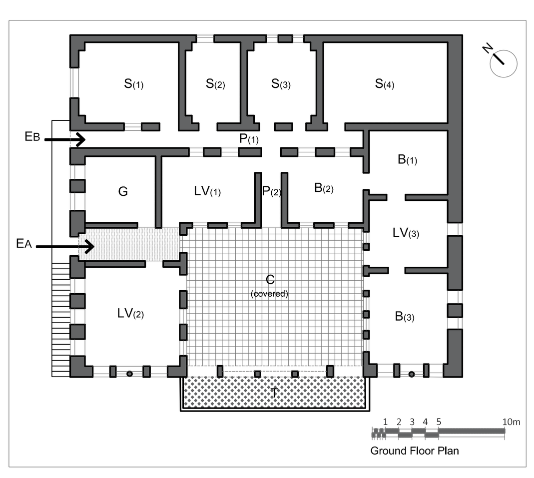
LBN-2 A courtyard house, Deir Al-Qamar, Lebanon (redrawn by the author, after Ragette, 2016, 172)



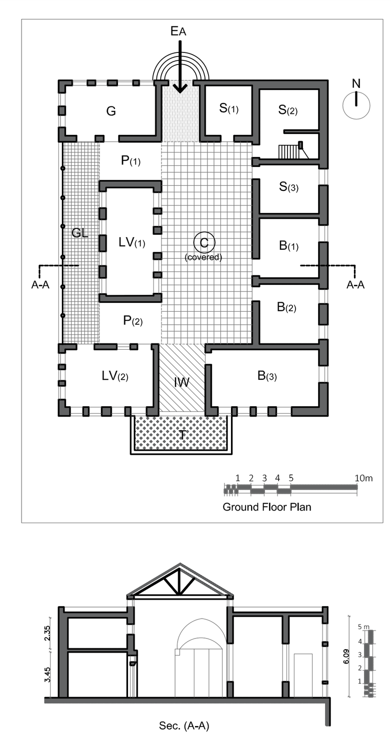
LBN-3 A courtyard House, Deir Al-Qamar, Lebanon (redrawn by the author, after Ragette, 2016, 173)



LBN-4 A courtyard house, Amchit, Lebanon (redrawn by the author, after Ragette, 2016, 175)

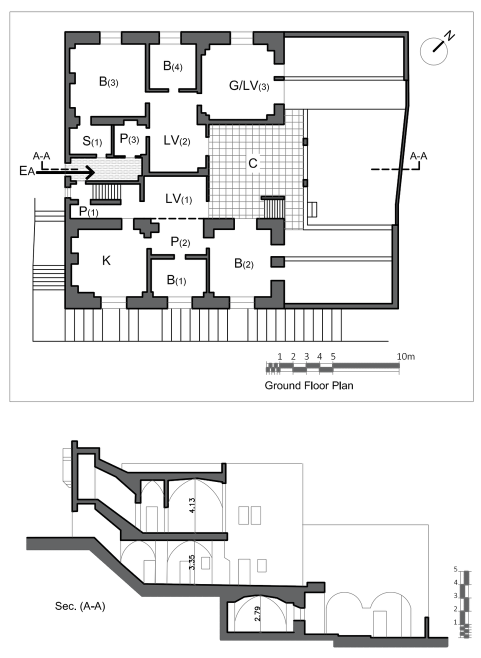


LBN-5 A courtyard house, Amchit, Lebanon (redrawn by the author, after Ragette, 2016, 177)

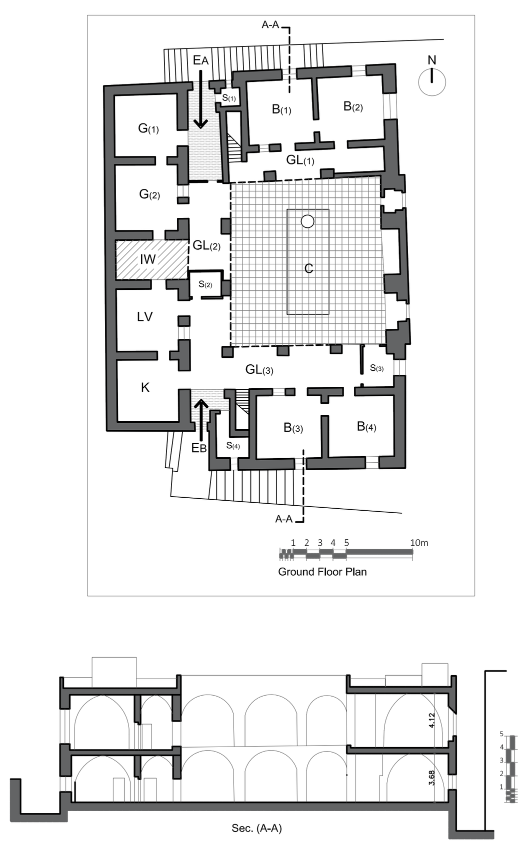


PALESTINE

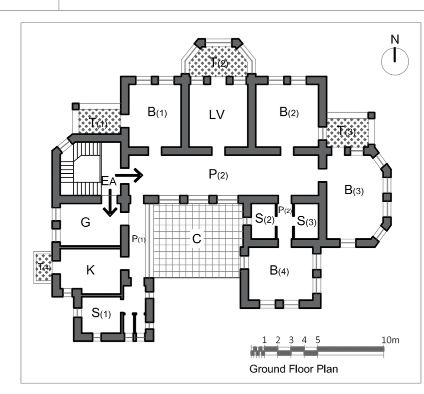
PAL-1 A courtyard house, Bethlehem, Palestine (redrawn by the author, after Ragette, 2016, 184)



PAL-2 A courtyard house, Bethlehem, Palestine (redrawn by the author, after Ragette, 2016, 184)

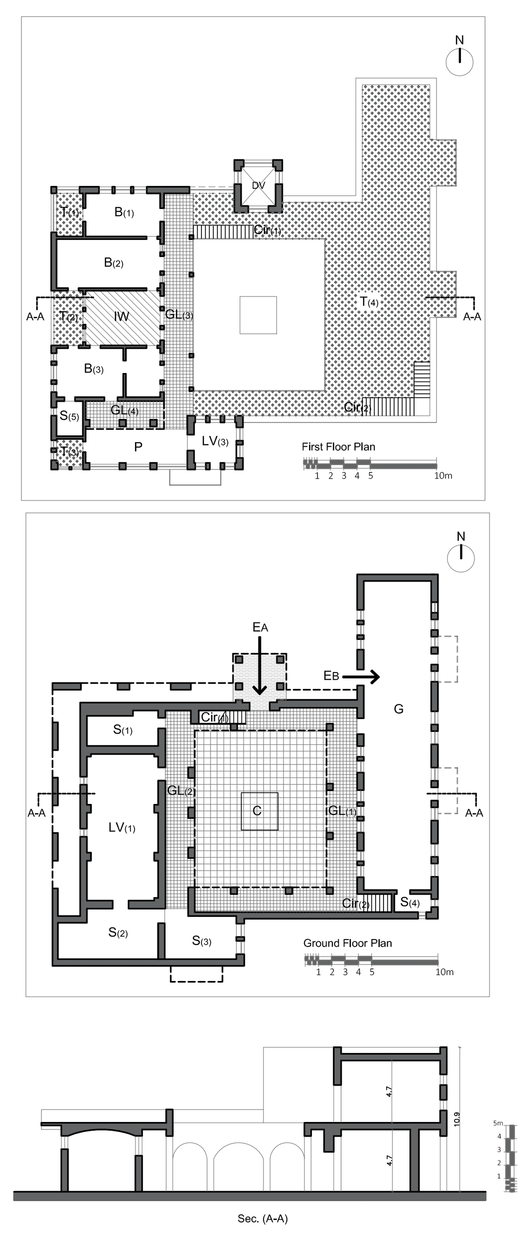


PAL-3 A courtyard house, Jerusalem, Palestine (redrawn by the author, after Khasawneh, 2001, 100)



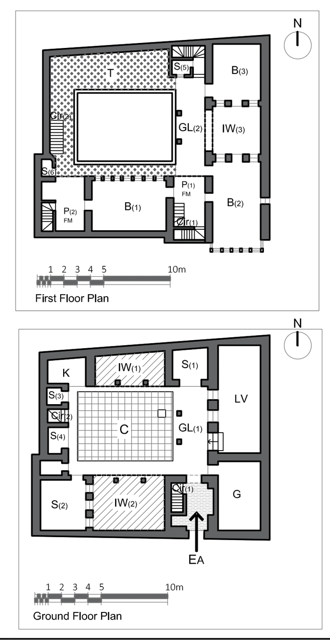
JORDAN

JOR-1 A courtyard house, Jerash, Jordan (redrawn by the author, after ?????)

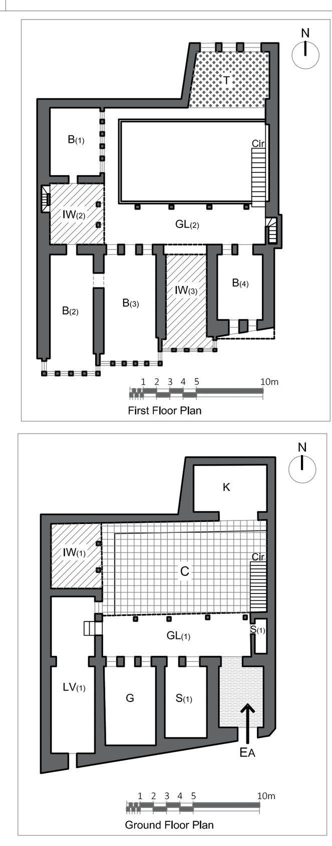


IRAQ

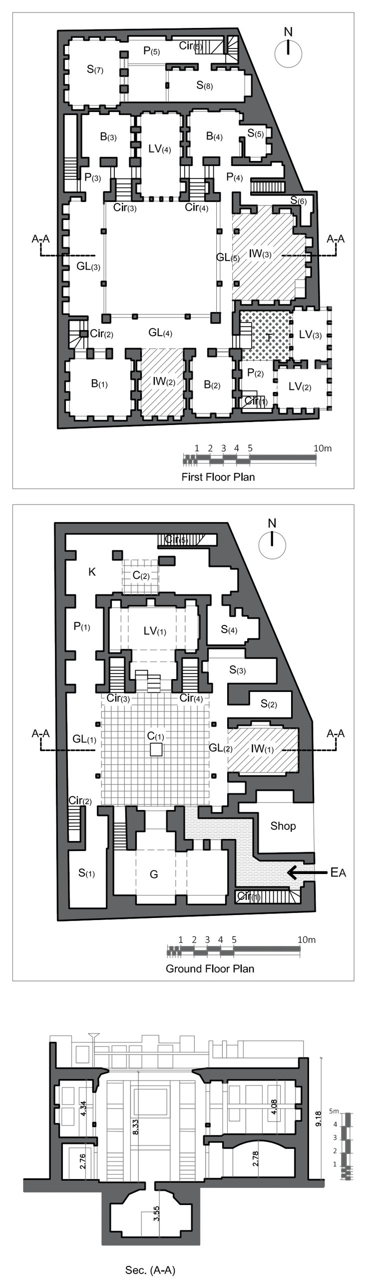
IRQ-1 A courtyard house, Baghdad, Iraq (redrawn by the author, after Ragette, 2016, 190)



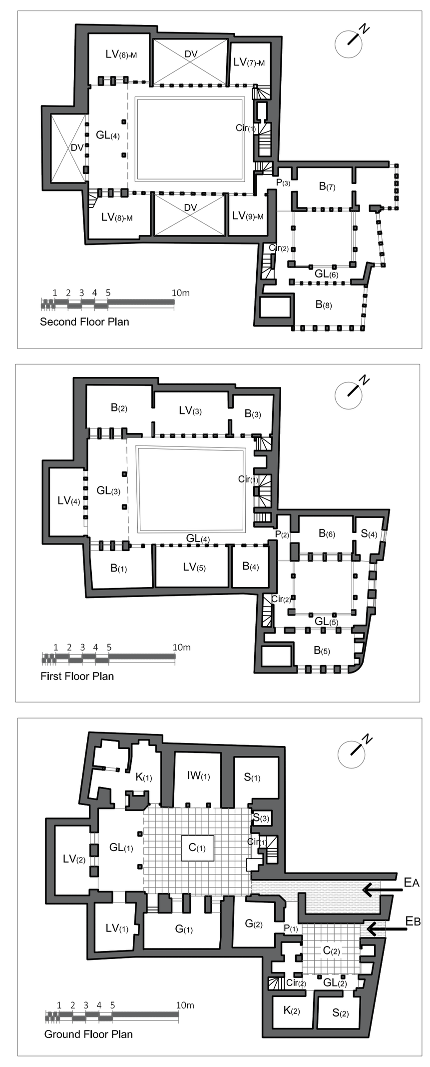
IRQ-2 A courtyard house, Baghdad, Iraq (redrawn by the author, after Ragette, 2016, 191)



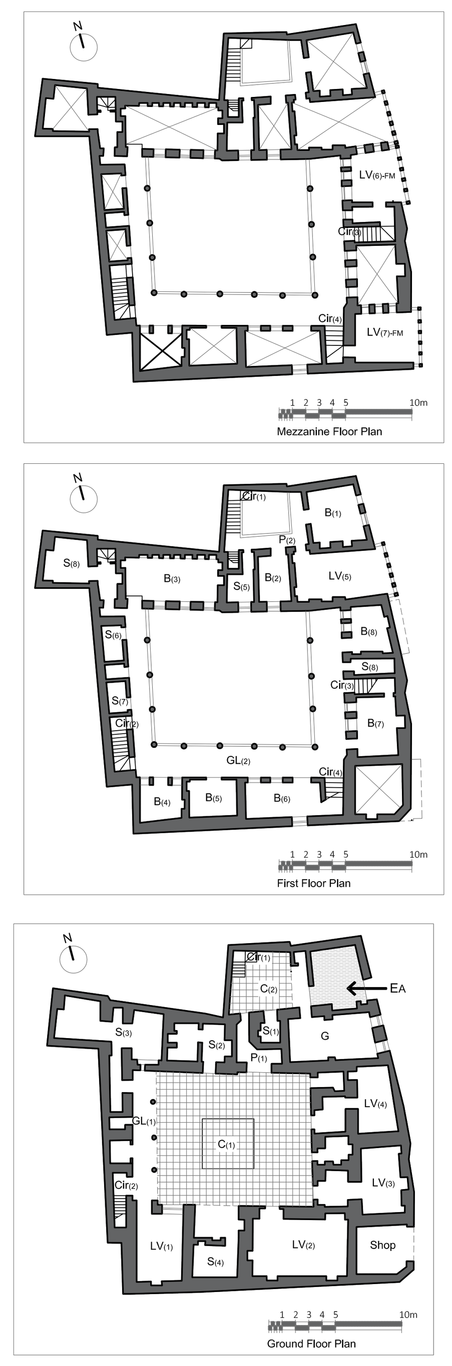
IRQ-3 A courtyard house, Hilleh, Iraq (redrawn by the author, after Ragette, 2016, 192)



IRQ-4 A courtyard house, Baghdad, Iraq (redrawn by the author, after Ragette, 2016, 193)



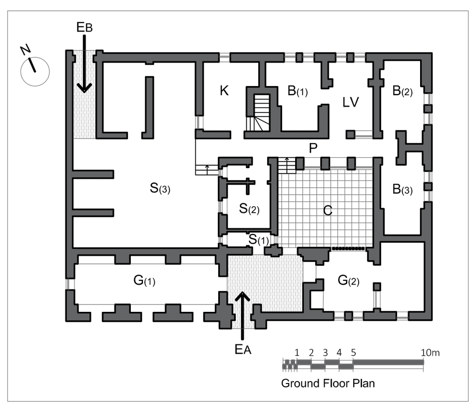
IRQ-5 A courtyard house, Baghdad, Iraq (redrawn by the author, after Ragette, 2016, 192)



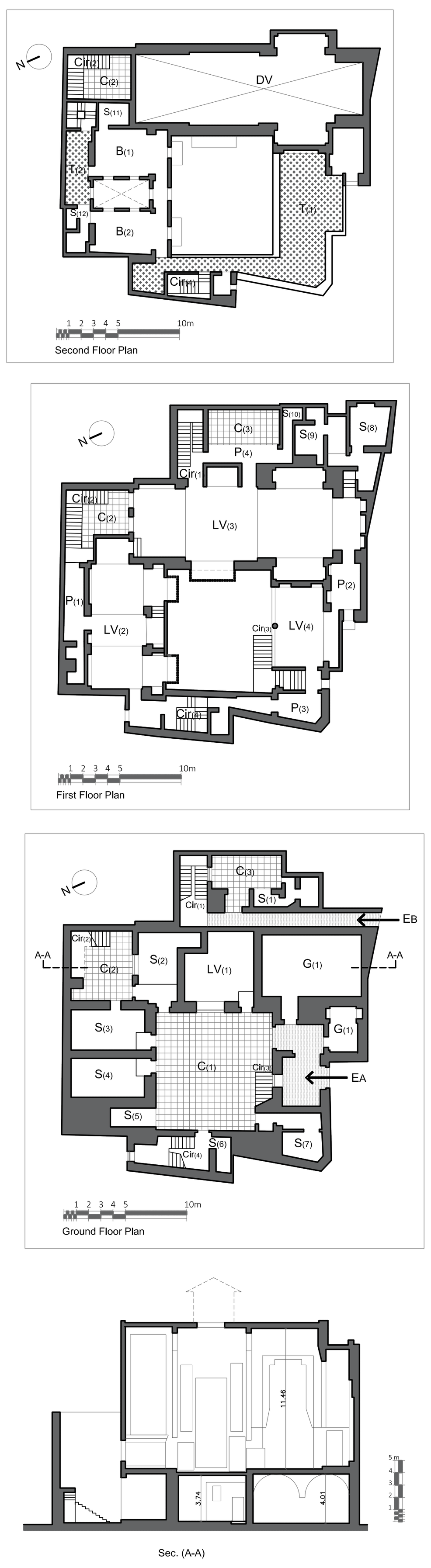
As-Built Plans - North Africa (15 cases)

EGYPT

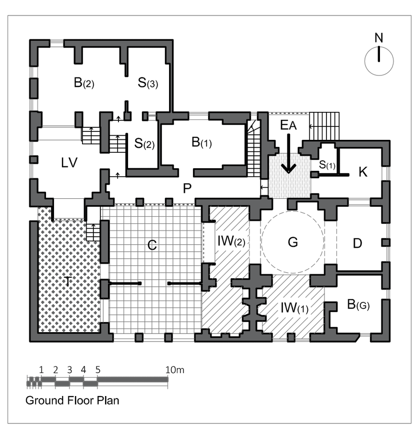
EGY-1 A courtyard house, Al-Mahameed, Egypt (designed by Hassan Fathy, 1981) (redrawn by the author, after Serageldin, 2007, 27)



EGY-2 A courtyard house, Cairo, Egypt (redrawn by the author, after Ragette, 2016, 147)



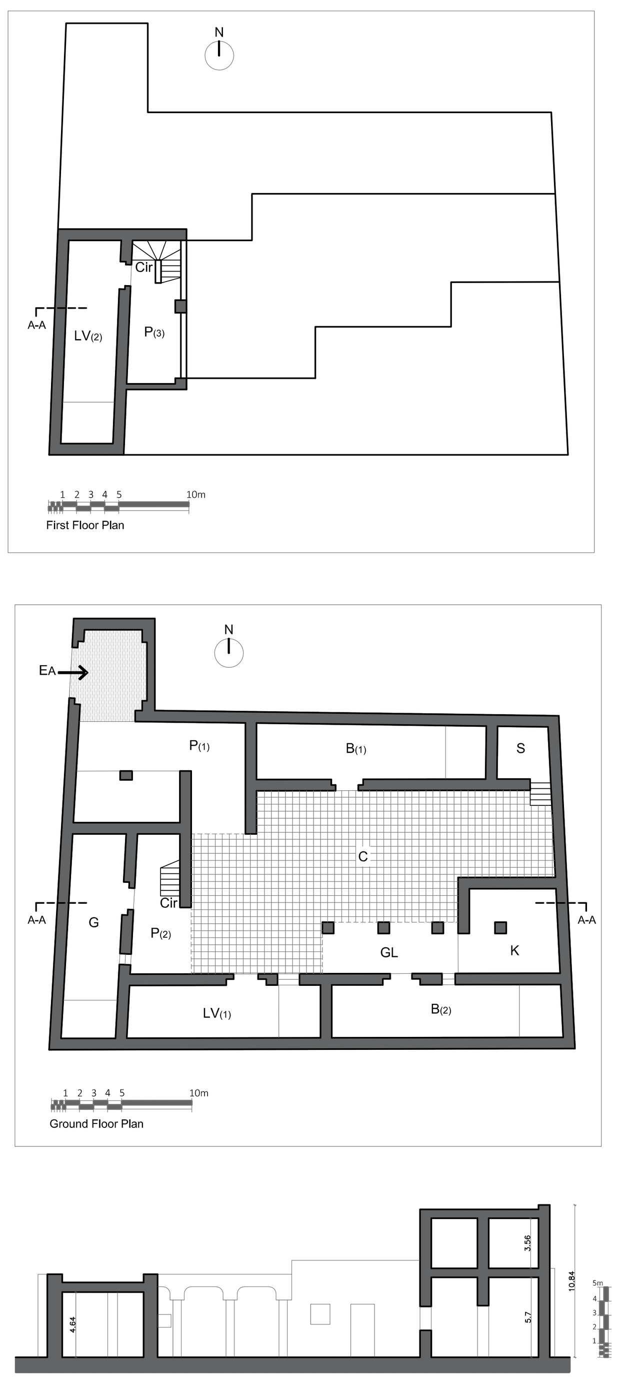
EGY-3 A courtyard house, Al-Giza, Egypt (designed by Hassan Fathy, 1978) (redrawn by the author, after Serageldin, 2007, 24)



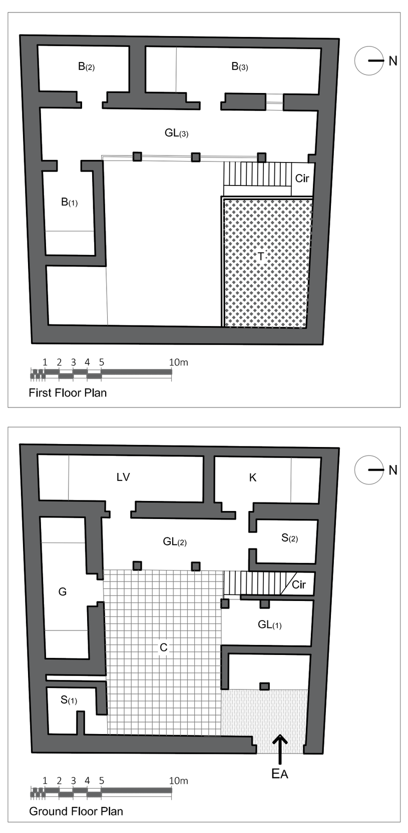
EGY-4 A courtyard house, Cairo, Egypt (redrawn by the author, after Ragette, 2016, 144)

TUNISIA

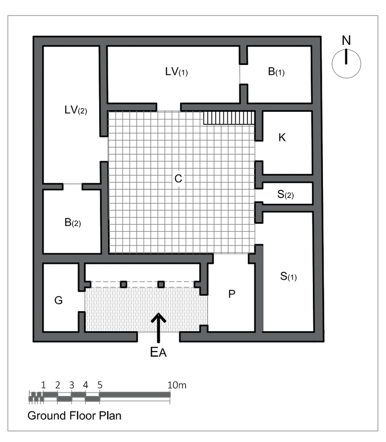
TUN-1 A courtyard house, Oudrif, Tunis (redrawn by the author, after Ragette, 2016, 127)



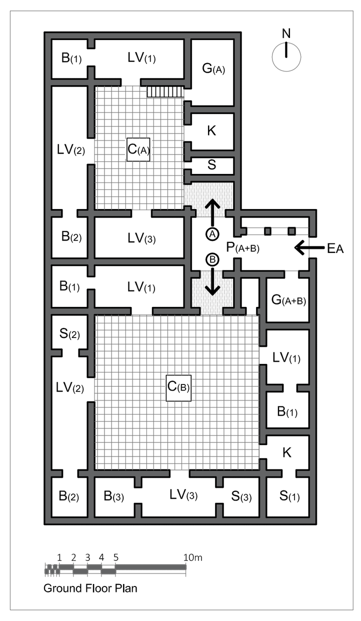
TUN-2 A courtyard house, Oudrif, Tunis (redrawn by the author, after Ragette, 2016, 127)



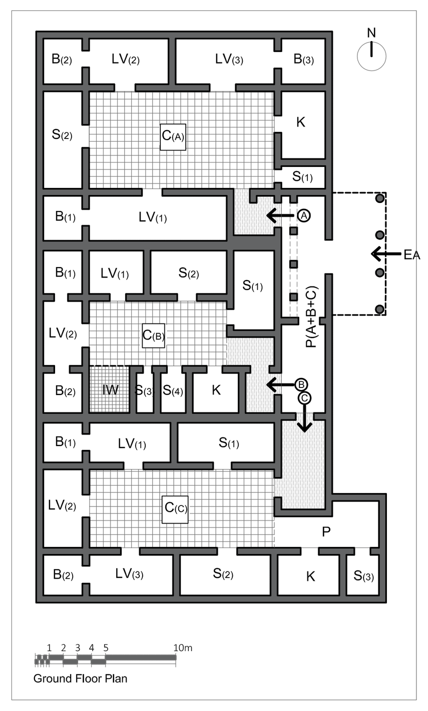
TUN-3 A courtyard house, Djerid, Tunis (redrawn by the author, after Ragette, 2016, 128)



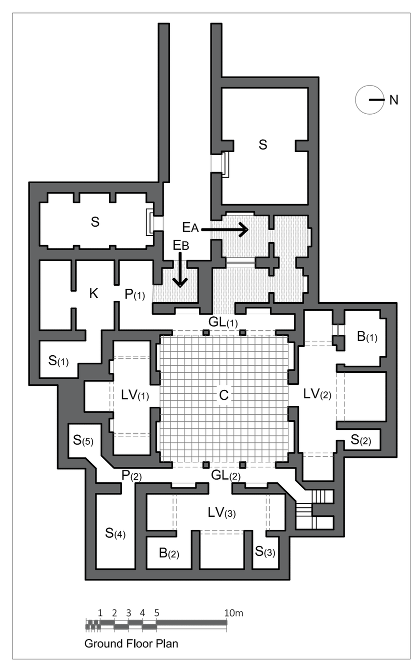
TUN- 4(A+B) Two-family courtyard house, Djerid, Tunis (redrawn by the author, after Ragette, 2016, 128)



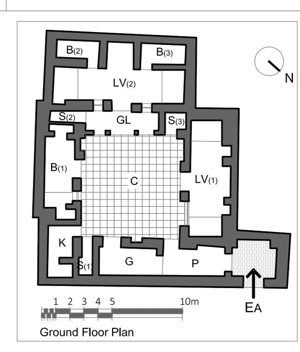
TUN- 5(A+B+C) Three-family courtyard house, Djerid, Tunis (redrawn by the author, after Ragette, 2016, 128)



TUN-6 A courtyard house, Tunis (redrawn by the author, after Ragette, 2016, 130)

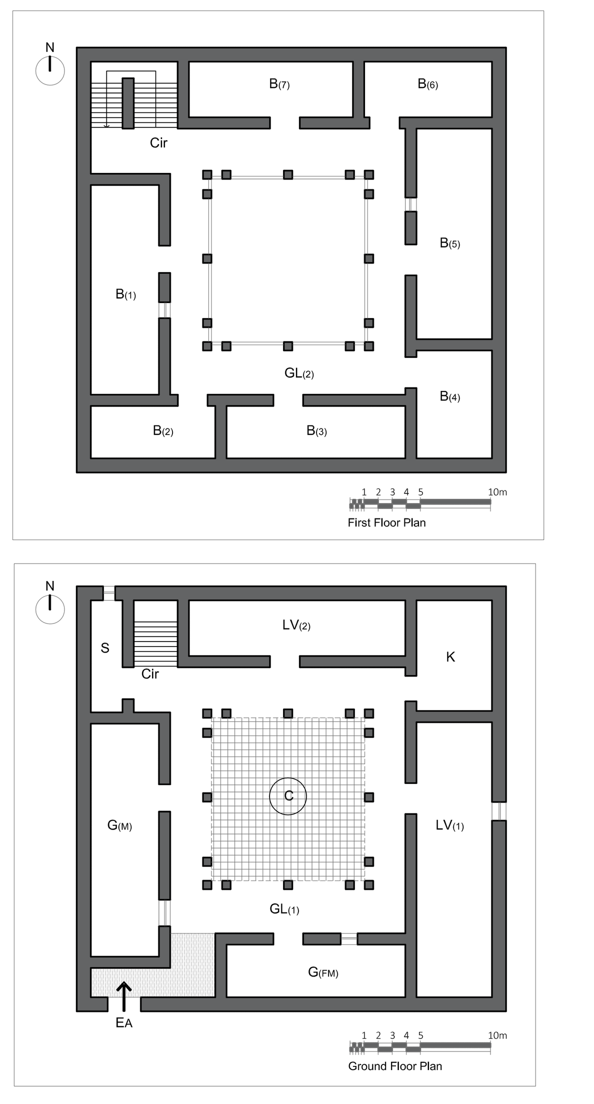


TUN-7 A courtyard house, Tunis (redrawn by the author, after Hakim, 1986, 97)

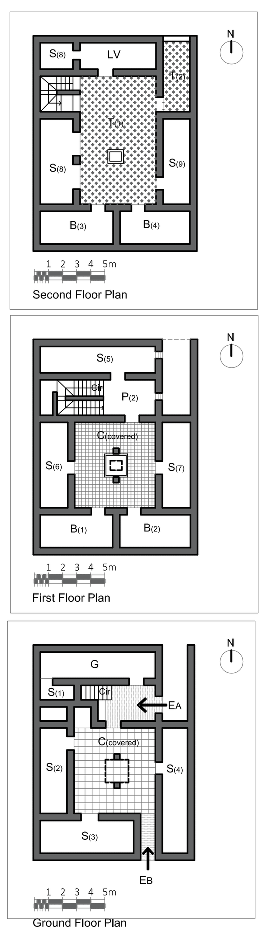


MOROCCO

MOR-1 A courtyard house, Tetouan, Morocco (redrawn by the author, after Ragette, 2016, 113)

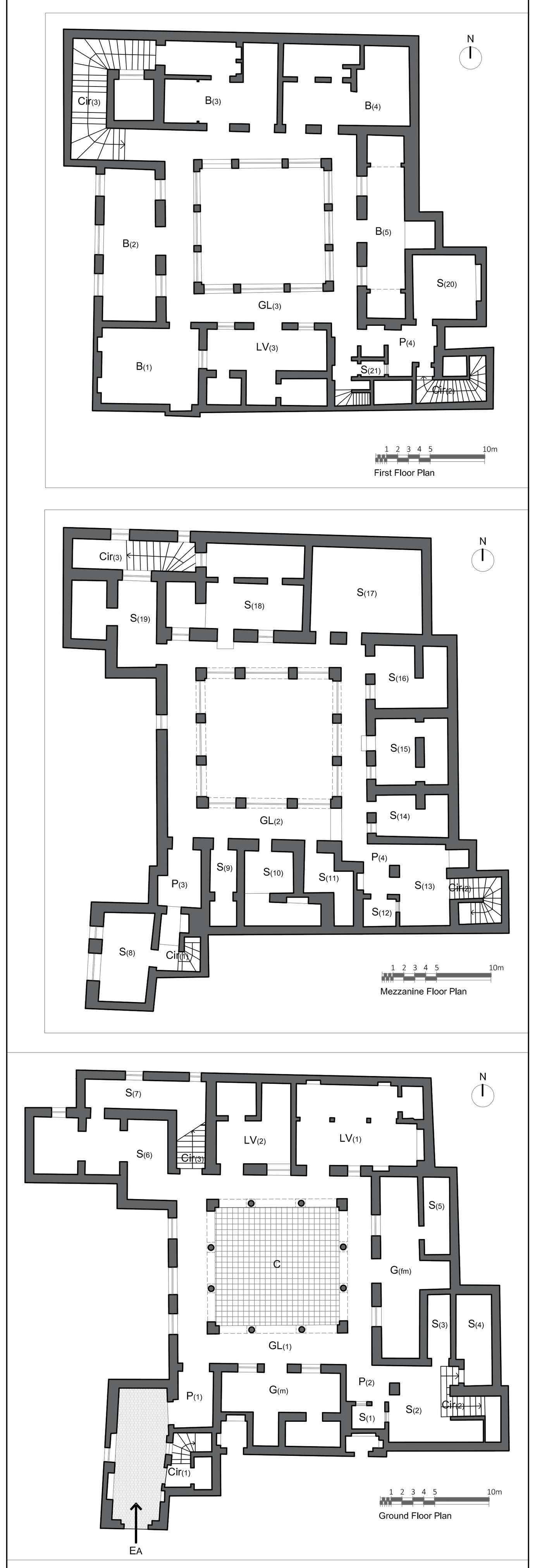


MOR-2 A courtyard house, Tabouhassamt, Morocco (redrawn by the author, after Ragette, 2016, 110)

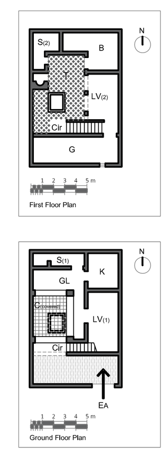


ALGERIA

ALG-1 A courtyard house, Constantine, Algeria (redrawn by the author, after Ragette, 2016, 124)



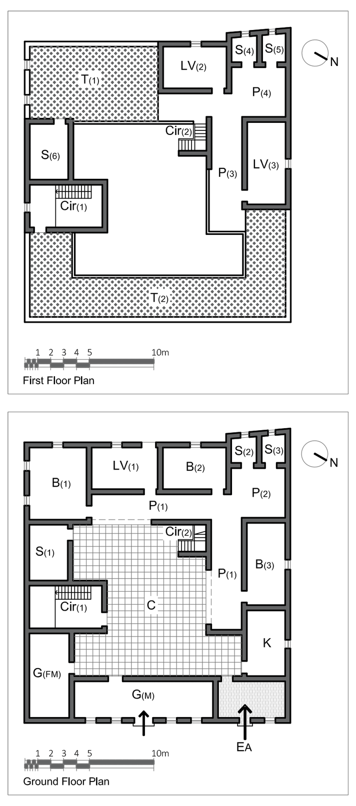
ALG-2 A house with a central space and roof opening, Mzab, Algeria (redrawn by the author, after Ragette, 2016, 118)



As-Built Plans - The Gulf Area (12 cases)

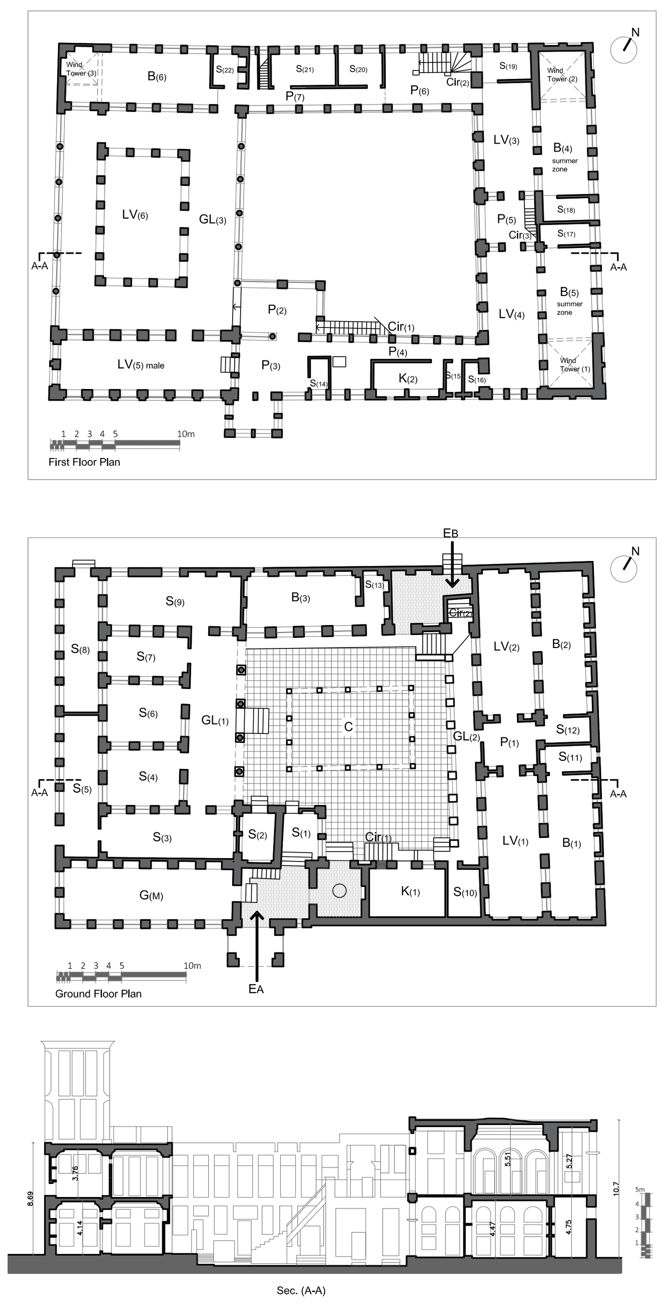
OMAN

OMA-1 A courtyard house, Mirbat, Oman
(redrawn by the author, after Ragette, 2016, 223)



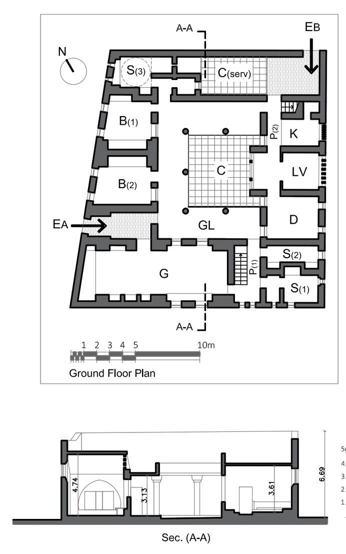
EMIRATES

UAE-1 A courtyard house, Dubai, UAE
(redrawn by the author, after Ragette, 2016, 215)

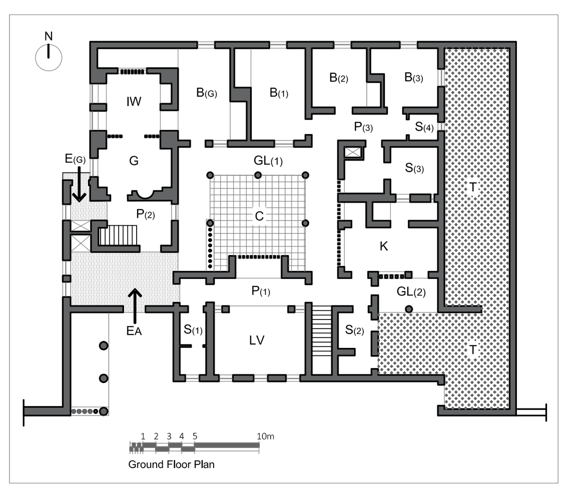


SAUDI ARABIA

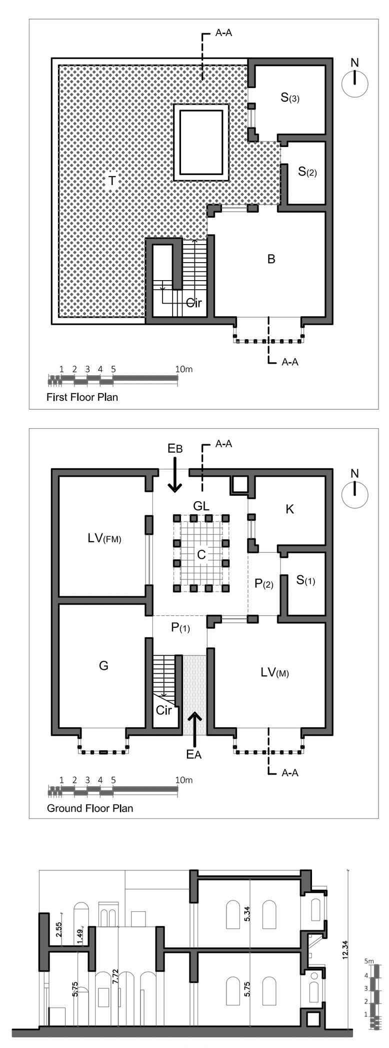
KSA-1 A courtyard house, Al-Dereyyah Village, KSA (designed by Hassan Fathy, 1965)
(redrawn by the author, after Serageldin, 2007, 53)



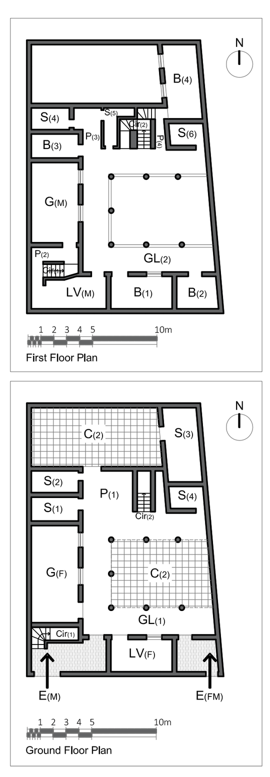
KSA-2 A courtyard house, Al-Dereyyah Village, KSA (designed by Hassan Fathy, 1985)
(redrawn by the author, after Serageldin, 2007, 53)



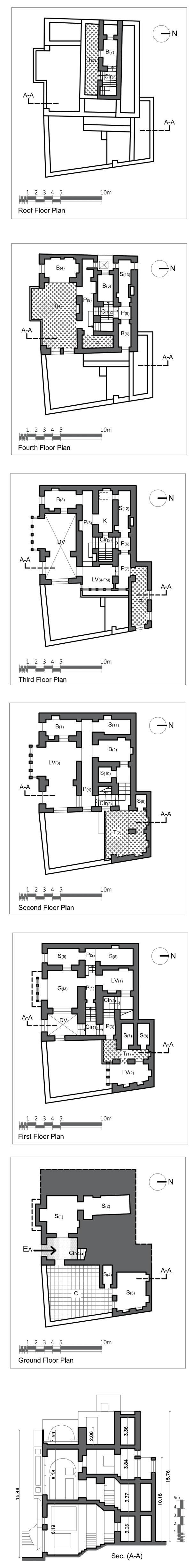
KSA-3 A vertical house in Mecca, KSA
(redrawn by the author, after Ragette, 2016 , 204)



KSA-4 A vertical house in Najd, KSA
(redrawn by the author, after Ragette, 2016 , 202)



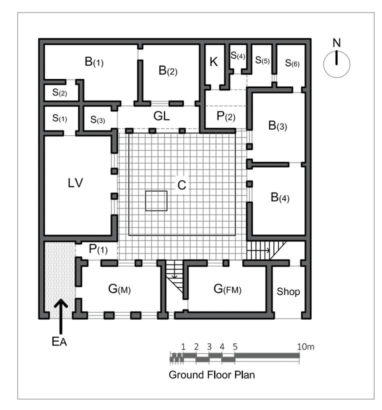
KSA-5 A tower house in Mecca, KSA
(redrawn by the author, after Ragette, 2016 , 208)



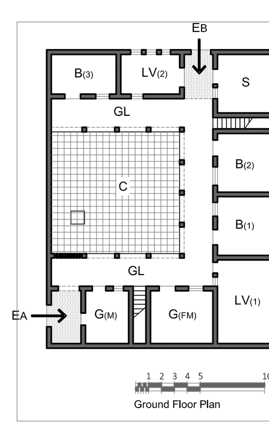
KUWAIT

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)

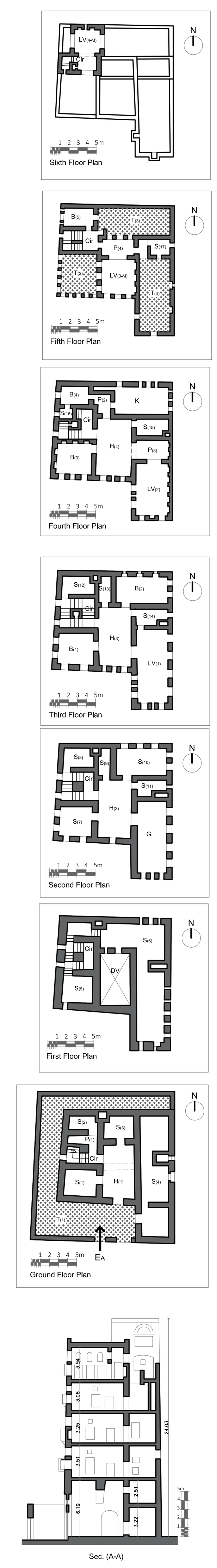


KUW-3 A courtyard house, Fahahil, Kuwait
(redrawn by the author, after http://www.kuwait-history.net, accessed on 25/10/2016)

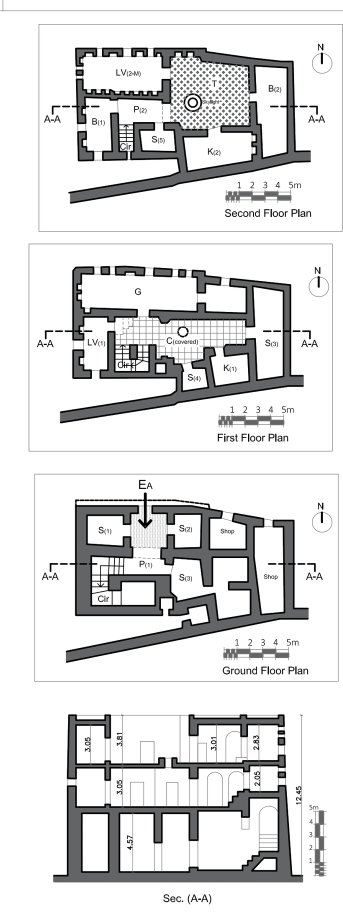


YEMEN

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)



Appendix (4-B-4)

Visibility Graph Analysis (VGA) for the Selected Vernacular Houses

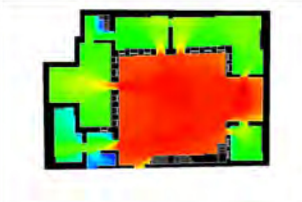
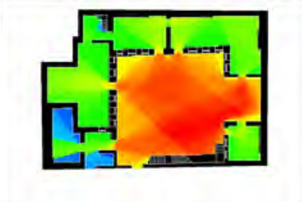
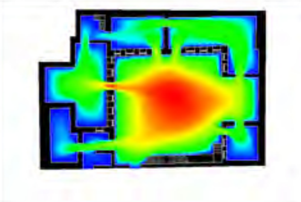
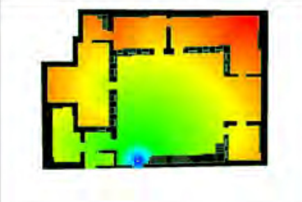
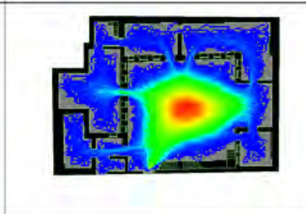
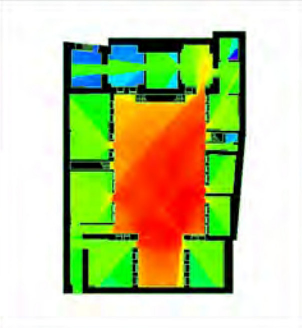
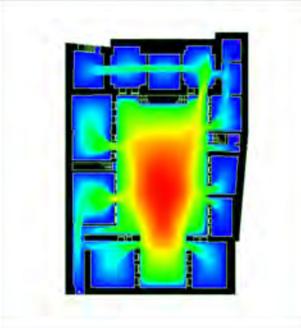
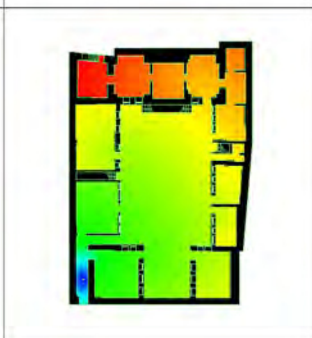
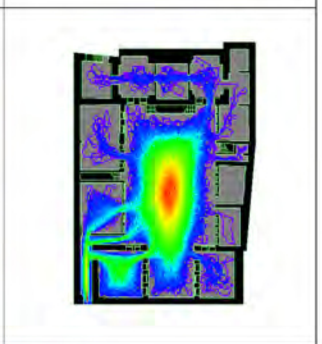
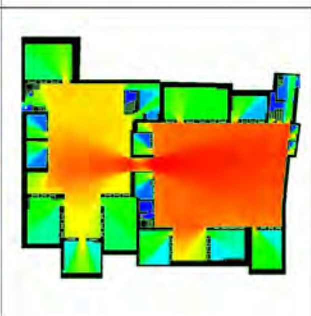
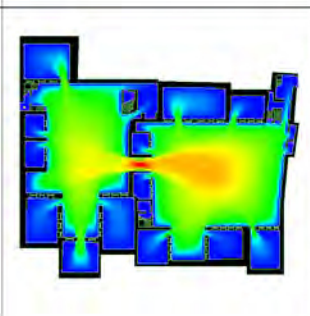
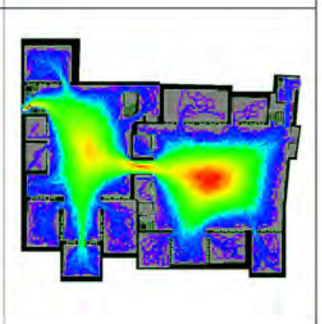
Syntactic Analysis (using Visibility Graph Analysis - VGA) for the Spatial Configuration of Traditional Town Houses located in the Middle East

(Carried out by Author using 'DepthMapX 0.50 Software')

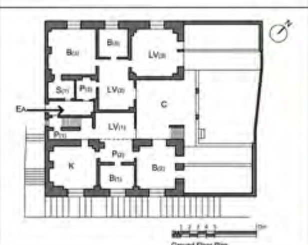
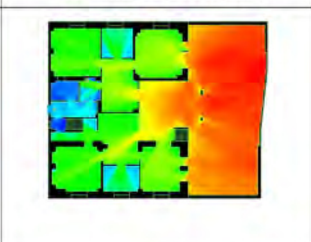
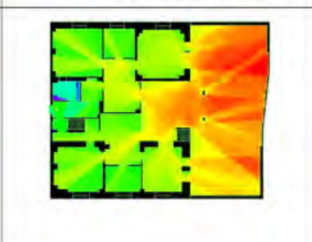
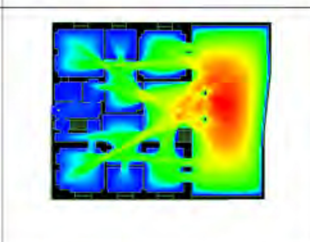
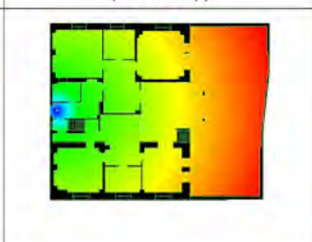
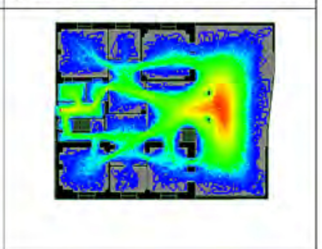
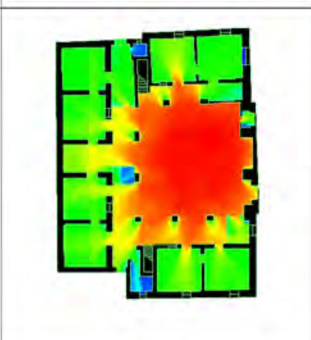
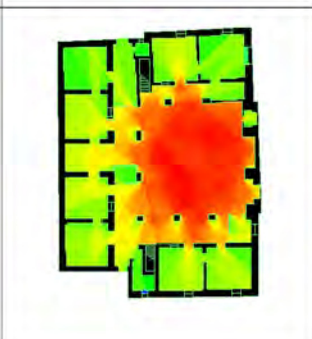
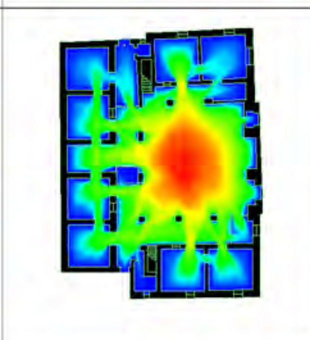
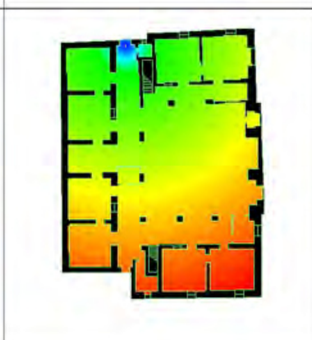
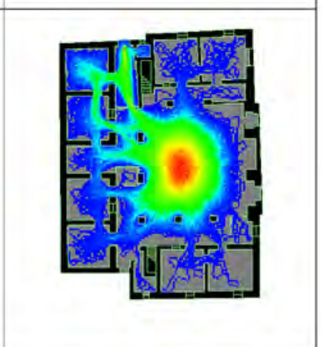
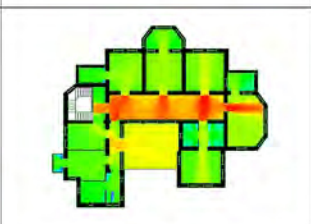
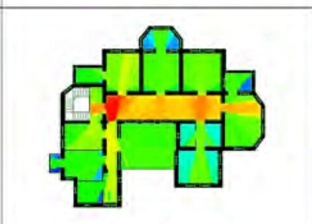
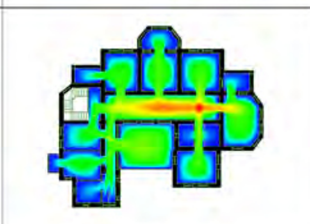
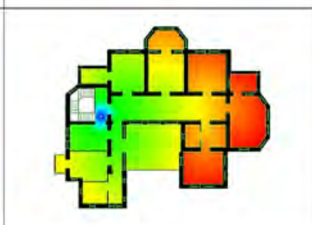
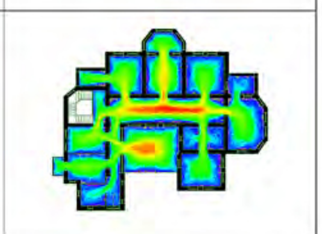
- ■ Syria (SYR)
- ■ Palestine (PAL)
- □ Lebanon (LBN)
- □ Jordan (JOR)
- □ Iraq (IRQ)

Key: Maximum Amount – Minimum Amount

SYRIA

Case No.	As-Built Plan	Connectivity (Number of points that are directly connected to other spaces)	Visual Integration (Representation of potentially core area in the layout)	Through-Vision Analysis	Depth of Spaces from the Main Entrance (Metric Step)	Agent Analysis (Pattern of movement and frequent use of spaces, released from the main entrance)
SYR-1						
SYR-2						
SYR-3						

PALESTINE

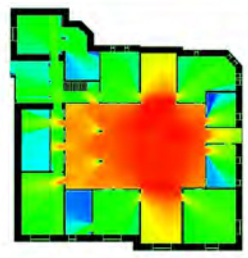
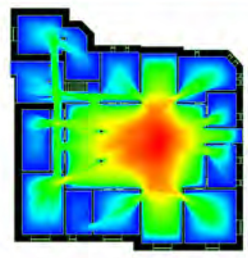
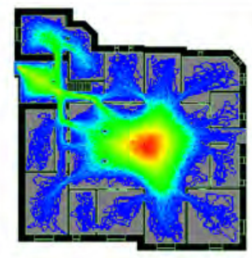
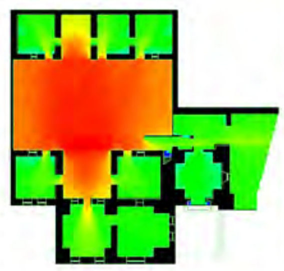
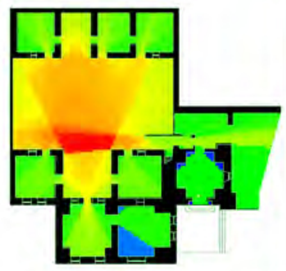
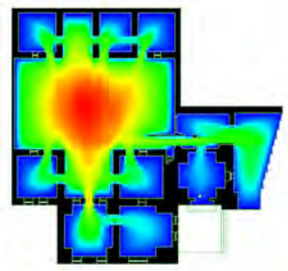
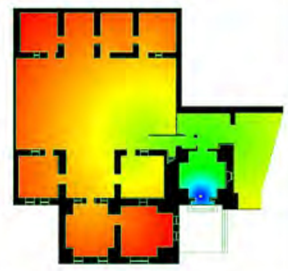
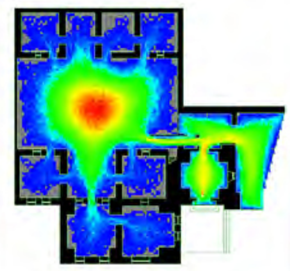
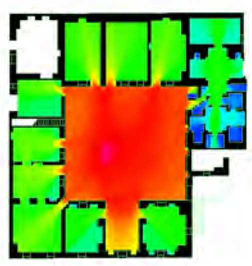
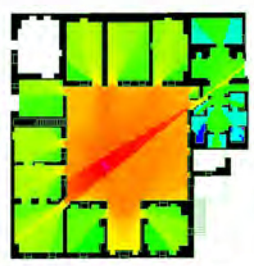
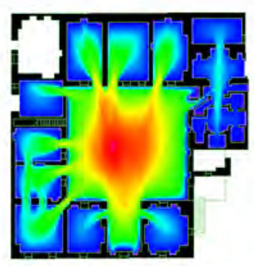
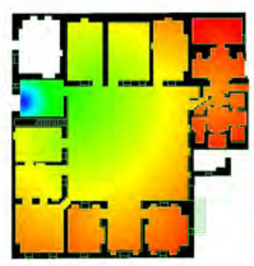
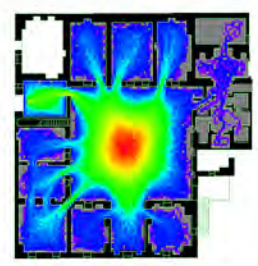
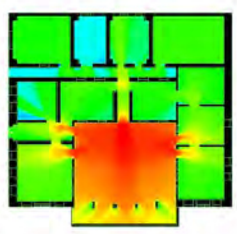
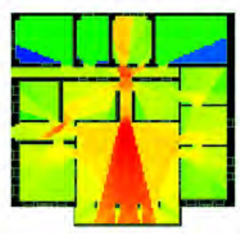
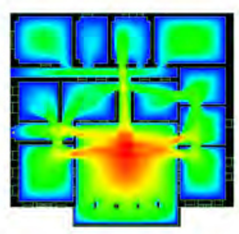
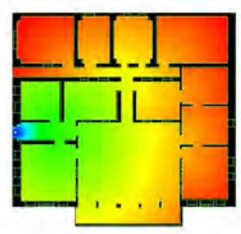
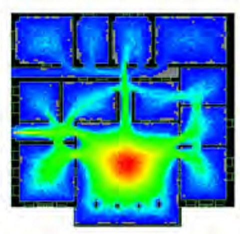
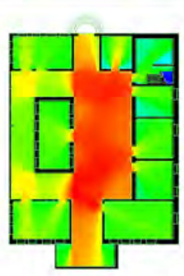
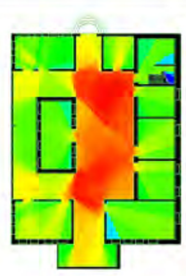
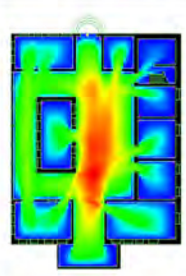
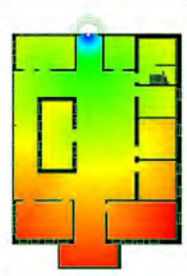
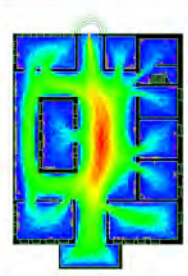
Case No.	As-Built Plan	Connectivity (Number of points that are directly connected to other spaces)	Visual Integration (Representation of potentially core area in the layout)	Through-Vision Analysis	Depth of Spaces from the Main Entrance (Metric Step)	Agent Analysis (Pattern of movement and frequent use 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)

Key: Maximum Amount – Minimum Amount

LEBANON

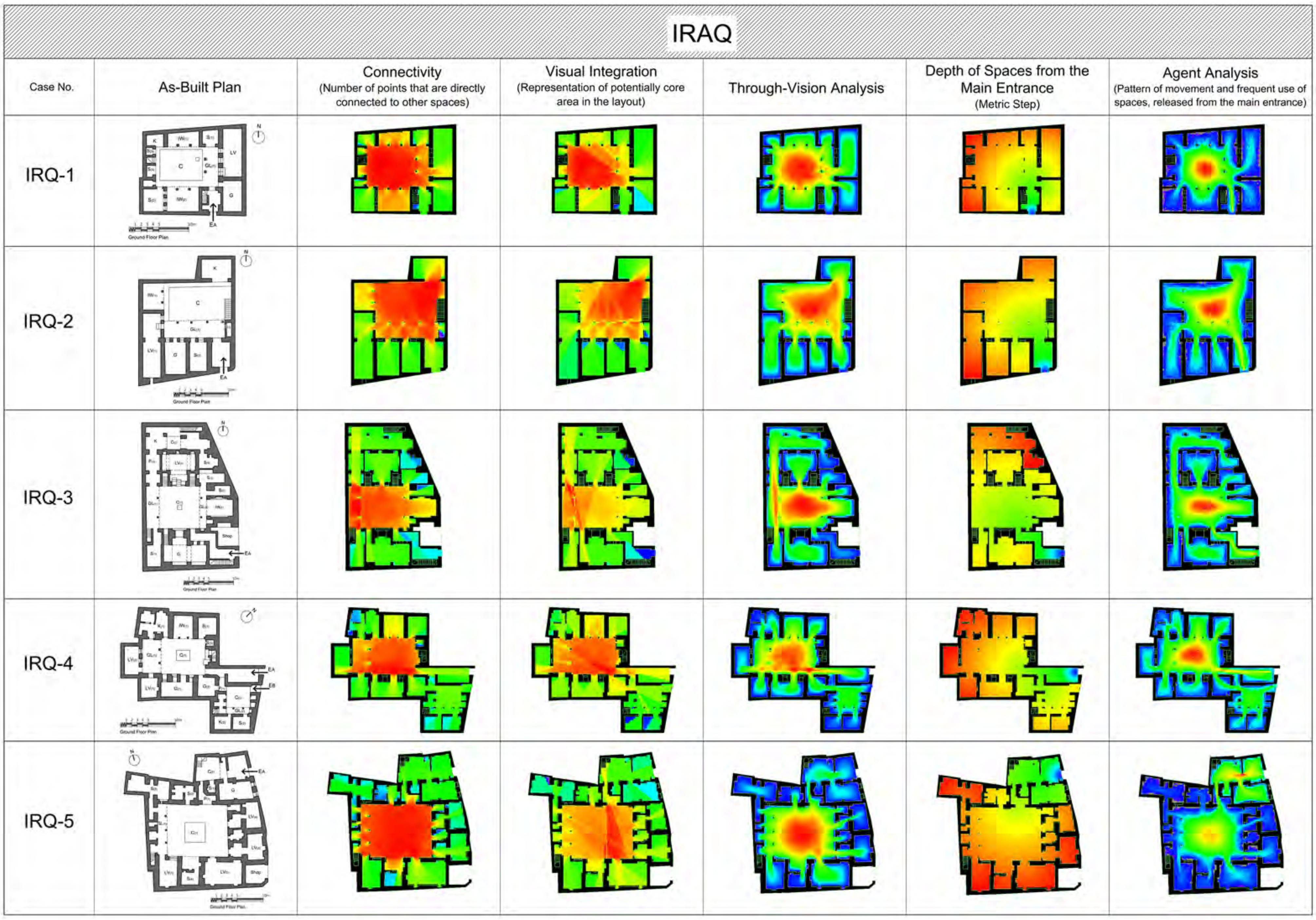
Case No.	As-Built Plan	Connectivity (Number of points that are directly connected to other spaces)	Visual Integration (Representation of potentially core area in the layout)	Through-Vision Analysis	Depth of Spaces from the Main Entrance (Metric Step)	Agent Analysis (Pattern of movement and frequent use of spaces, released from the main entrance)
LBN-1						
LBN-2						
LBN-3						
LBN-4						
LBN-5						

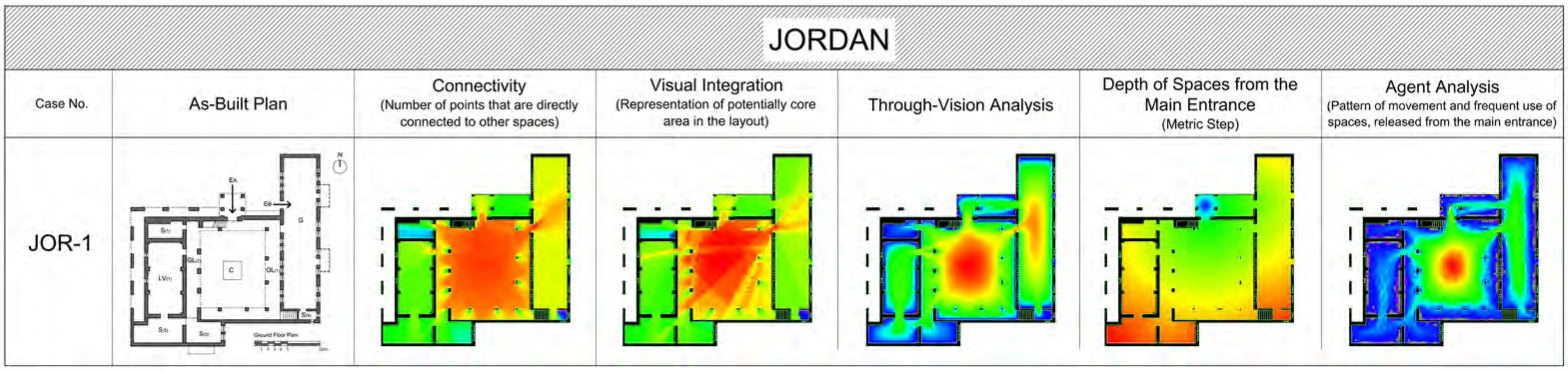
Syntactic Analysis (using Visibility Graph Analysis - VGA) for the Spatial Configuration of Traditional Town Houses located in the Middle East

(Carried out by Author using 'DepthMapX 0.50 Software')

- Syria (SYR)
- Palestine (PAL)
- Lebanon (LBN)
- Jordan (JOR)
- Iraq (IRQ)

Key: Maximum Amount – Minimum Amount





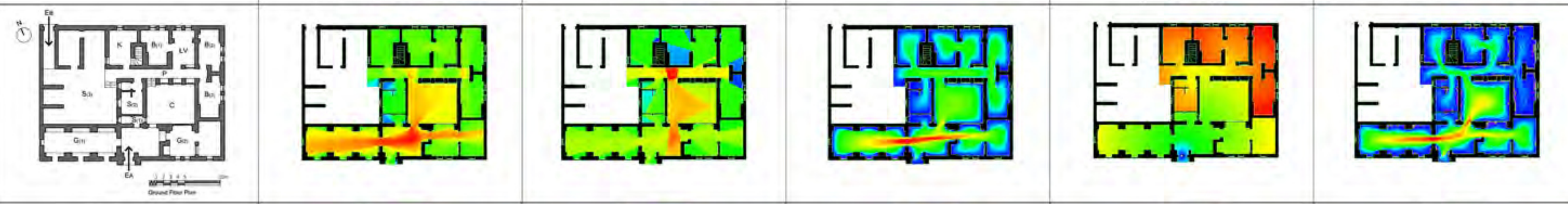
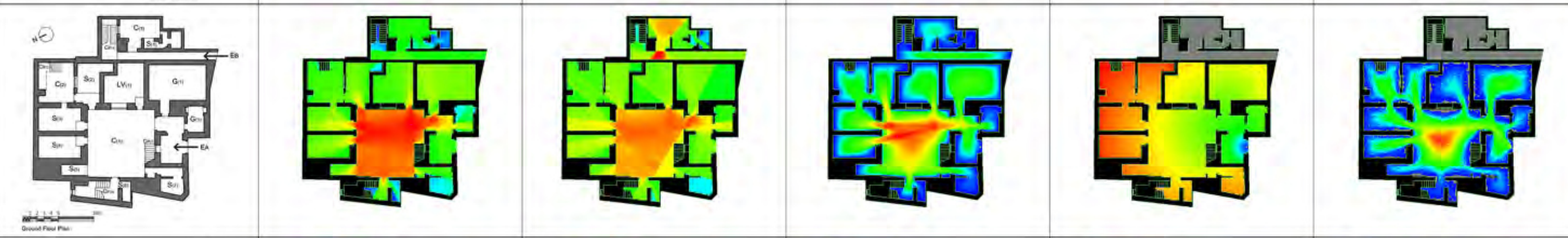
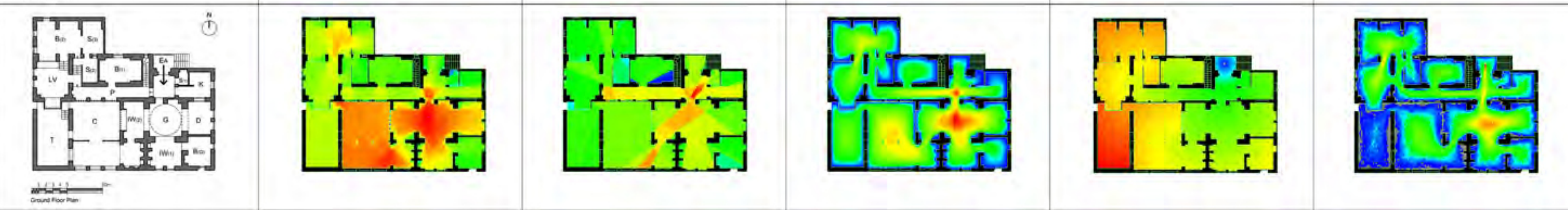
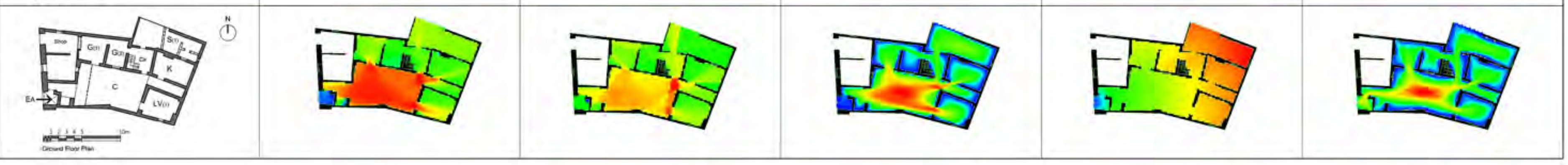
Syntactic Analysis (using Visibility Graph Analysis - VGA) for the Spatial Configuration of Traditional Town Houses located in North Africa

(Carried out by Author using 'DepthMapX 0.50 Software')

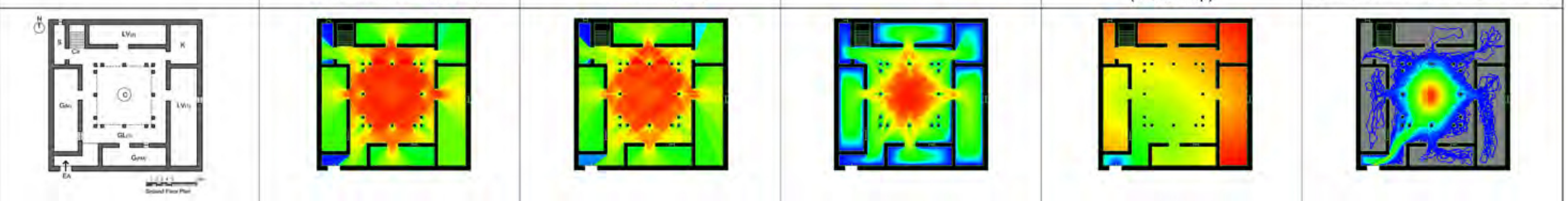
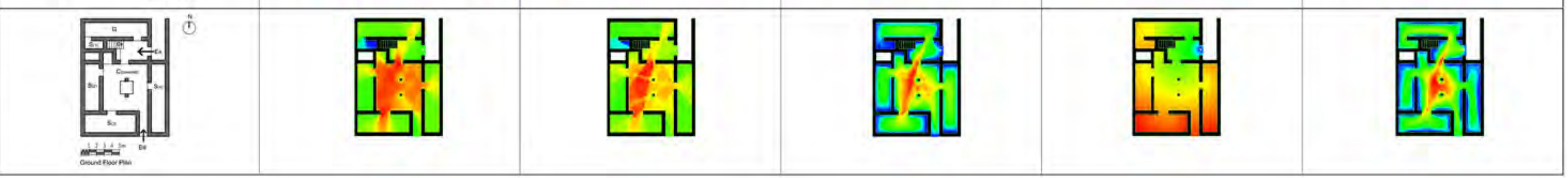
- ■ Egypt (EGY)
- ■ Morocco (MOR)
- ■ Algeria (ALG)
- □ TUNISIA (TUN)

Key: Maximum Amount – Minimum Amount

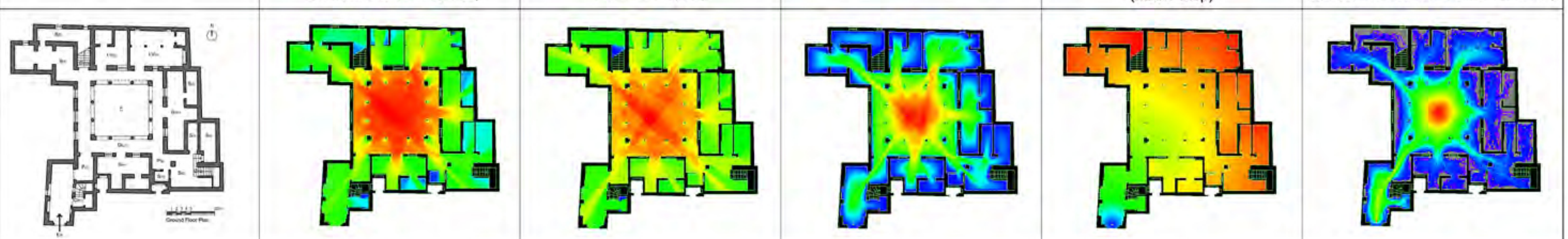
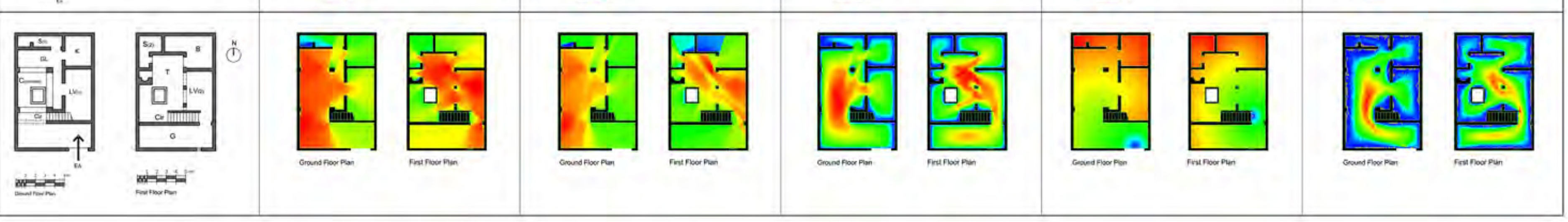
EGYPT

Case No.	As-Built Plan	Connectivity (Number of points that are directly connected to other spaces)	Visual Integration (Representation of potentially core area in the layout)	Through-Vision Analysis	Depth of Spaces from the Main Entrance (Metric Step)	Agent Analysis (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 (Number of points that are directly connected to other spaces)	Visual Integration (Representation of potentially core area in the layout)	Through-Vision Analysis	Depth of Spaces from the Main Entrance (Metric Step)	Agent Analysis (Pattern of movement and frequent use of spaces, released from the main entrance)
MOR-1						
MOR-2						

ALGERIA

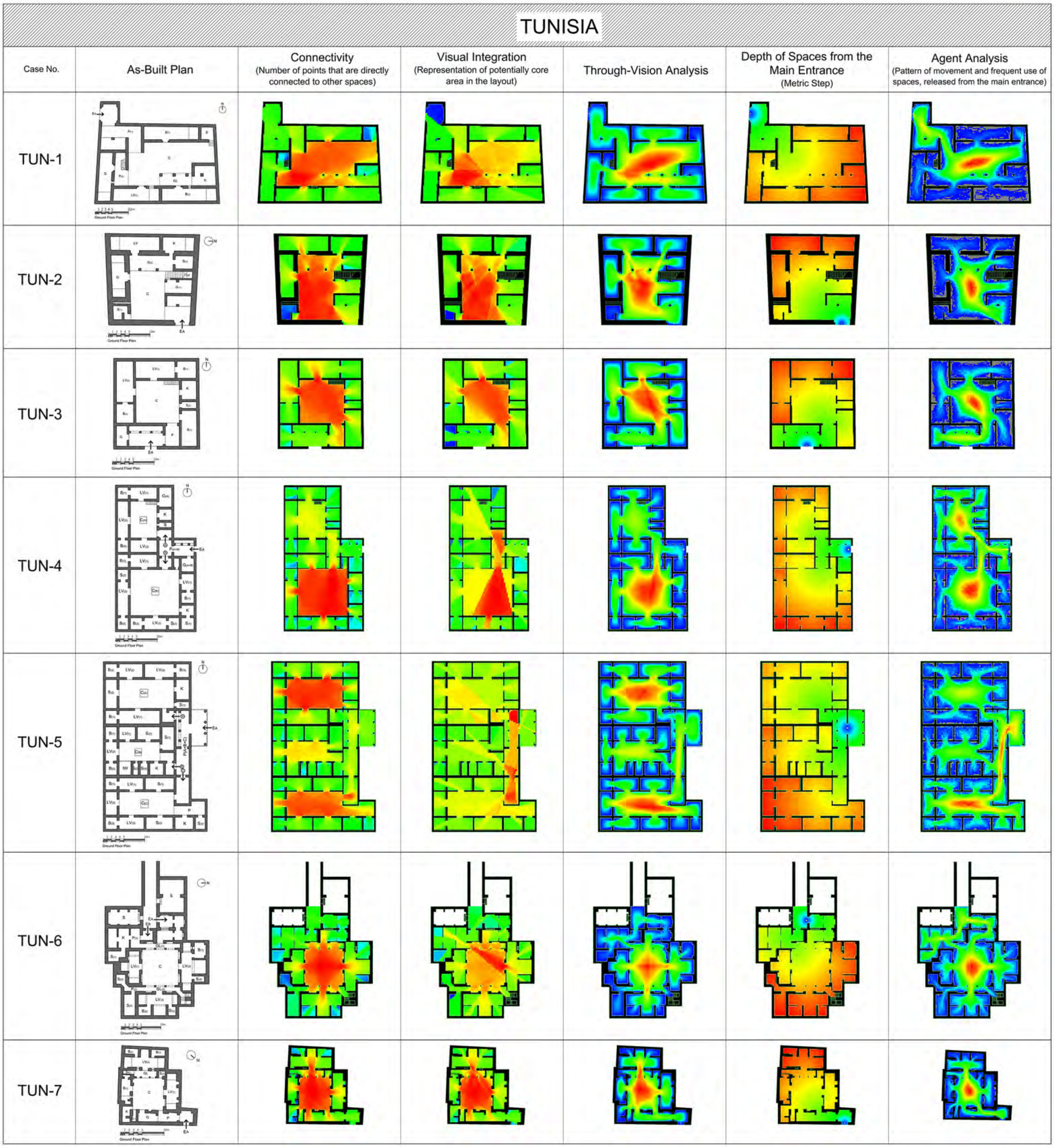
Case No.	As-Built Plan	Connectivity (Number of points that are directly connected to other spaces)	Visual Integration (Representation of potentially core area in the layout)	Through-Vision Analysis	Depth of Spaces from the Main Entrance (Metric Step)	Agent Analysis (Pattern of movement and frequent use 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)

Key: Maximum Amount – Minimum Amount

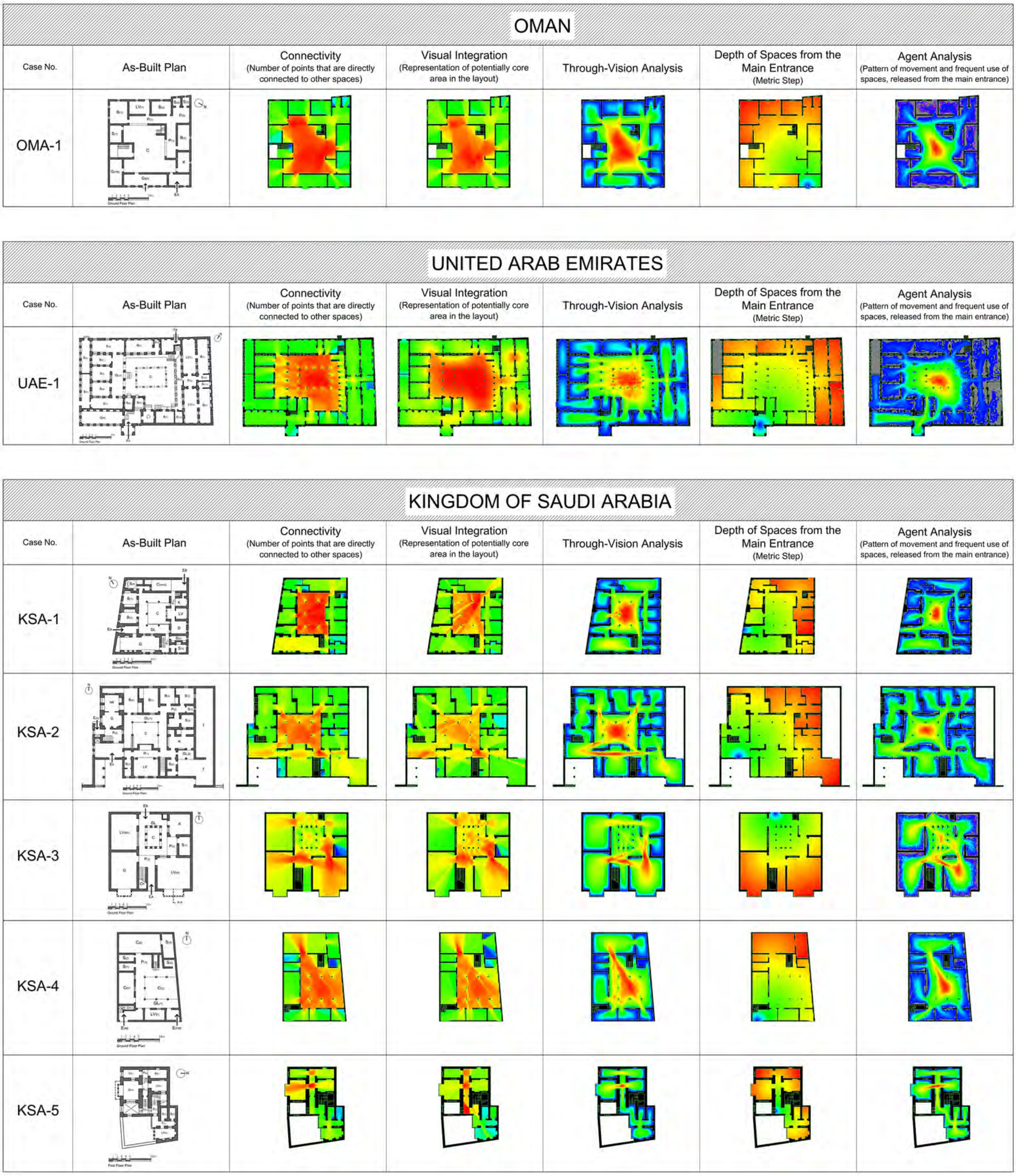


Syntactic Analysis (using Visibility Graph Analysis - VGA) for the Spatial Configuration of Traditional Town Houses located in the Gulf Area

(Carried out by Author using 'DepthMapX 0.50 Software')

- Oman (OMA)
- United Arab Emirates (UAE)
- Kingdom of Saudi Arabia (KSA)
- Kuwait (KUW)
- Yemen (YEM)

Key: Maximum Amount – Minimum Amount

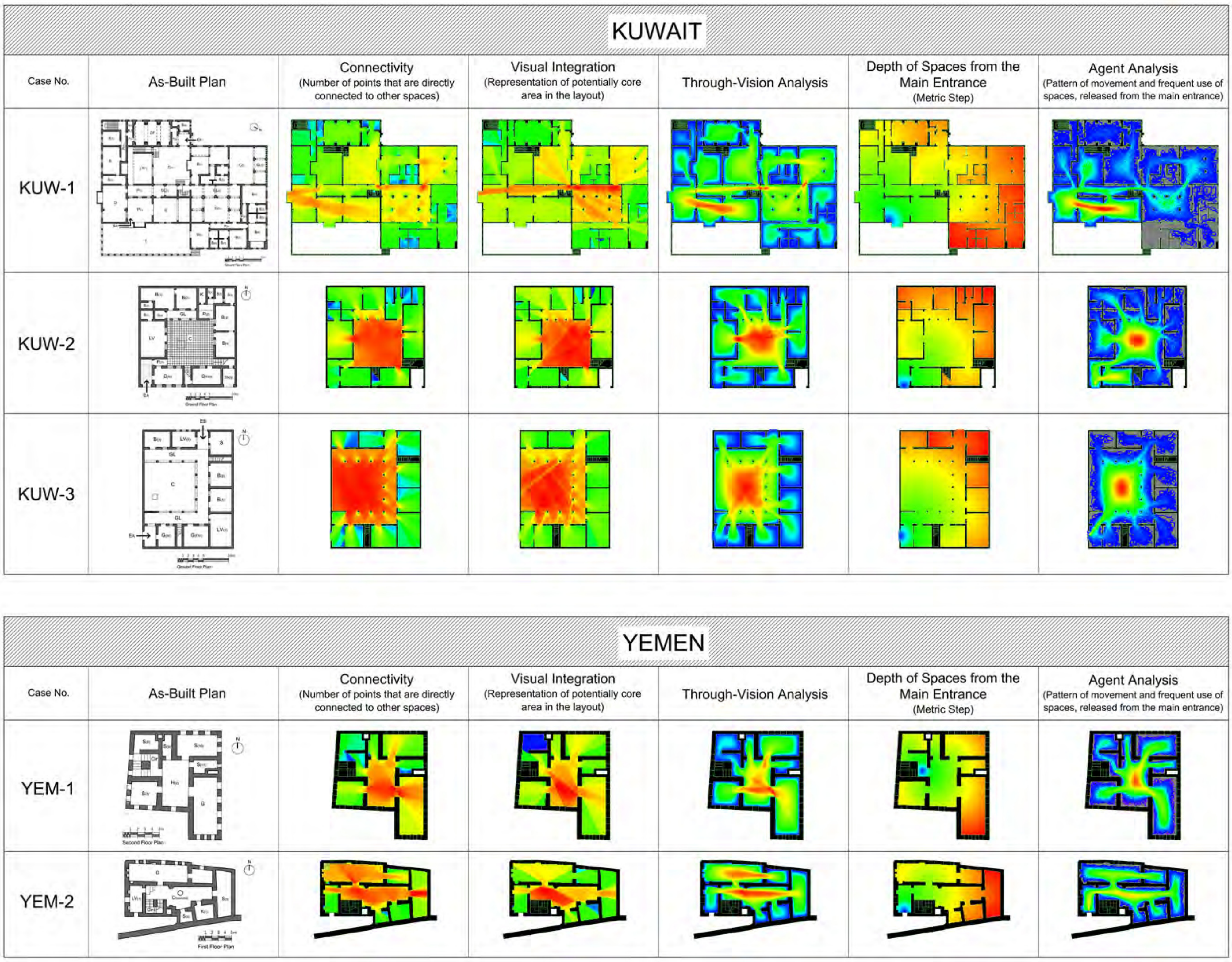


Syntactic Analysis (using Visibility Graph Analysis - VGA) for the Spatial Configuration of Traditional Town Houses located in the Gulf Area

(Carried out by Author using 'DepthMapX 0.50 Software')

- Oman (OMA)
- United Arab Emirates (UAE)
- Kingdom of Saudi Arabia (KSA)
- Kuwait (KUW)
- Yemen (YEM)

Key: Maximum Amount – Minimum Amount



<u>Appendix (4-B-5)</u>

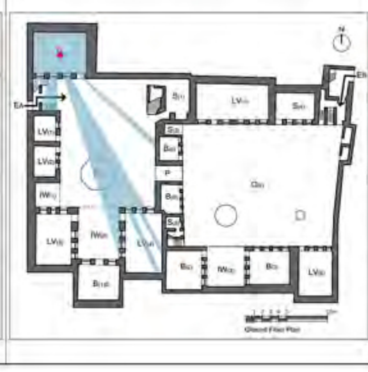
Isovist Analysis for the Selected Vernacular Houses

Visibility Study for the Main Floor from Different Points Inside Traditional Town Houses located in the Middle East

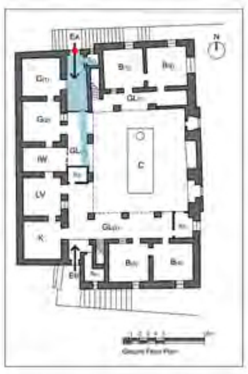
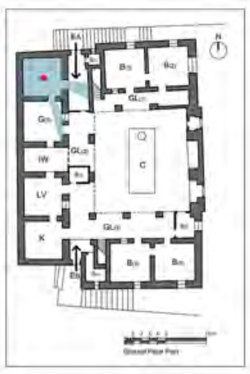
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')

- 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

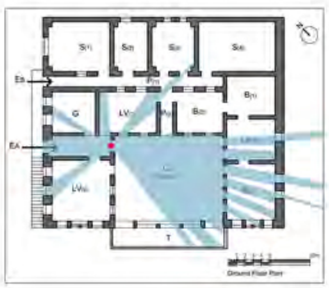
Case No.	Visual Fields from the Main Entry Point of the House	Visual Fields from the Entry Point of the Courtyard	Visual Fields from the Entry Point of the Guest Room	Visual Fields from the Centroid of the Guest Room	Visual Fields along the Movement Path of Guests inside the House
PAL-1					
PAL-2					
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

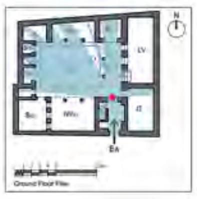
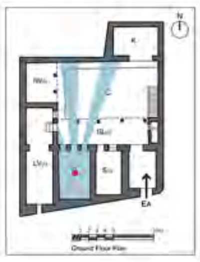
Case No.	Visual Fields from the Main Entry Point of the House	Visual Fields from the Entry Point of the Courtyard	Visual Fields from the Entry Point of the Guest Room	Visual Fields from the Centroid of the Guest Room	Visual Fields along the Movement Path of Guests inside the House
LBN-1					
LBN-2					
LBN-3					
LBN-4					
LBN-5					

Visibility Study for the Main Floor from Different Points Inside Traditional Town Houses located in the Middle East

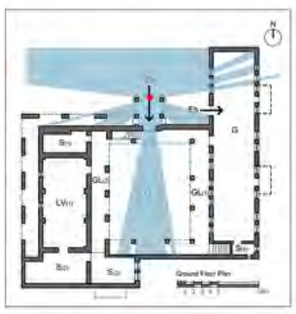
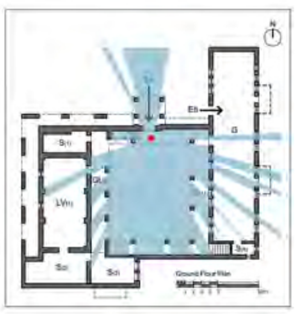
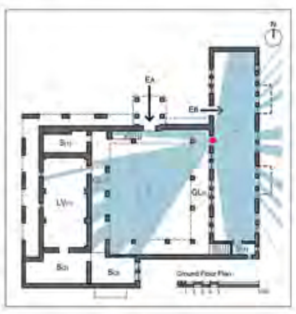
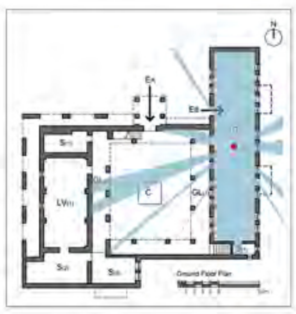
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')

- ☐ 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					

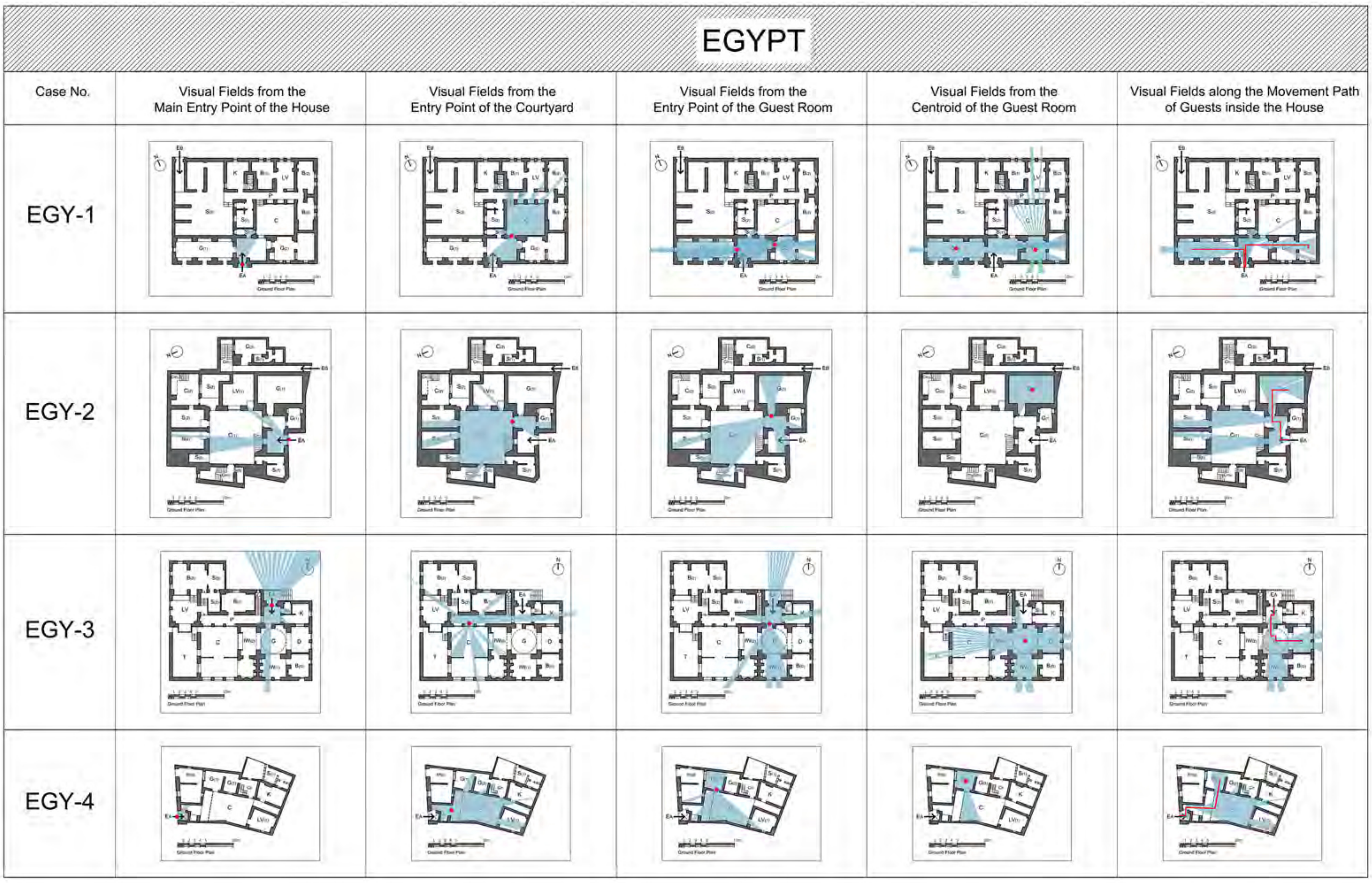
JORDAN

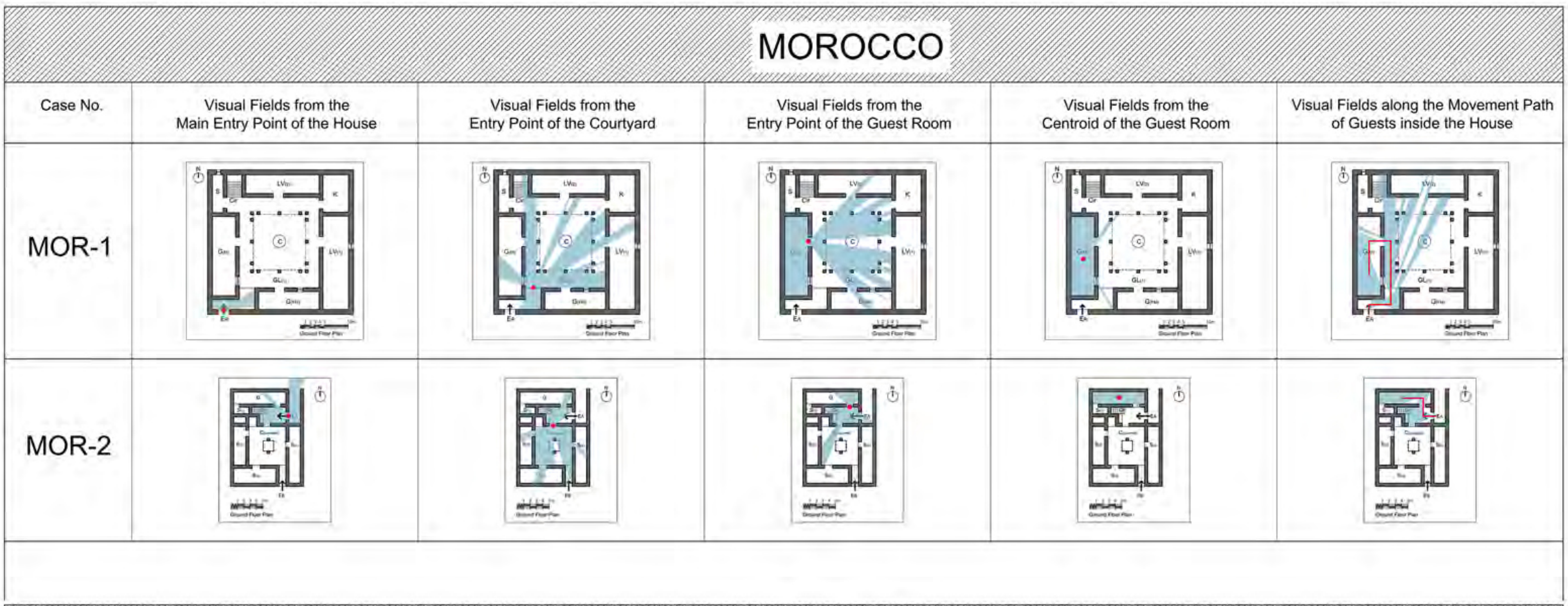
Case No.	Visual Fields from the Main Entry Point of the House	Visual Fields from the Entry Point of the Courtyard	Visual Fields from the Entry Point of the Guest Room	Visual Fields from the Centroid of the Guest Room	Visual Fields along the Movement Path of Guests inside the House
JOR-1					

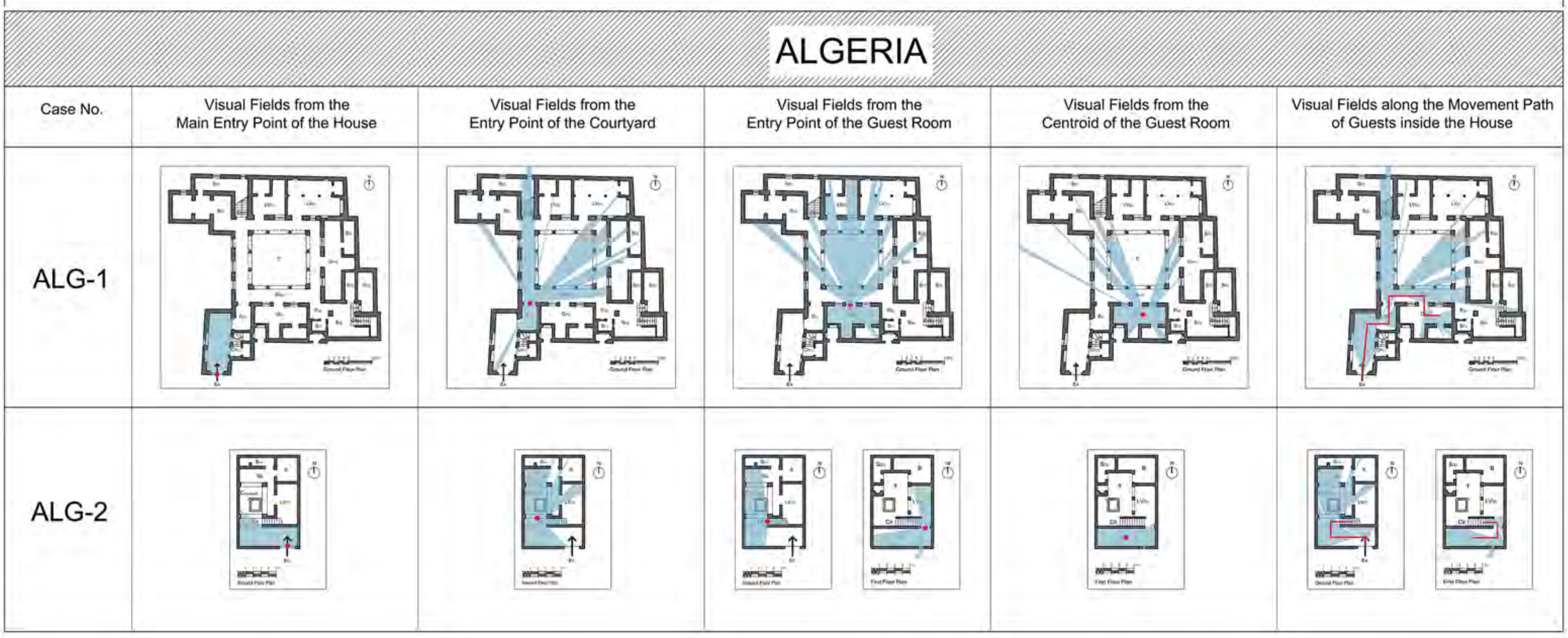
Visibility Study for the Main Floor from Different Points Inside Traditional Town Houses located in North Africa

(Carried out by Author using 'Syntax2D 1.3.0.7 Software')

- Egypt (EGY)
- Morocco (MOR)
- Algeria (ALG)
- TUNISIA (TUN)





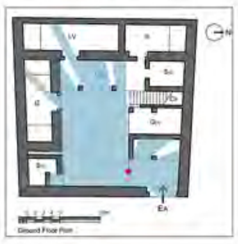
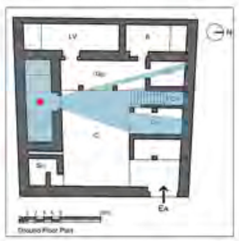


Visibility Study for the Main Floor from Different Points Inside Traditional Town Houses located in North Africa

(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					

KSA-1

KSA-2

KSA-3

KSA-4

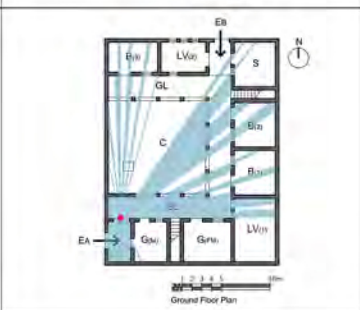
KSA-5

Visibility Study for the Main Floor from Different Points Inside Traditional Town Houses located in the Gulf Area

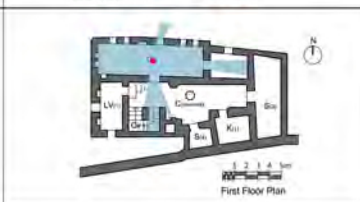
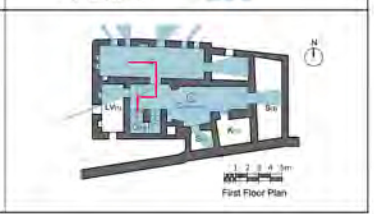
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')

- ☐ 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

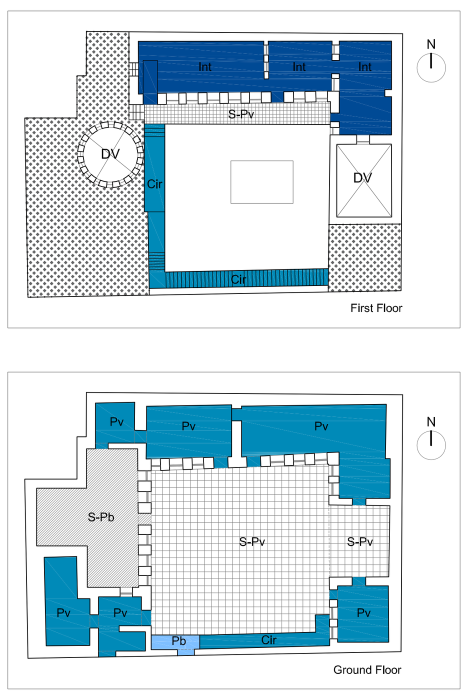
The Middle East (17 cases)

Key:

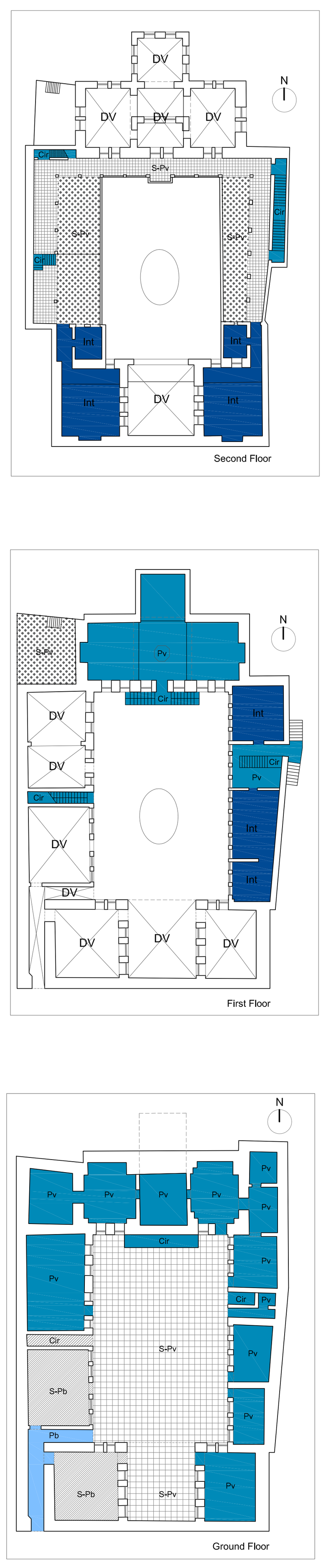
- Public Spaces (Pb) (Main Entry Hall)
- Semi-Public Spaces (S-Pb) (Guest Room, Toilet for Guests)
- Semi-Private Spaces (S-Pv) (Courtyard, Gallery, Iwan, Service Entrance)
- Private Spaces (Pv) (Living Room, Multi-Purpose Hall, Toilet, Kitchen, Storage Area)
- Intimate Spaces (Int) (Bedroom, Bathroom)

SYRIA

SYR-1



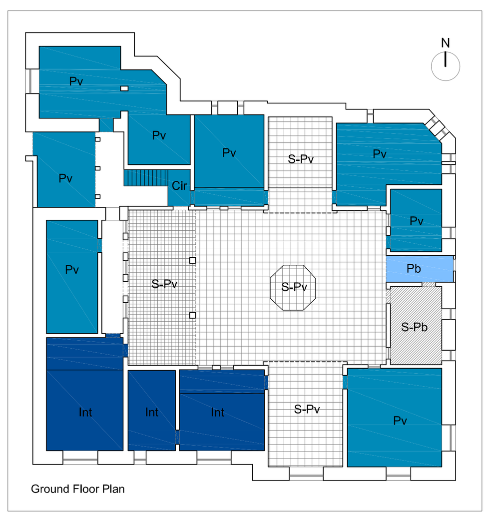
SYR-2



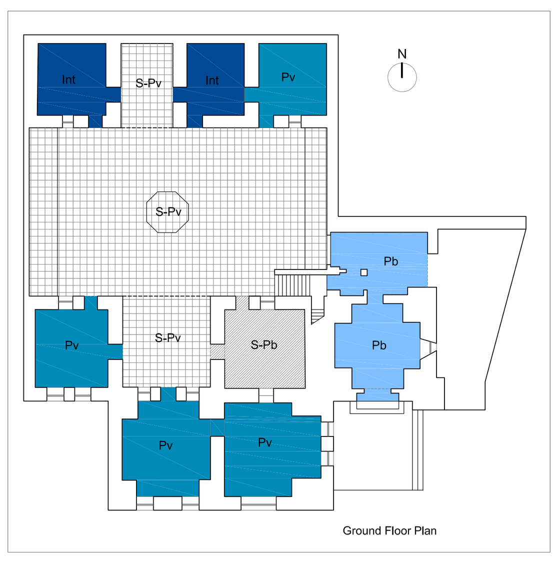
SYR-3

LEBANON

LBN-1

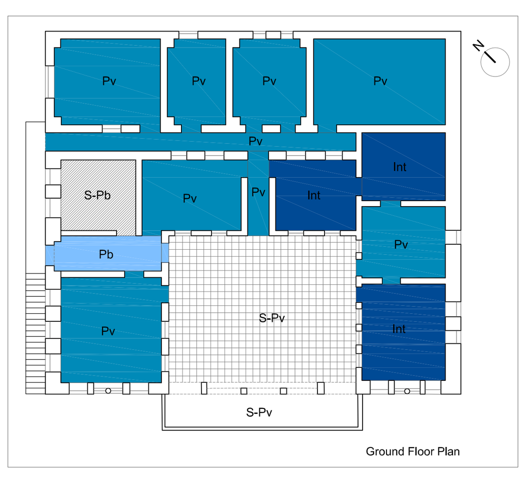


LBN-2

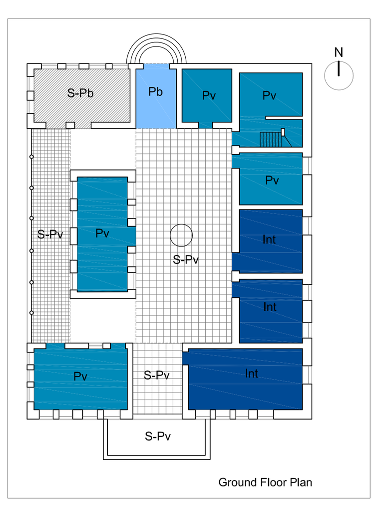


LBN-3

LBN-4



LBN-5

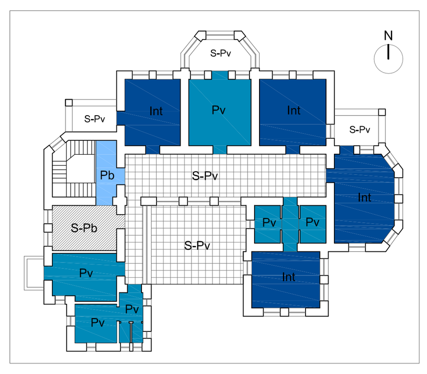


PALESTINE

PAL-1

PAL-2

PAL-3

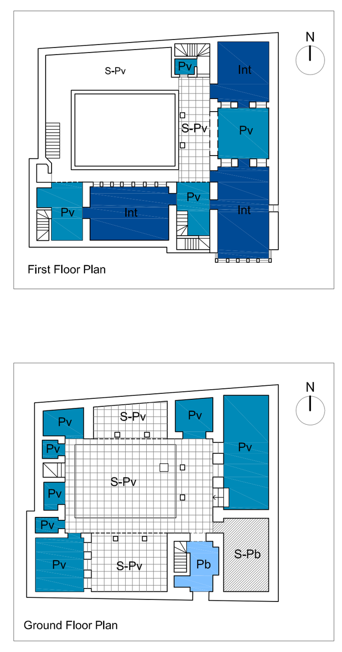


JORDAN

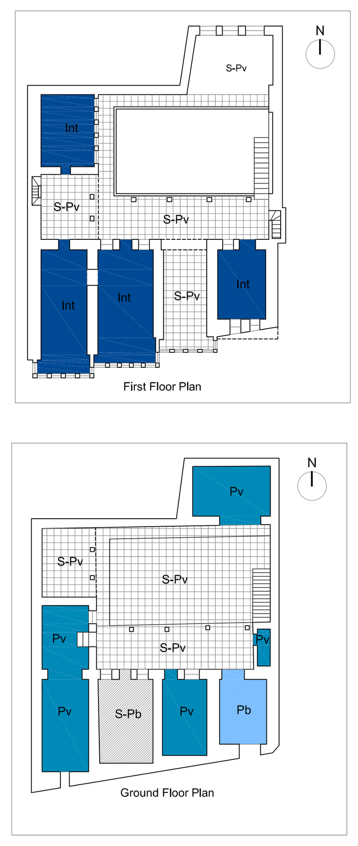
JOR-1

IRAQ

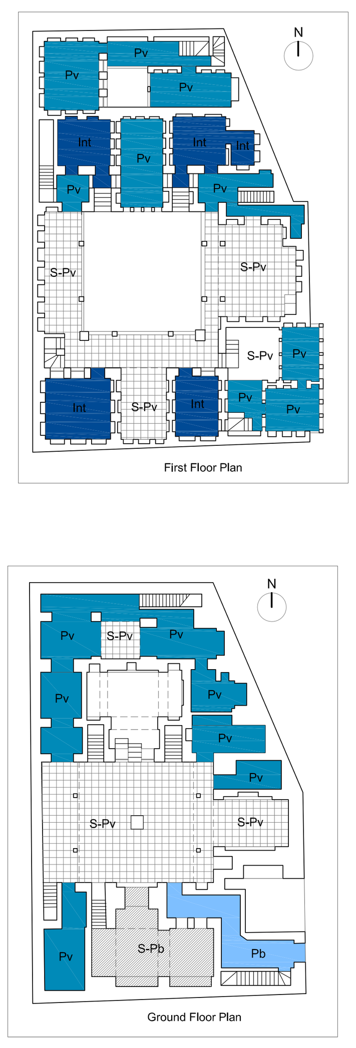
IRQ-1



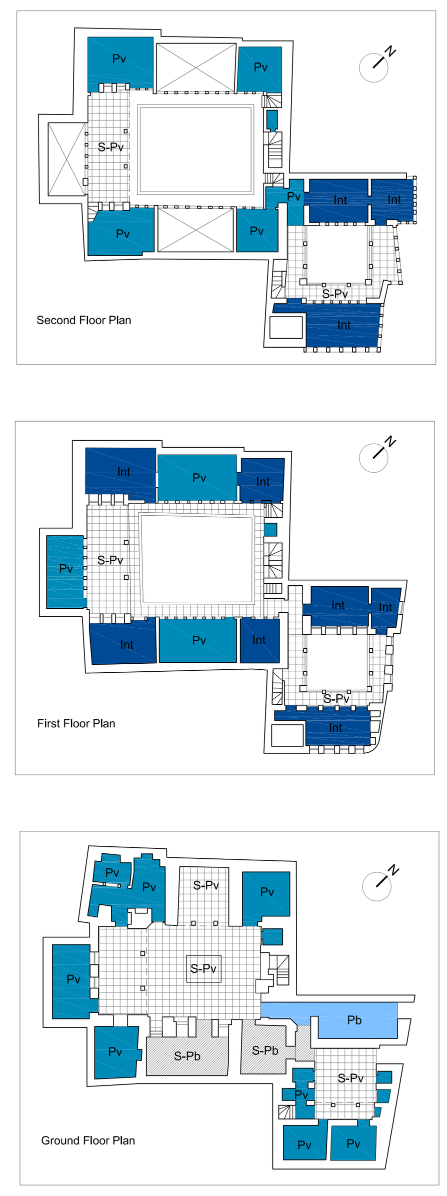
IRQ-2



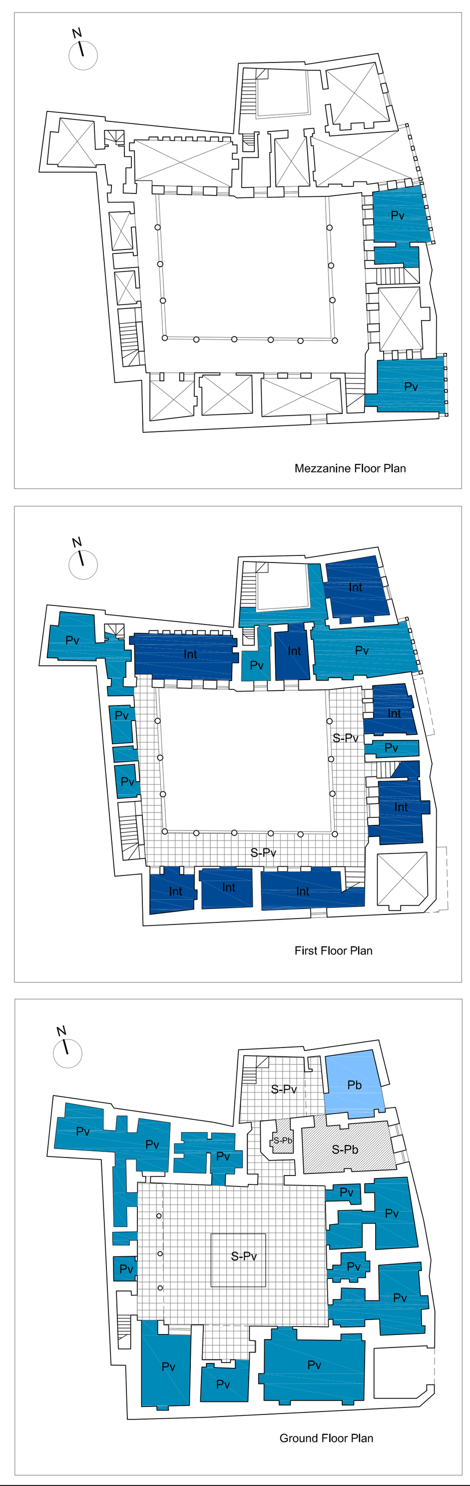
IRQ-3



IRQ-4



IRQ-5

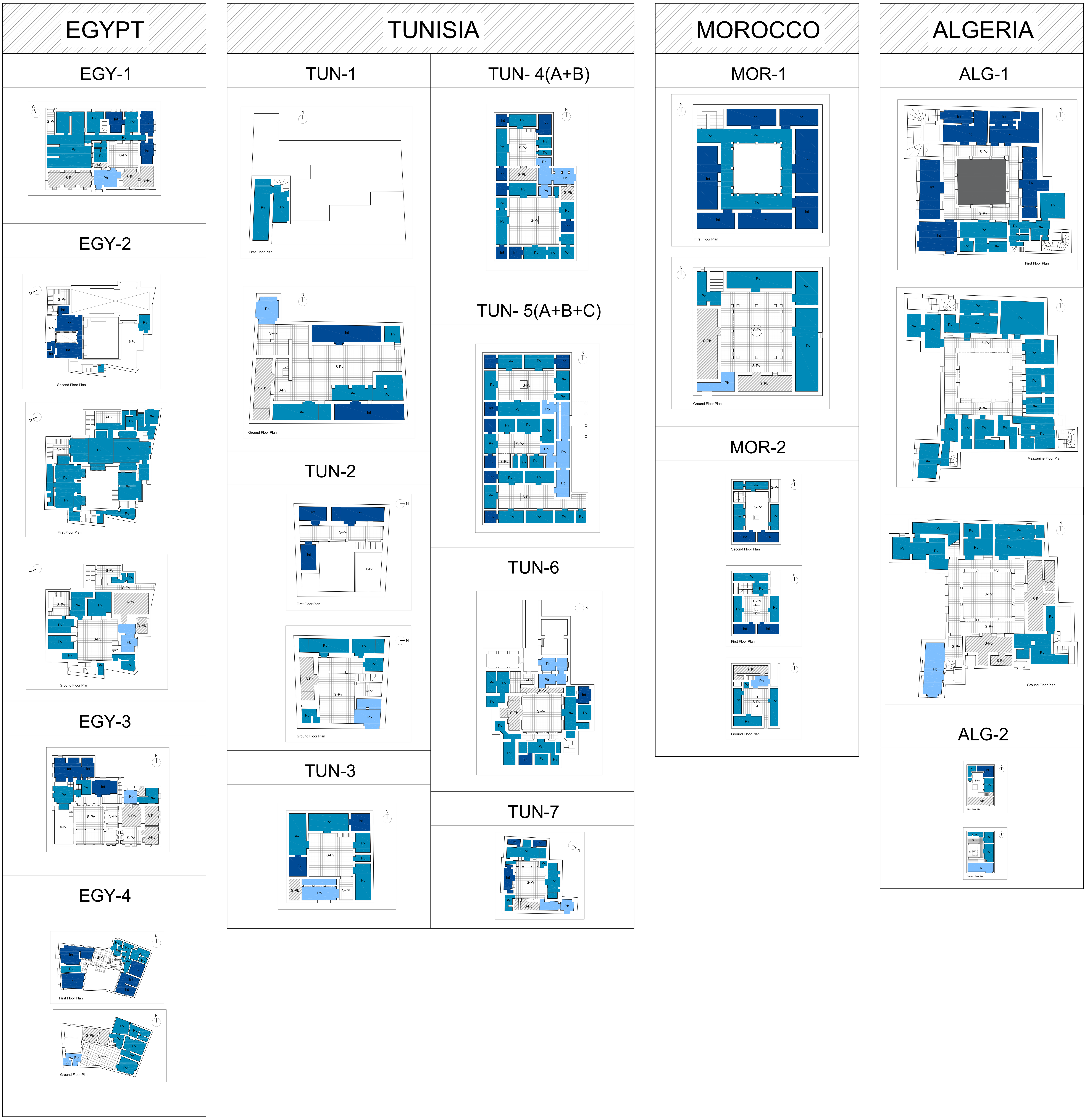


Hierarchy of Spaces

North Africa (15 cases)

Key:

- Public Spaces (Pb) (Main Entry Hall)
- Semi-Public Spaces (S-Pb) (Guest Room, Toilet for Guests)
- 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)



Hierarchy of Spaces

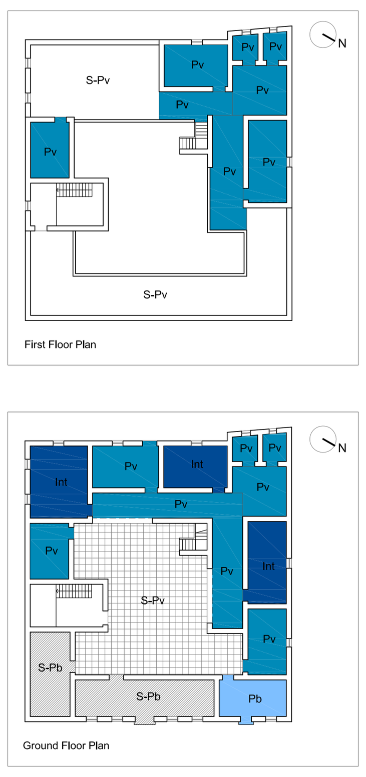
The Gulf Area (12 cases)

Key:

- Public Spaces (Pb) (Main Entry Hall)
- Semi-Public Spaces (S-Pb) (Guest Room, Toilet for Guests)
- 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)

OMAN

OMA-1

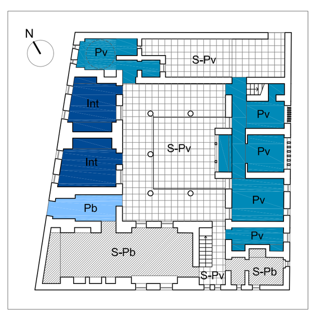


EMIRATES

UAE-1

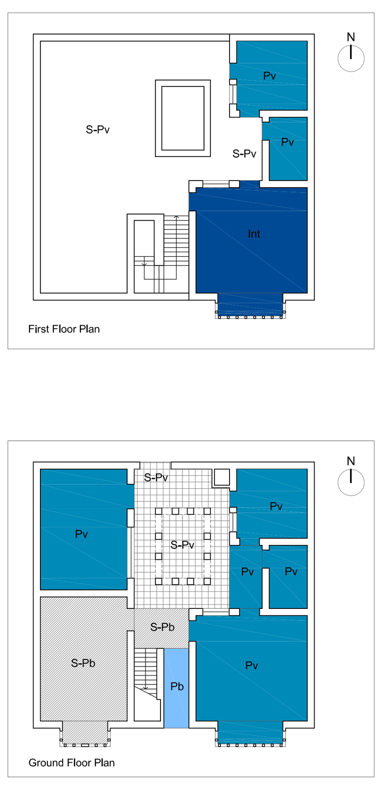
SAUDI ARABIA

KSA-1

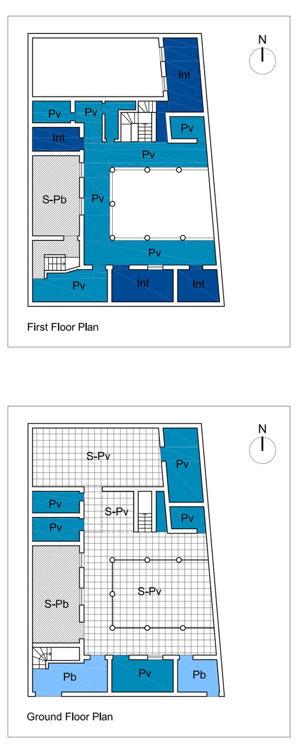


KSA-2

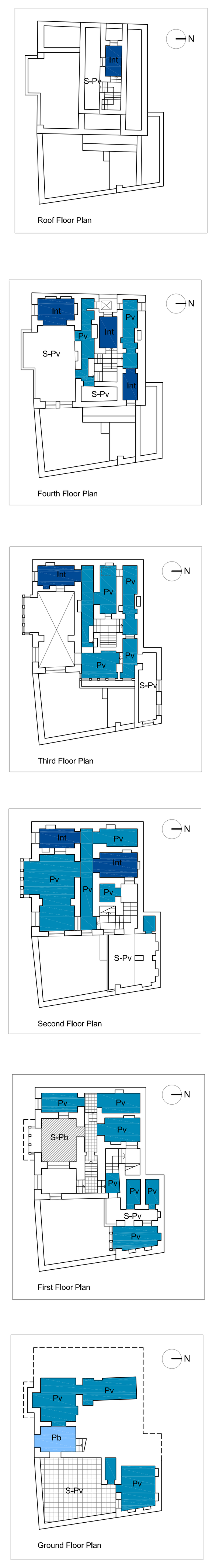
KSA-3



KSA-4

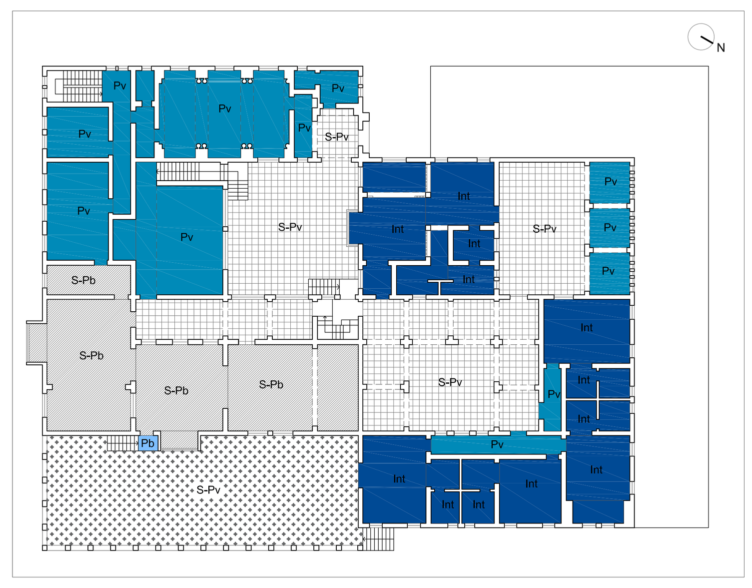


KSA-5

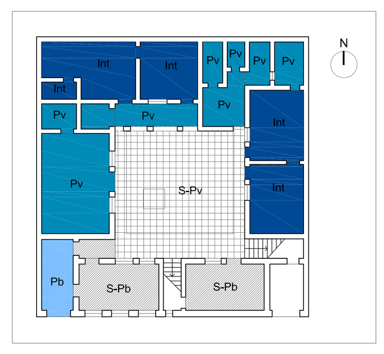


KUWAIT

KUW-1



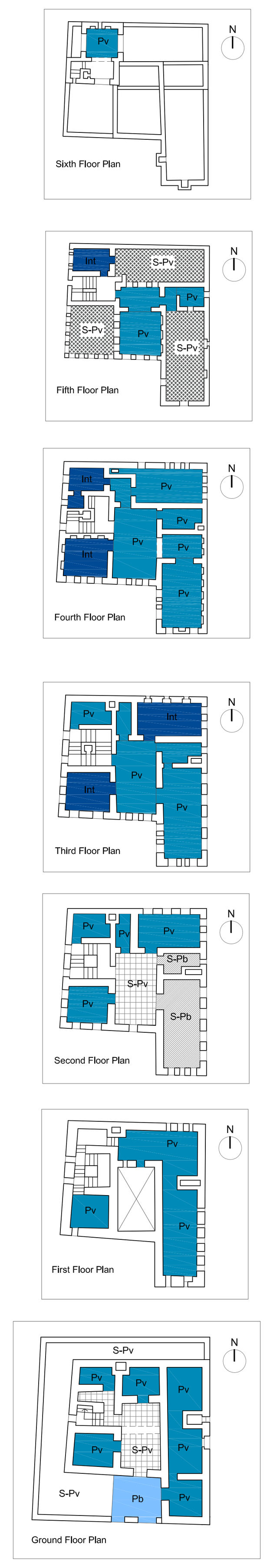
KUW-2



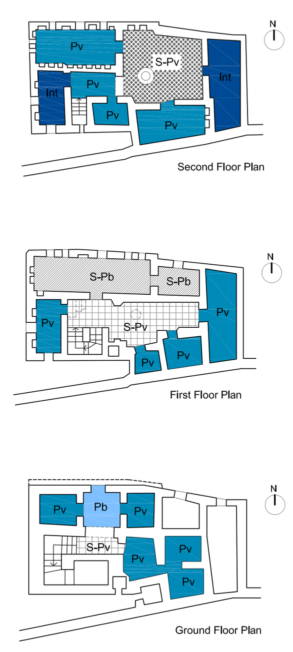
KUW-3

YEMEN

YEM-1



YEM-2

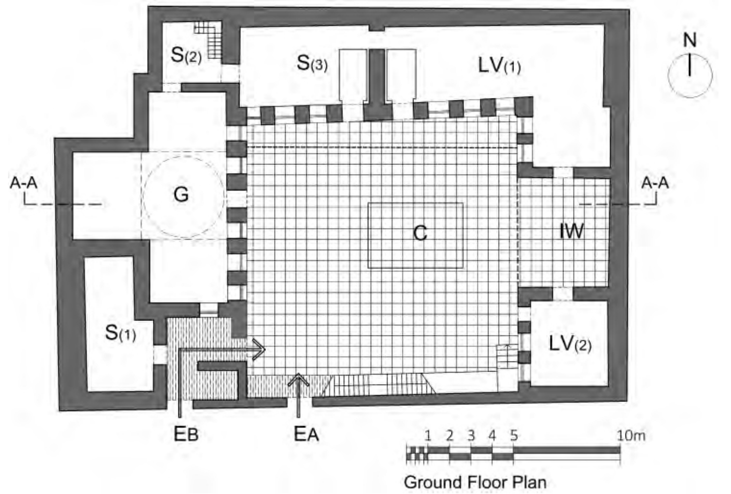


Appendix (4-B-7)

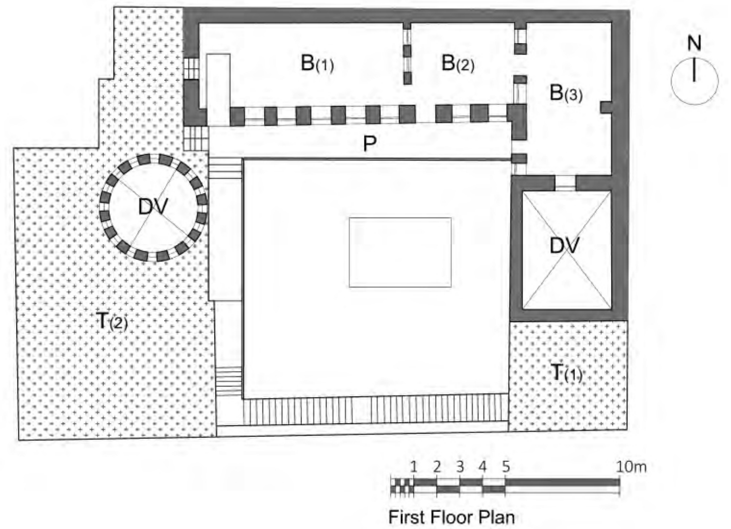
Syntactic Diagrams for the Selected Vernacular Houses

The Social Logic of the Spatial Arrangement of a Courtyard House in Aleppo, Syria	Region	Middle East	Country	Syria	Case No.	ME-S-1

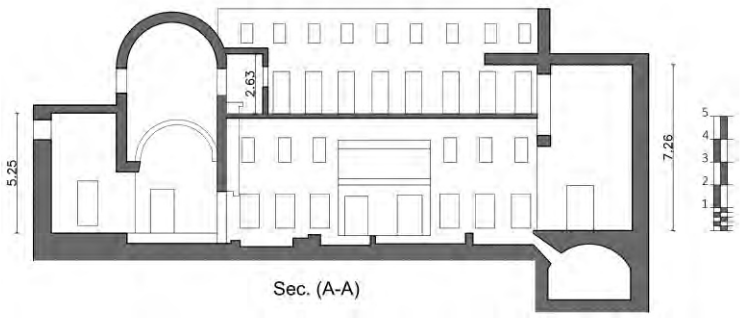
Architectural Plans for a Courtyard House, Aleppo, Syria
(Redrawn by Researcher, after (Ragette, 2016, 157))



Ground Floor Plan



First Floor Plan

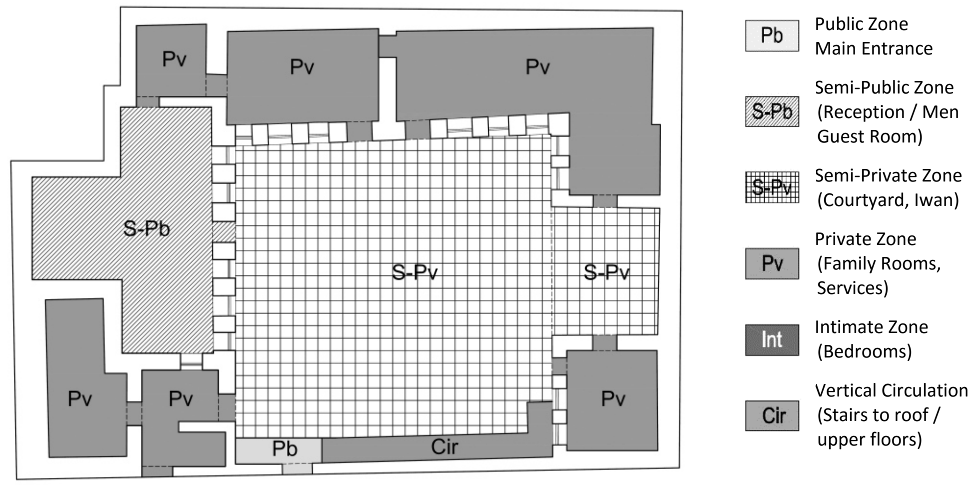


Sec. (A-A)

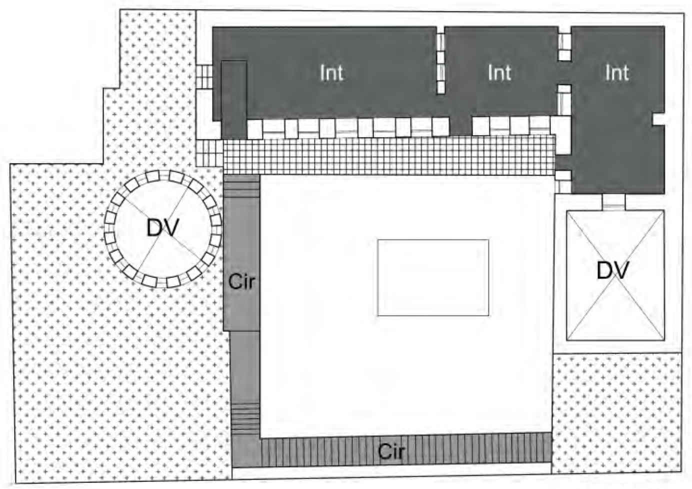
EA: Main Entrance Hall/Corridor
EB: Services Entrance
C : Courtyard
IW: Iwan
GL : Gallery
T : Roof Terrace / Balcony

G : Guest Room (Reception)
LV: Family Living Room
B : Intimate Spaces (Bedrooms)
S : Services (Kitchen, Toilets, Storage)
P : Passage / Transitional Space
DV: Double Volume

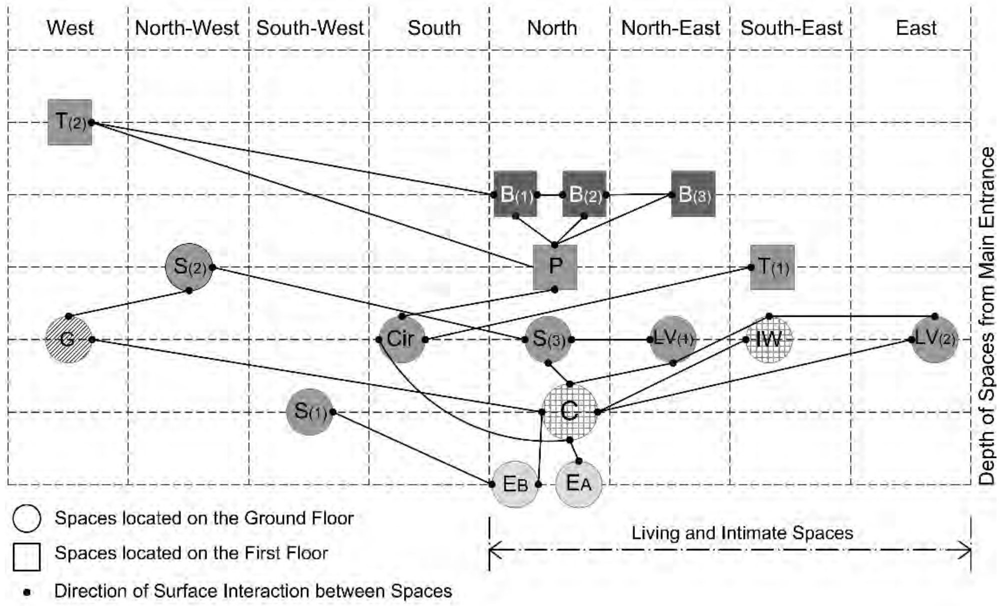
Hierarchy and Depth of Spaces
(according to the orientation, and type of spaces)
(Researcher)



Ground Floor

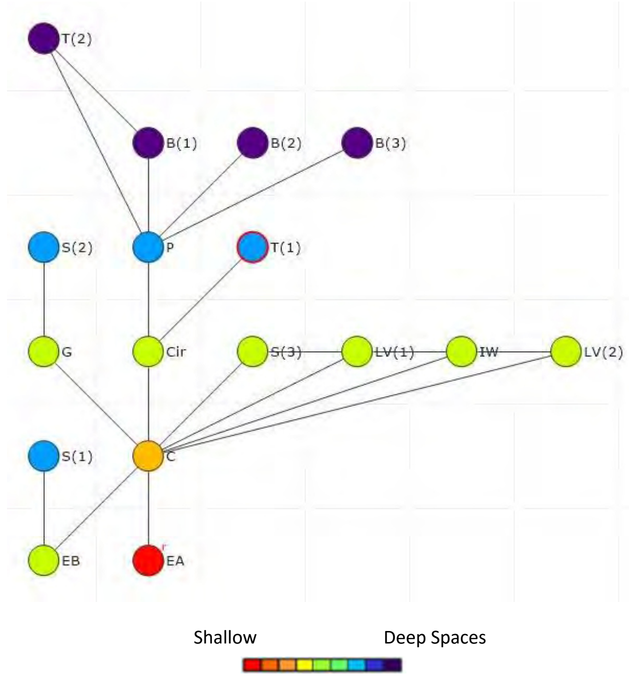


First Floor

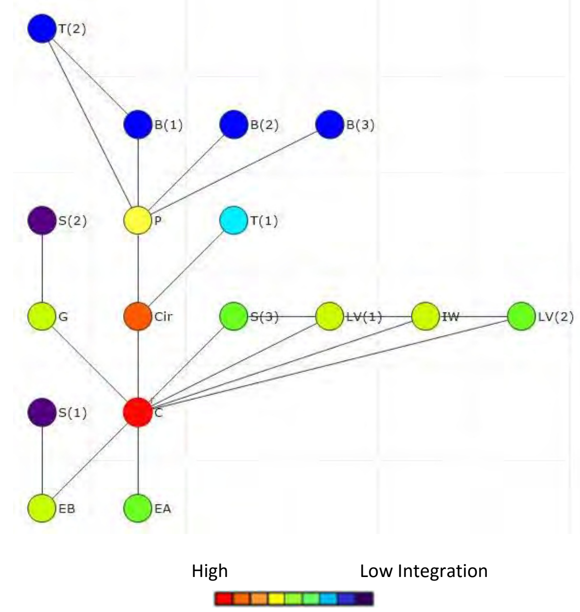


Space Syntax Analysis
Diagrams produced by Researcher using AGRAPH Online software
(https://www.ntnu.no/ab/spacesyntax)

Depth of Spaces from the Main Entrance

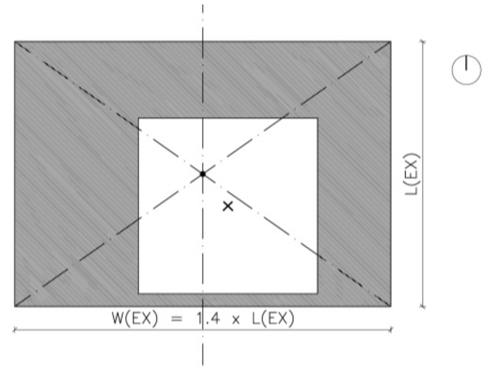


Integration of Spaces with the Courtyard
(the courtyard has the greatest control value)



The Social Logic of the Spatial Design of a Courtyard House in Aleppo, Syria	Region	Middle East	Country	Syria	Case No.	ME-S-1

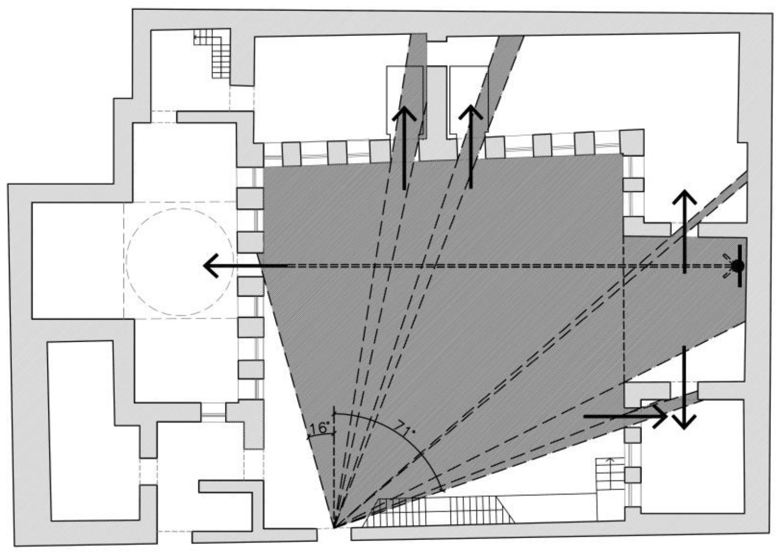
Typology and Geometric Properties of the House
(Researcher)



Typology	Recatngular layout with one courtyard adjacent to the edge of the house
Exterior layout	1: 1.4
Courtyard	1 : 1
	25 % of the total area of the house, 37% of the GF
Distance (D) between the center of the exterior layout (●) and the center of the courtyard (x)	Dx = 1/12 W(Ex) Dy = - (Dx)
Thickness of exterior walls	80 cm
Height of Guest/Living spaces on the Ground Floor	525 – 725 cm
Height of Bedrooms on the First Floor	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	1st		
Courtyard	M+F	25 %	37 %	-	1 : 1	1 : 1
Iwan	M+F	4 %	5 %	-	0.13 : 1	1 : 1.1
Terraces	M+F	23 %	-	56 %	0.90 : 1	
Guest Room	M	9 %	13 %	-	0.34 : 1	1 : 2.7 , 1 : 1.15 , 1 : 1.2
Living Rooms	M+F	9 %	13 %	-	0.36 : 1	1 : 1.1 , 1 : 3
Bedrooms	M+F	15 %	68 %	37 %	0.50 : 1	1 : 2.5 , 1 : 1.25 , 1 : 1.8
Services (kitchen and storage) (Toilets)	F M+F	8 %	12 %	-	0.32 : 1	

Visual Analysis from the Main Entrance towards inside the House
(Researcher)

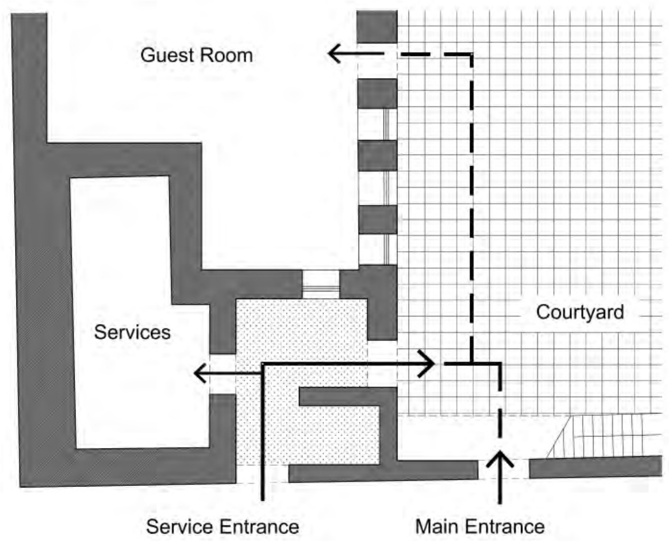


Visual access from the main entrance towards guest rooms, and from guest rooms towards living areas and intimate spaces

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 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	

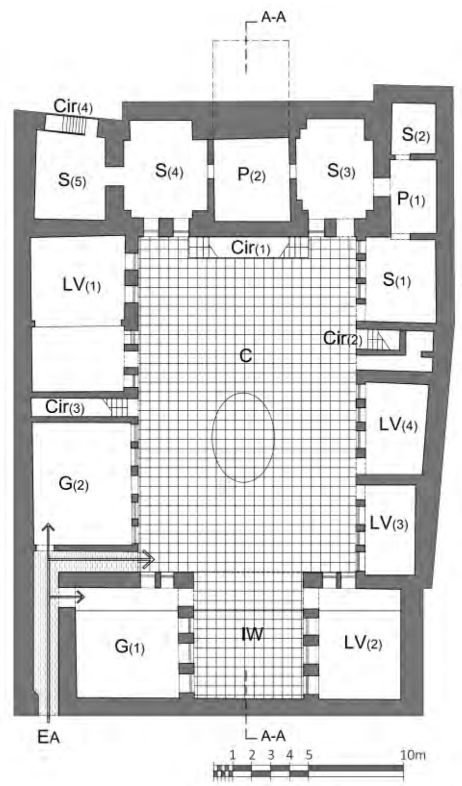
Integration Values:
Courtyard > Vertical Circulation > Entrance, Guest Room > Living Rooms, Iwan > Bedrooms > Services (Kitchen, Storage, and Toilets)

Lowest Integration Values:
- Intimate spaces (bedrooms)
- Services

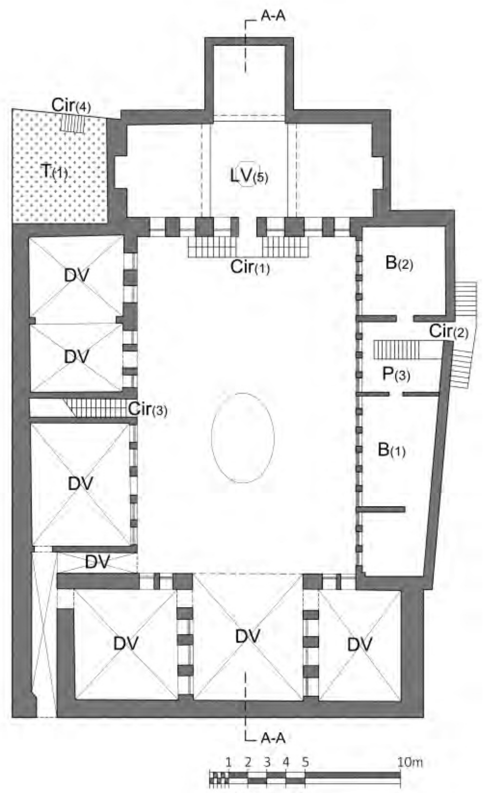
Highest Integration and Control Values:
- Courtyard
- Vertical circulation (stairs)
- Passage on the first floor

The Social Logic of the Spatial Arrangement of a Courtyard House in Damascus, Syria	Region	Middle East	Country	Syria	Case No.	ME-S-2

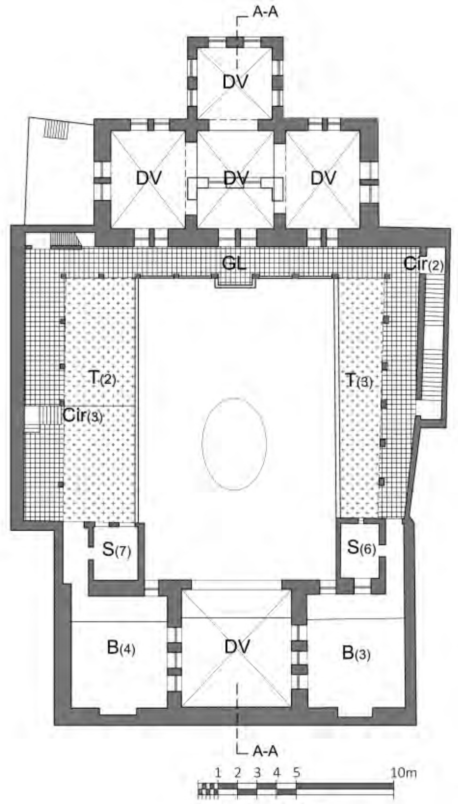
Architectural Plans for a Courtyard House, Damascus, Syria
(Redrawn by Researcher, after (Ragette, 2016, 158))



Ground Floor Plan

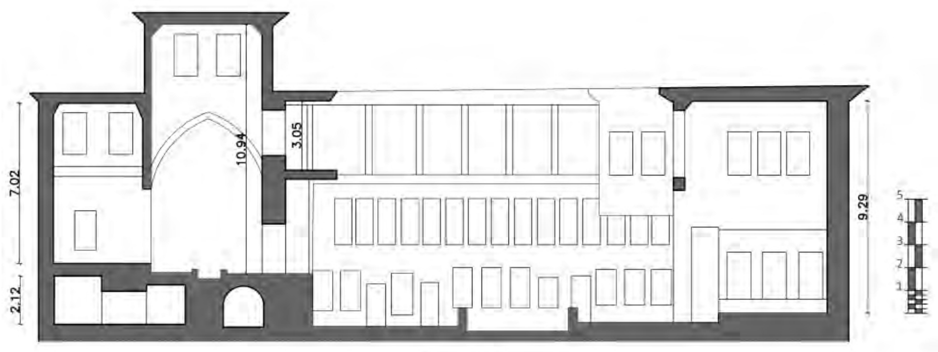


First Floor Plan



Second Floor Plan

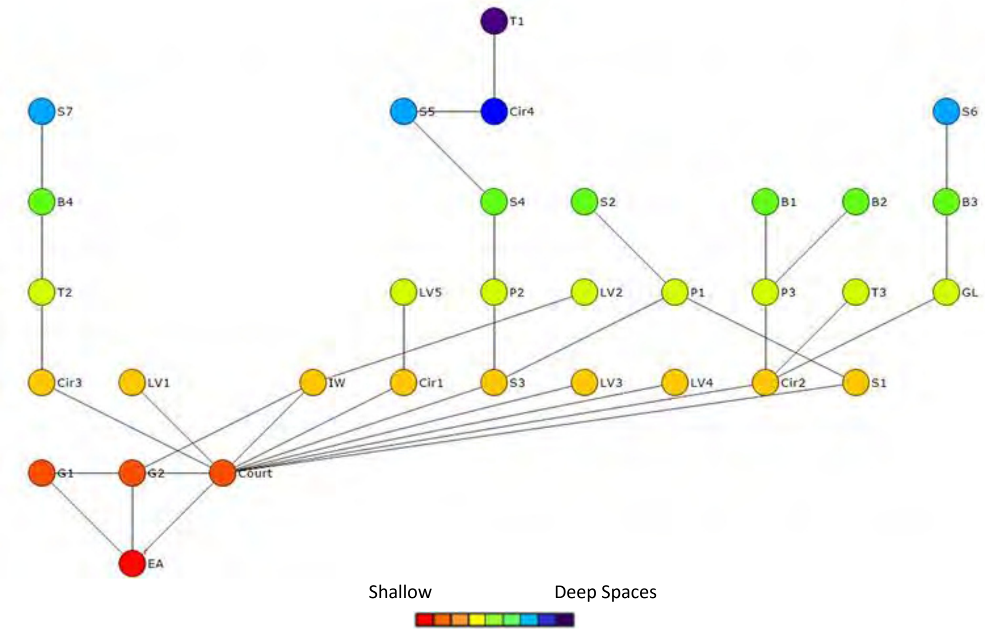
EA: Main Entrance Hall/Corridor
EB: Services Entrance
C : Courtyard
IW: Iwan
GL : Gallery
T : Roof Terrace / Balcony
G : Guest Room (Reception)
LV: Family Living Room
B : Intimate Spaces (Bedrooms)
S : Services (Kitchen, Toilets, Storage)
P : Passage / Transitional Space
DV: Double Volume



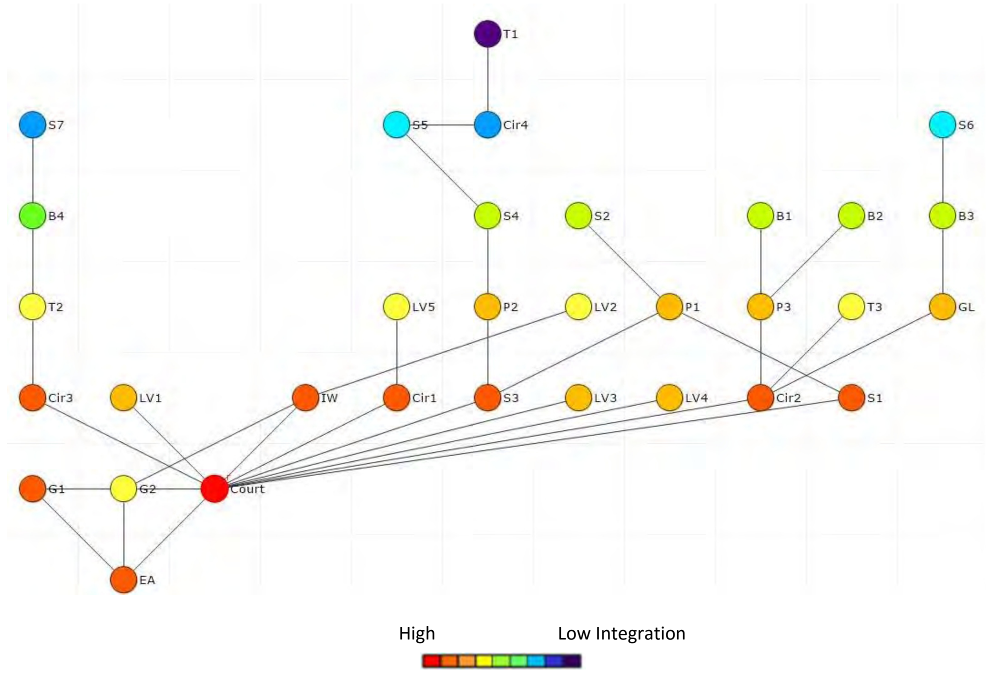
Sec. (A-A)

Space Syntax Analysis
Diagrams produced by Researcher using AGRAPH Online software
(https://www.ntnu.no/ab/spacesyntax)

Depth of Spaces from the Main Entrance

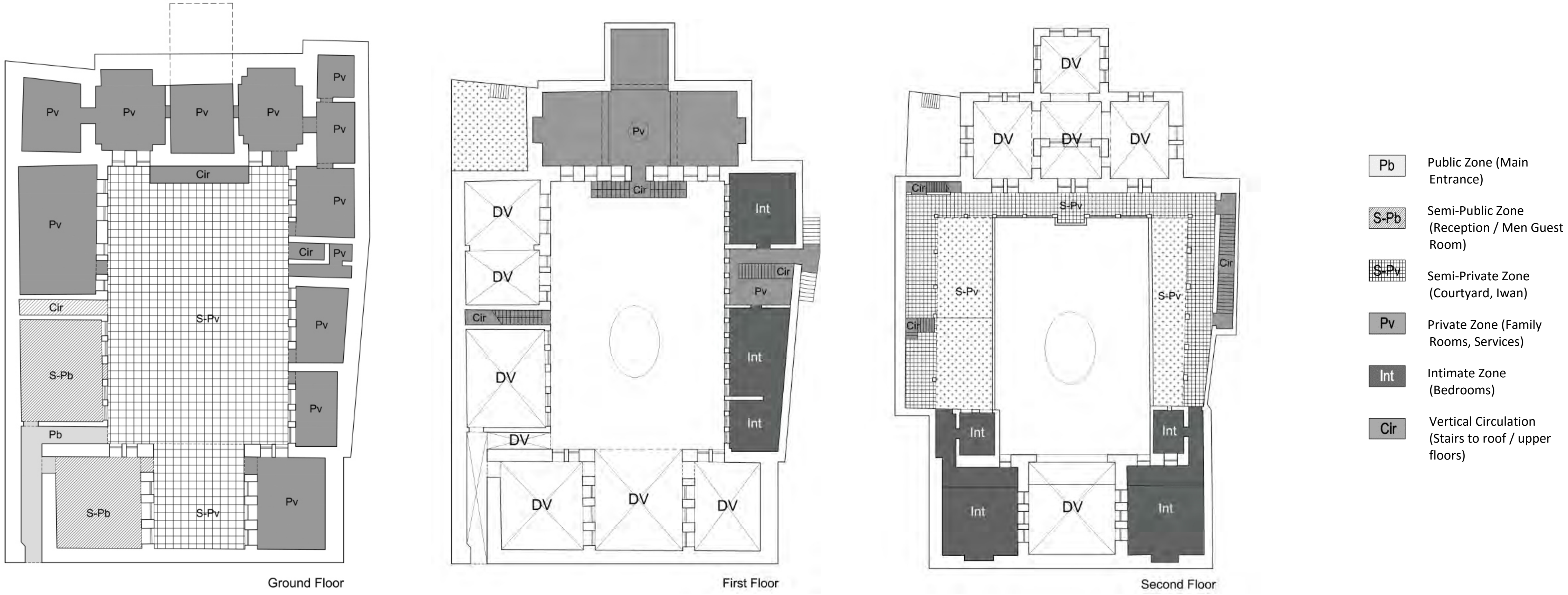


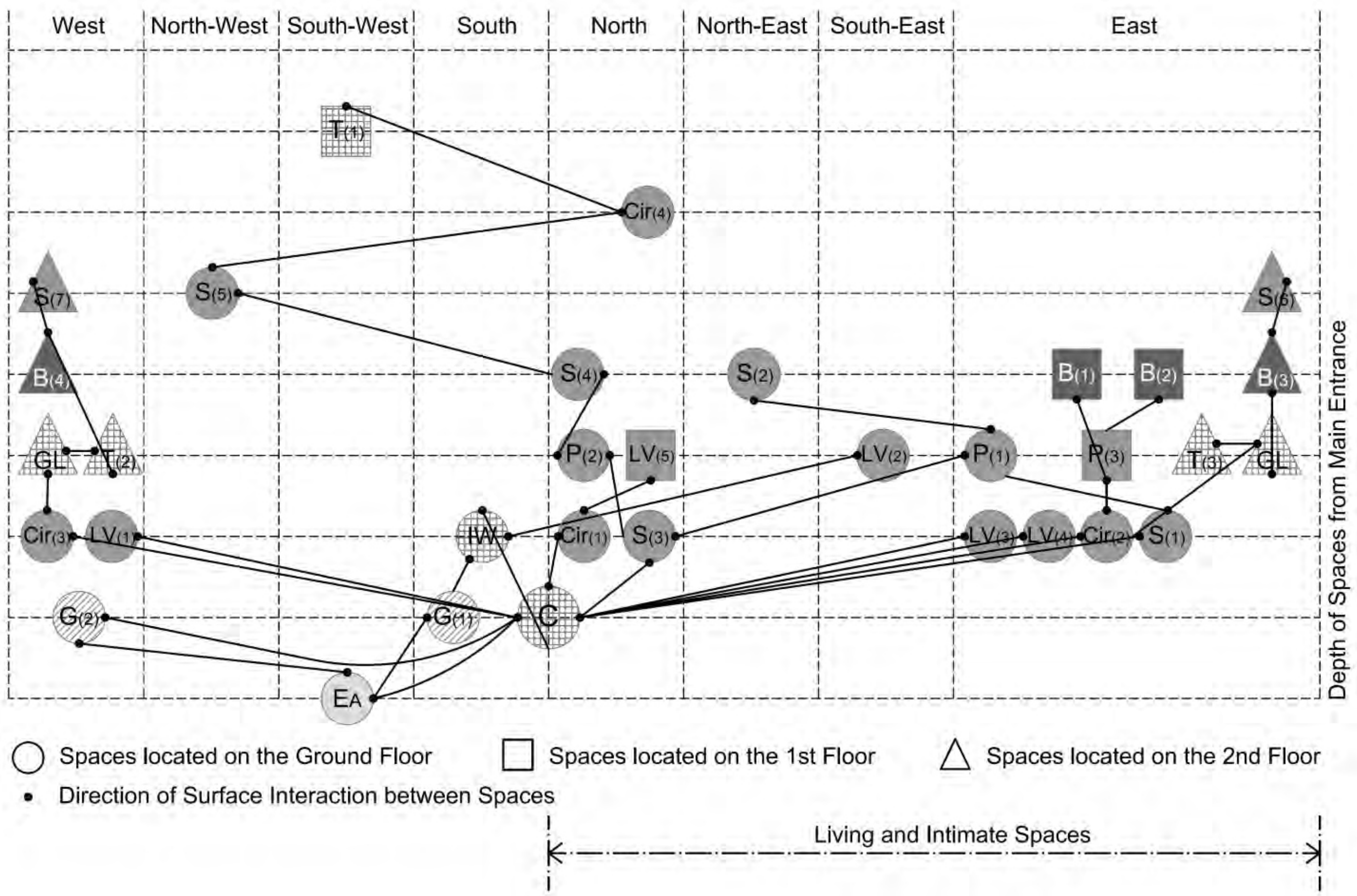
Integration of Spaces with the Courtyard
(the courtyard has the greatest control value)



The Social Logic of the Spatial Arrangement of a Courtyard House in Damascus, Syria	Region	Middle East	Country	Syria	Case No.	ME-S-2

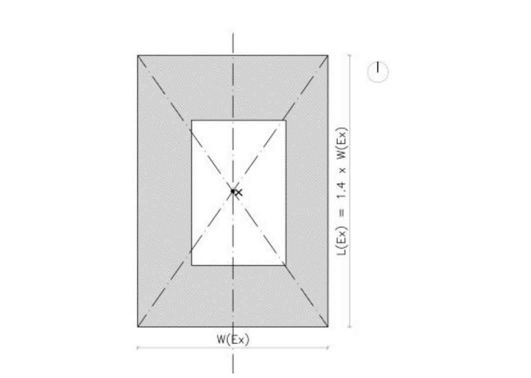
Hierarchy and Depth of Spaces (according to the orientation, and type of spaces)
(Researcher)





The Social Logic of the Spatial Design of a Courtyard House in Damascus, Syria	Region	Middle East	Country	Syria	Case No.	ME-S-2

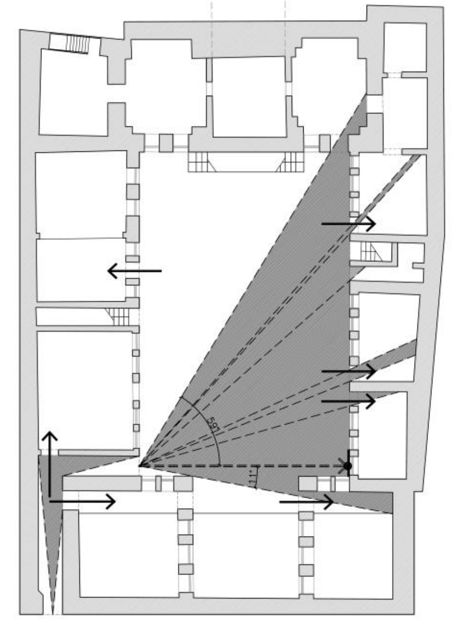
Typology and Geometric Properties of the House
(Researcher)



Typology	Recatngular layout with one courtyard at the center of the house
Exterior layout	1: 1.4
Courtyard	1 : 1.55
	17 % of the total area of the house, 33 % of the GF
Distance (D) between the center of the exterior layout (●) and the center of the courtyard (x)	Center of the Courtyard ≈ Center of the House
Thickness of exterior walls	80 cm
Height of Guest/Living spaces on the Ground Floor	415 cm
Height of Bedrooms on the First Floor	305 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
			G	1st	2nd		
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 M+F	10 %	17 %	9 %	5 %	0.60 : 1	

Visual analysis from the main entrance towards guest rooms and private/intimate spaces (Researcher)

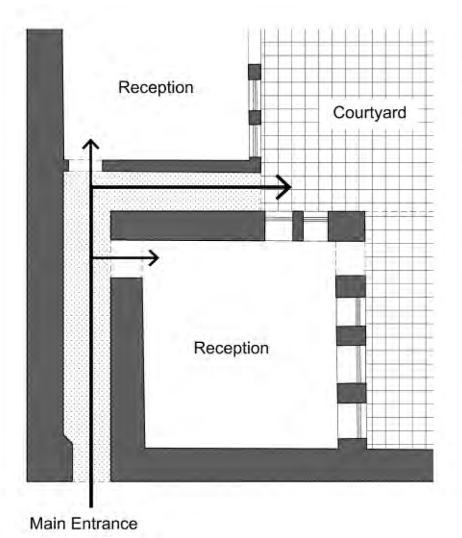


Visual access from the main entrance towards guest rooms, and from guest rooms towards living areas and intimate spaces

⟵ 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 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	

Integration Values:
Courtyard > Vertical Circulation, Service > Entrance > Living Rooms, Iwan > , Guest Room > Bedrooms > Services (Kitchen, Storage, and Toilets) > Terraces

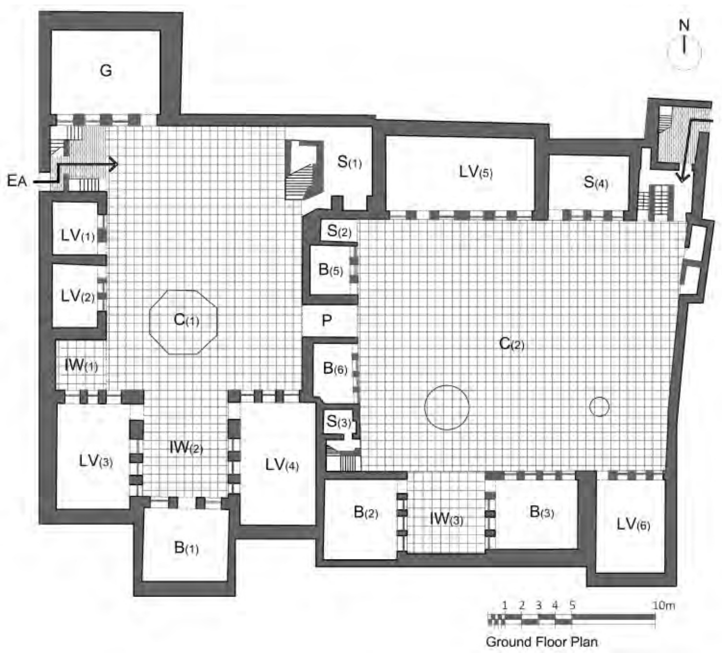
Lowest Integration Values:
- Terraces
- Intimate spaces (bedrooms), and services

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))



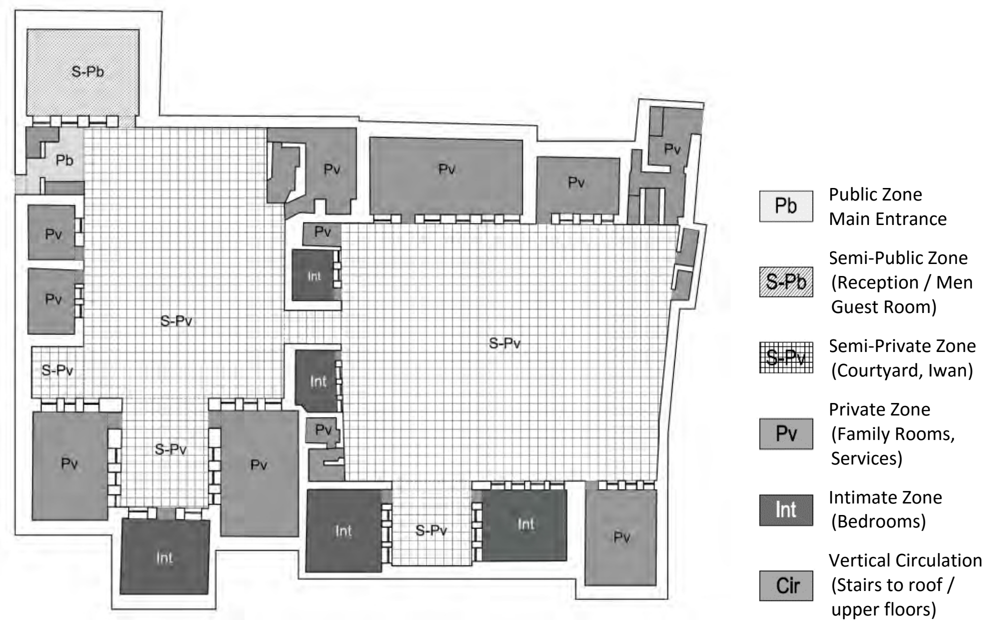
EA: Main Entrance Hall/Corridor
EB: Services Entrance
C : Courtyard
IW: Iwan
GL : Gallery
T : Roof Terrace / Balcony

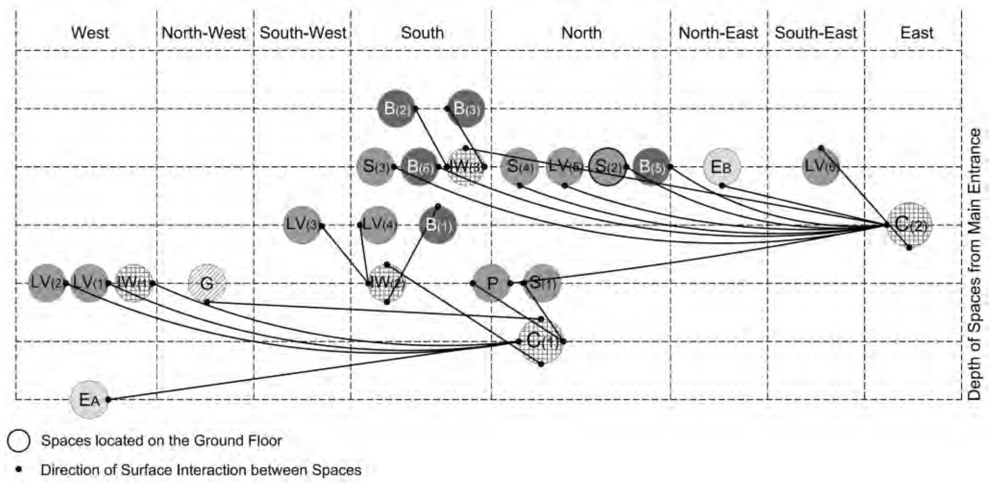
G : Guest Room (Reception)
LV: Family Living Room
B : Intimate Spaces (Bedrooms)
S : Services (Kitchen, Toilets, Storage)
P : Passage / Transitional Space
DV: Double Volume

Hierarchy and Depth of Spaces

(according to the orientation, and type of spaces)

(Researcher)



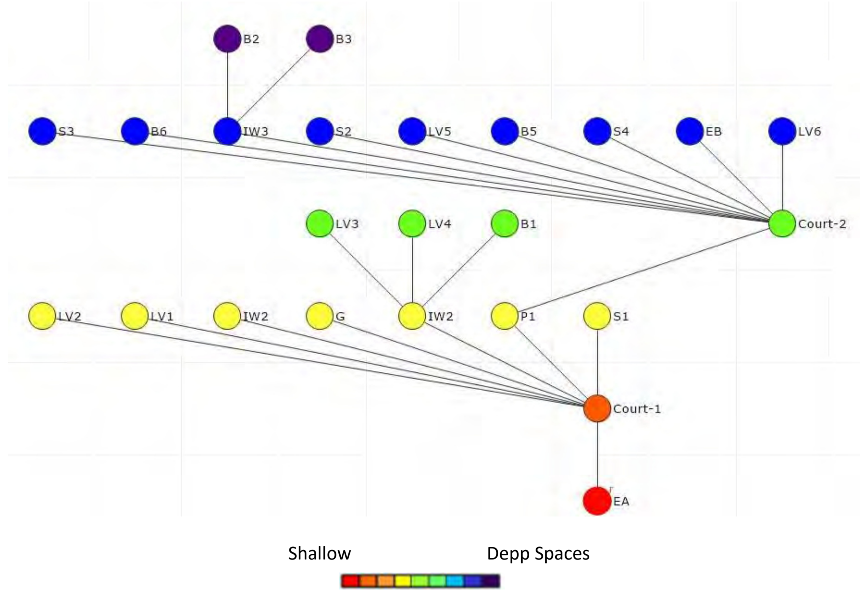


Space Syntax Analysis

Diagrams produced by Researcher using AGRAPH Online software

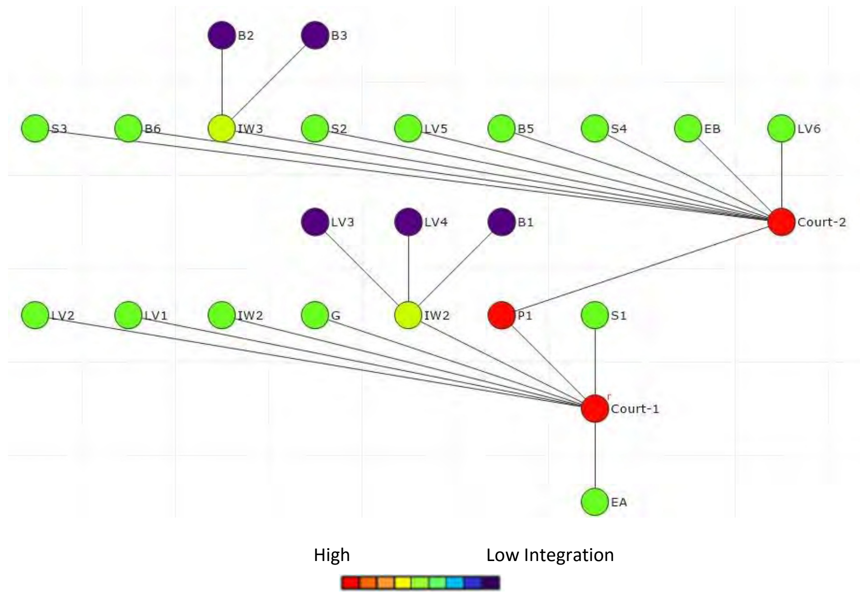
(https://www.ntnu.no/ab/spacesyntax)

Depth of Spaces from the Main Entrance



Integration of Spaces with Courtyards

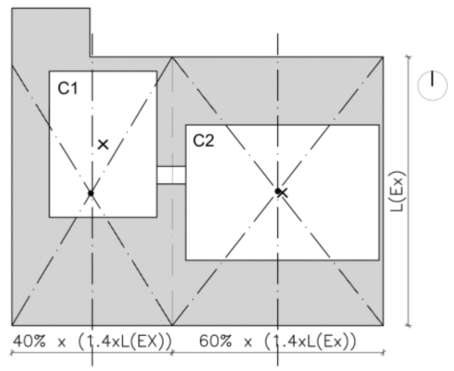
(the courtyard has the greatest control value)



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)

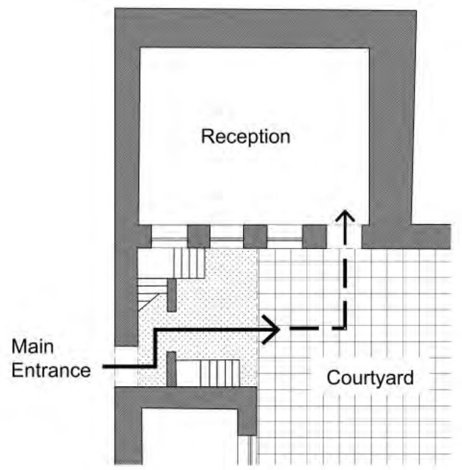


Typology	Recatngular layout with two courtyards, both are adjacant to the edge of the house
Exterior layout	1: 1.4 (for the overall exterior layout) Zone(1): W(Ex1) = 40% x (1.4 x L(Ex)) Zone(2): W(Ex2) = 60% x (1.4 x L(Ex))
Courtyard	C1: 1 : 1.35 , C2: 1 : 1.25 39 % of the total area of the house (C1: 37% of Zone (1), C2: 46% of Zone (2))
Distance (D) between the center of the exterior layout (●) and the center of the courtyard C1 (x)	Dx1 = 1/15 x W(Ex1) Dy1 = 5 x W(Ex1))
Distance (D) between the center of the exterior layout (●) and the center of the courtyard C2 (x)	Center of Courtyard C2 ≈ Center of Zone (2) Dx2 = 0 , Dy2 = 0
Thickness of exterior walls	55 cm
Height of Ceiling	

	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
Courtyards	M+F	48 %	47 %	48 %	1 : 1	1 : 1	(C1) 1 : 1.35 , (C2) 1 : 1.25
Iwan	M+F	7 %	11 %	10 %	0.23 : 1	0.07 : 1	1 : 1 , 1 : 1.25
Guest Room	M	4 %	8 %	-	0.18 : 1	-	1 : 1.30
Living Rooms	M+F	15 %	20 %	11 %	0.43 : 1	0.23 : 1	1 : 1.4 , 1 : 1.35 , 1 : 2.25
Bedrooms	M+F	9 %	6 %	10 %	0.13 : 1	0.21 : 1	1 : 1.15 , 1 : 1
Services (kitchen and storage) (Toilets)	F M+F	5 %	6 %	4 %	0.12 : 1	0.08 : 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 use of 'bent entrance', with an entry hall located near the reception room for guests

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
Court-1	51	2.21	0.11	9.03	6.75	8.00
S1	73	3.17	0.19	5.06	0.12	1.00
P1	49	2.13	0.10	9.73	0.22	2.00
IW2	67	2.91	0.17	5.75	3.12	4.00
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	3.83	0.25	1.00
B1	89	3.86	0.26	3.83	0.25	1.00
Court-2	49	2.13	0.10	9.73	8.83	10.00
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
IW3	67	2.91	0.17	5.75	2.10	3.00
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	3.83	0.33	1.00
B3	89	3.86	0.26	3.83	0.33	1.00
Min	49.00	2.13	0.10	3.83	0.10	
Mean	**72.25**	**3.14**	**0.19**	**5.48**	**1.00**	
Max	89.00	3.86	0.26	9.73	8.83	

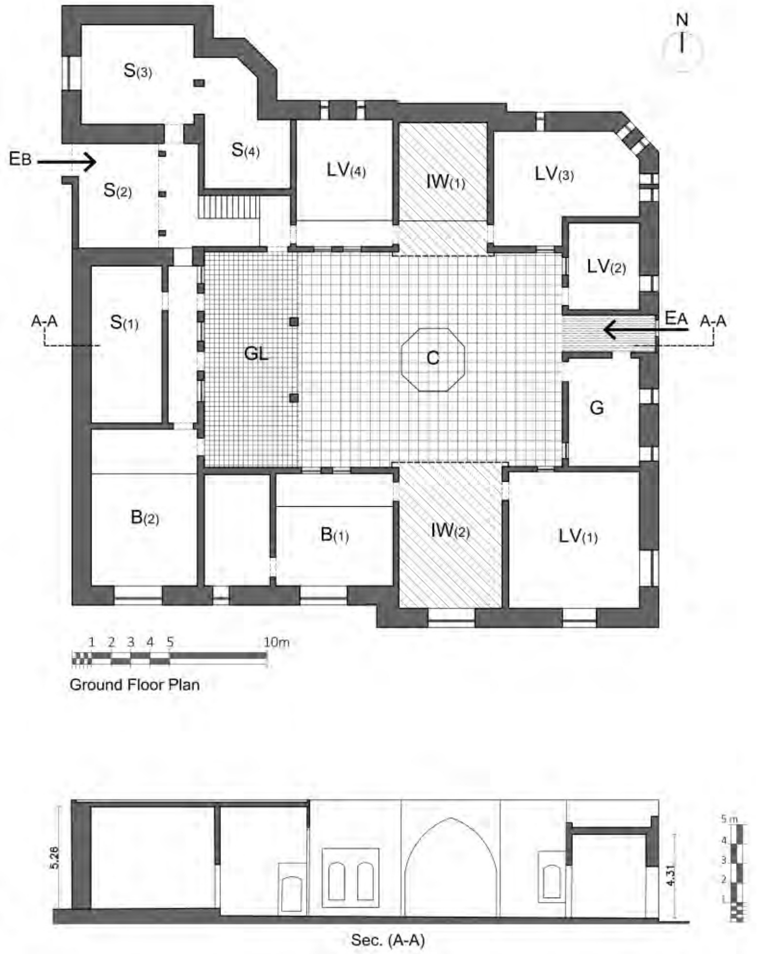
Integration Values:
Courtyard-2 > Courtyard-1 > Iwan > Entrance, Guest Room, Living Rooms, Services > Bedrooms

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

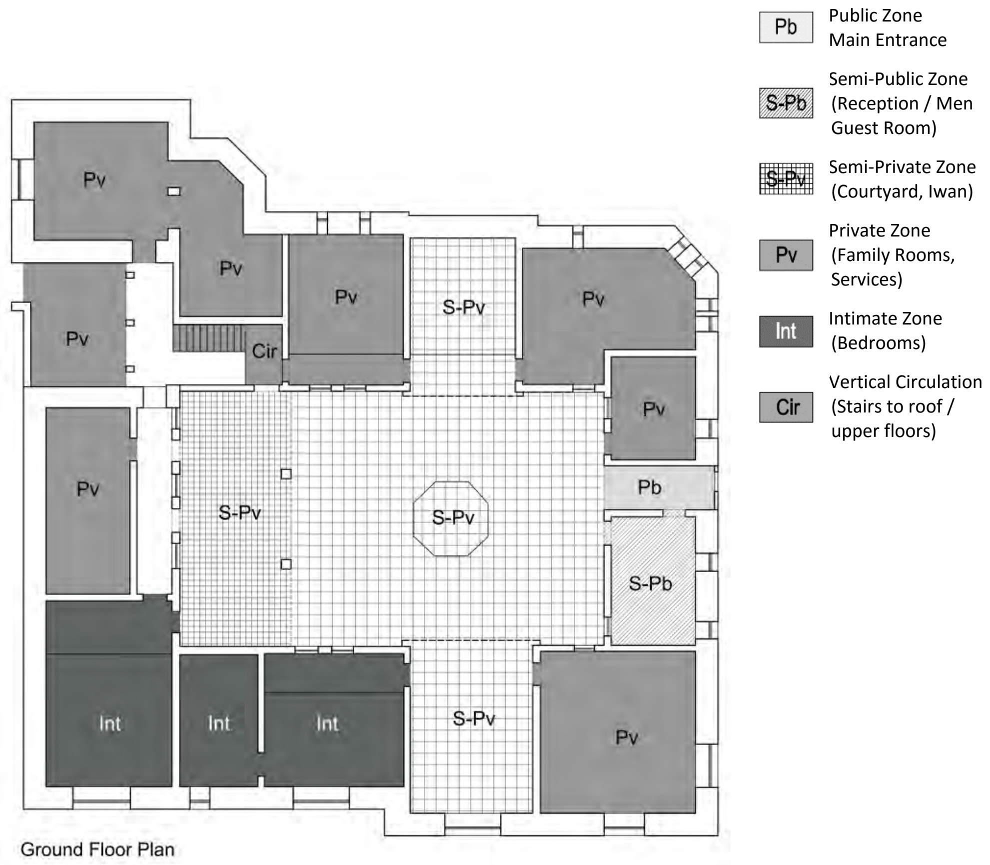
The Social Logic of the Spatial Arrangement of a Courtyard House in Lebanon	Region	Middle East	Country	Lebanon	Case No.	ME-L-1

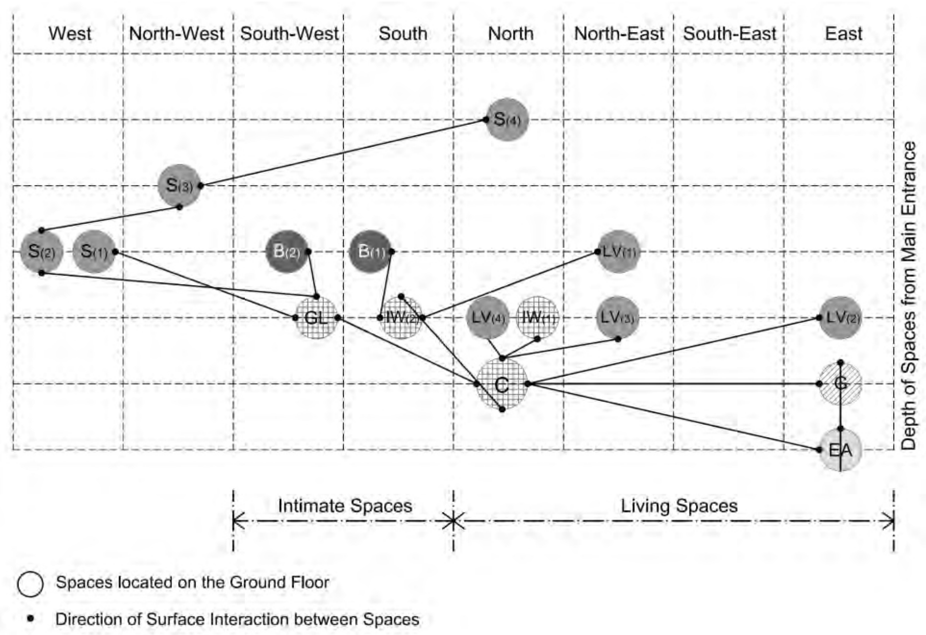
Architectural Plans for a Courtyard House, Lebanon (Redrawn by Researcher, after (Ragette, 2016, 171))	Hierarchy and Depth of Spaces (according to the orientation, and type of spaces) (Researcher)	Space Syntax Analysis Diagrams produced by Researcher using AGRAPH Online software (https://www.ntnu.no/ab/spacesyntax)

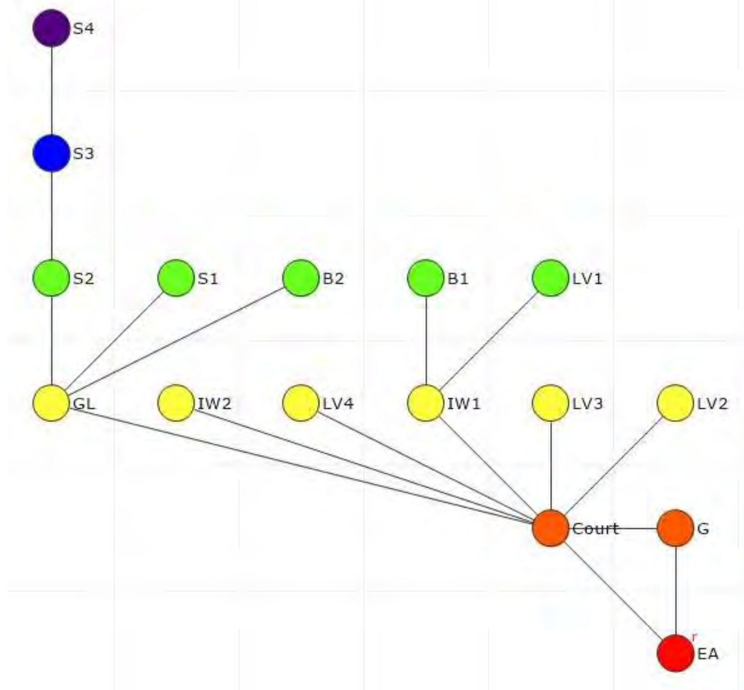


EA: Main Entrance Hall/Corridor
EB: Services Entrance
C : Courtyard
IW: Iwan
GL : Gallery
T : Roof Terrace / Balcony

G : Guest Room (Reception)
LV: Family Living Room
B : Intimate Spaces (Bedrooms)
S : Services (Kitchen, Toilets, Storage)
P : Passage / Transitional Space
DV: Double Volume

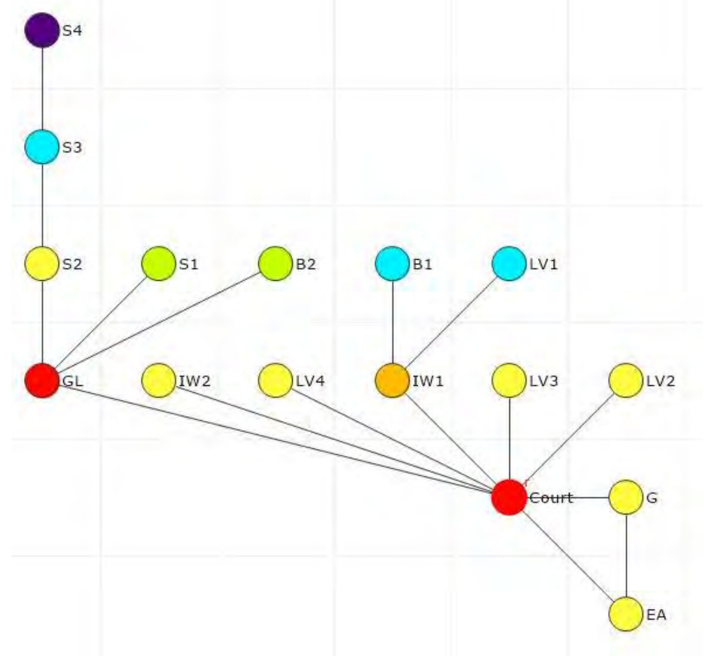






Depth of Spaces from the Main Entrance

Shallow Deep Spaces

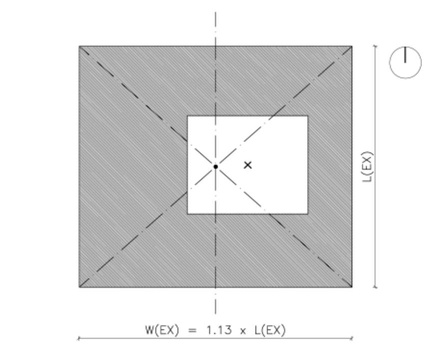


Integration of Spaces with the Courtyard
(the courtyard has the greatest control value)

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-1

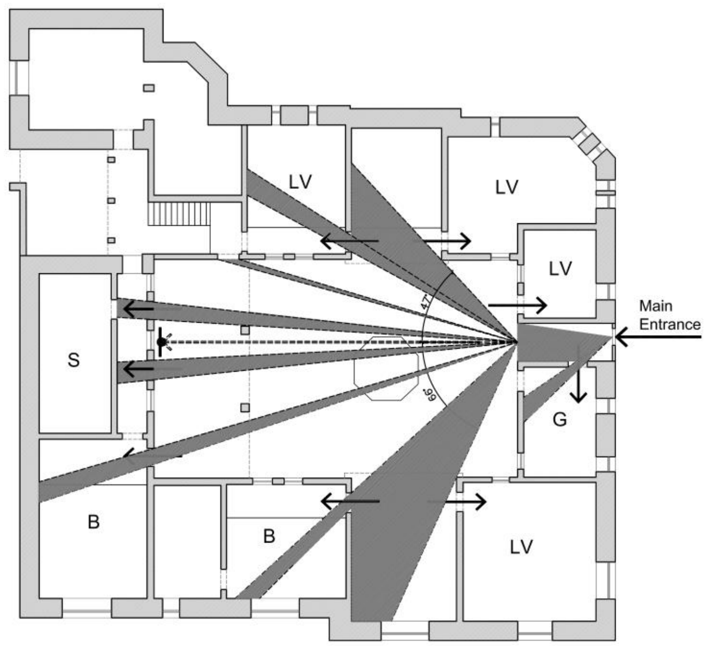
Typology and Geometric Properties of the House
(Researcher)



Typology	Recatngular layout with one courtyard at the center of the house
Exterior layout	1: 1.13
Courtyard	1 : 1.25 21 % of the total area of the house
Distance (D) between the center of the exterior layout (●) and the center of the courtyard (x)	Dx = 1/8 W(Ex) Dy = 0
Thickness of exterior walls	95 cm
Height of spaces located on the ground floor	430 – 530 cm

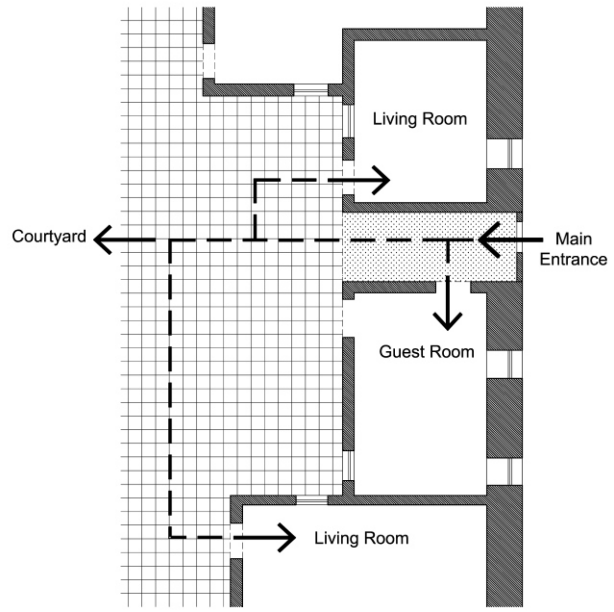
	Dominant Users (Male / Female)	Percentage of area of this space related to the total area of the house	Percentage of area of this space related to the floor area where it is located	Proportion of the area of this space, to the area of the courtyard	Proportion of Spaces
Courtyard	M+F	21 %	21 %	1 : 1	1 : 1.25
Iwan	M+F	9 %	9 %	0.42 : 1	1 : 1.1 , 1 : 1.35
Gallery	M+F	7 %	7 %	0.35 : 1	
Guest Room	M	3 %	3 %	0.14 : 1	1 : 1.5
Living Rooms	M+F	18 %	18 %	0.85 : 1	1 : 1.05 , 1 : 1.70 , 1 : 1.25
Bedrooms	M+F	14 %	14 %	0.65 : 1	1 : 1.5 , 1 : 1.05
Services (kitchen and storage) (Toilets)	F M+F	15 %	15 %	0.72 : 1	

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 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	38	2.53	0.21	4.56	0.62	2.00
G	38	2.53	0.21	4.56	0.62	2.00
Court	25	1.66	0.09	10.50	5.58	8.00
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
GL	29	1.93	0.13	7.50	2.62	4.00
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
Min	25.00	1.66	0.09	2.10	0.12	
Mean	**41.25**	**2.75**	**0.25**	**4.55**	**1.00**	
Max	65.00	4.33	0.47	10.50	5.58	

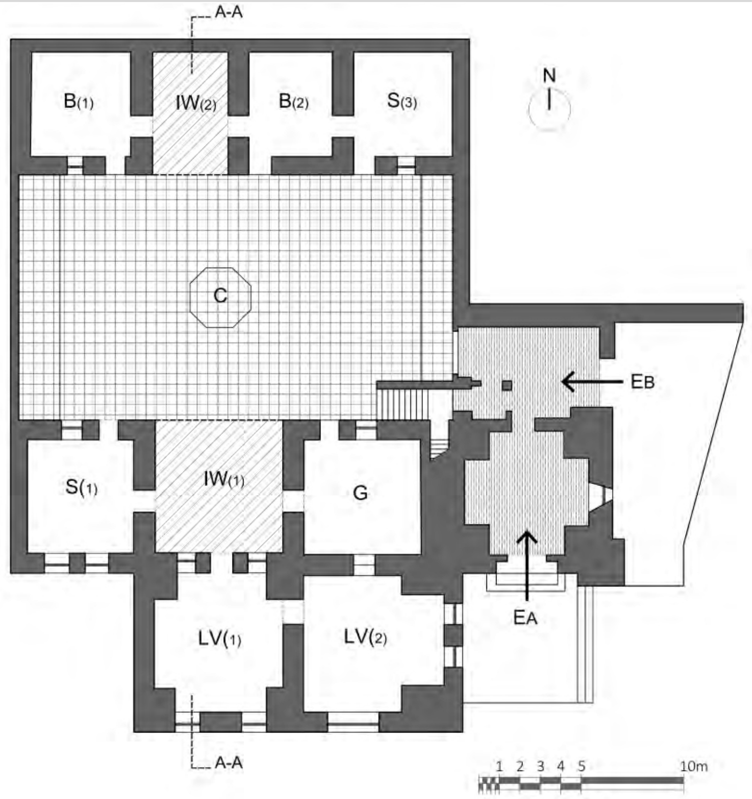
Integration Values:
Courtyard > Gallery > Iwan > Entrance, Guest Room > Living Rooms > Bedrooms > Services (Kitchen, Storage, and Toilets)

Lowest Integration Values:
- Intimate spaces (bedrooms)
- Services

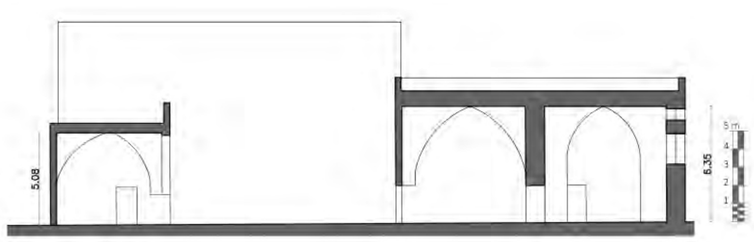
Highest Integration and Control Values:
- Courtyard
- Gallery
- Iwan

The Social Logic of the Spatial Arrangement of a Courtyard House in Lebanon	Region	Middle East	Country	Lebanon	Case No.	ME-L-2

Architectural Plans for a Courtyard House, Lebanon
(Redrawn by Researcher, after (Ragette, 2016, 172))



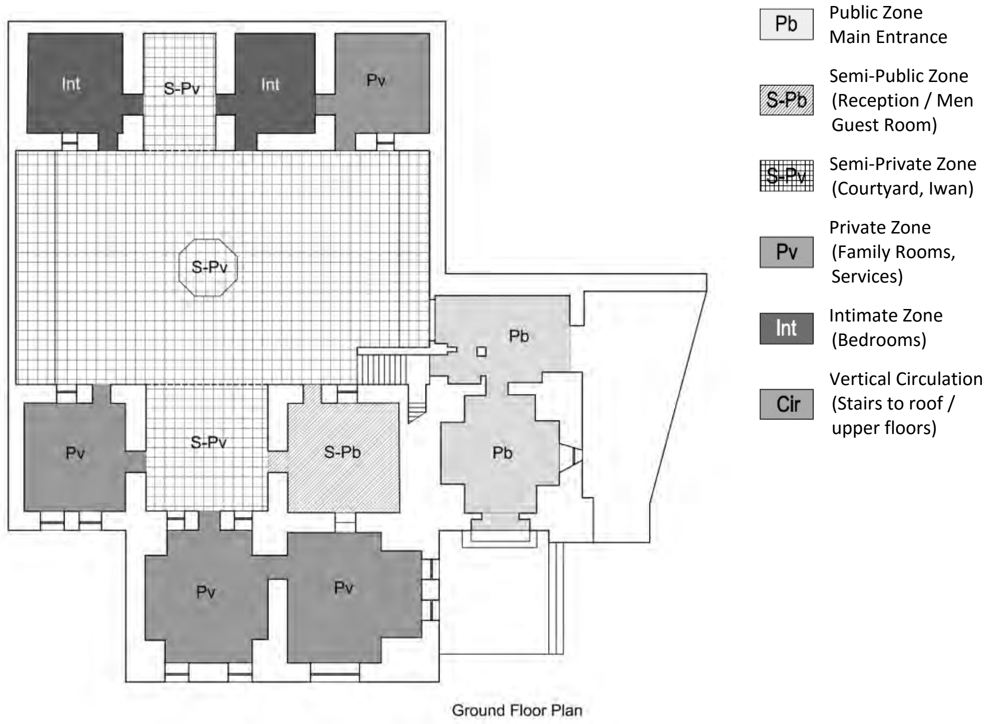
Ground Floor Plan

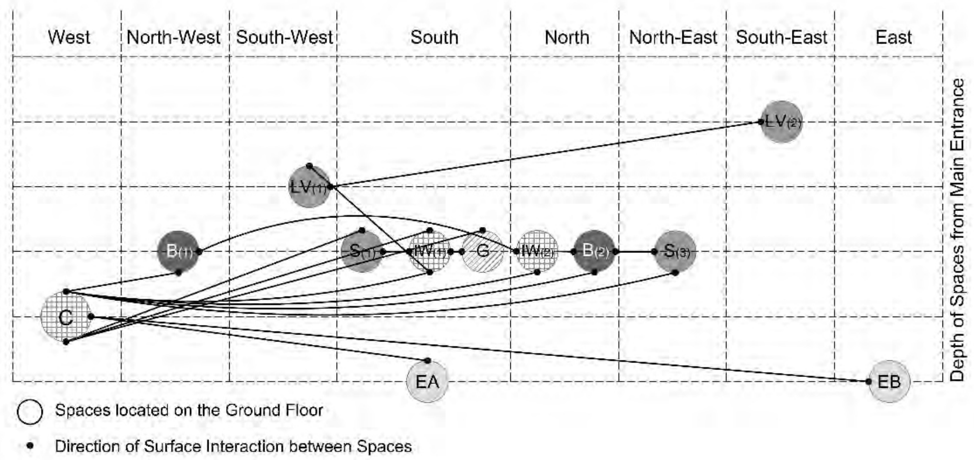


Sec. (A-A)

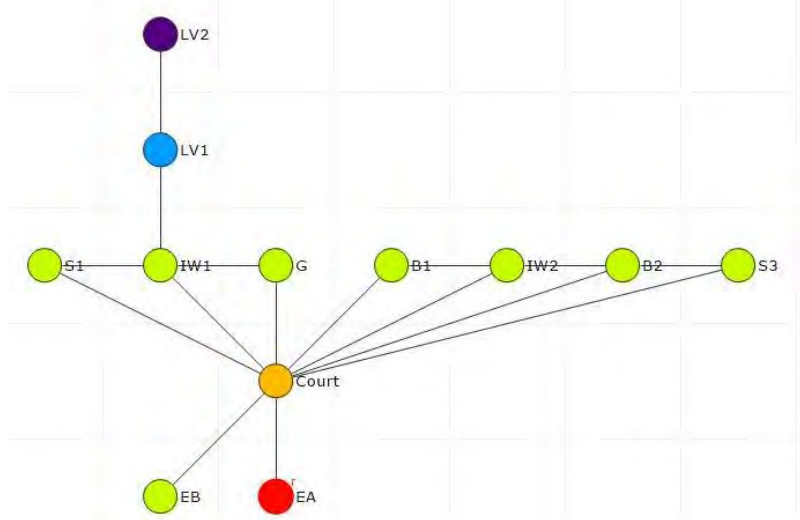
EA: Main Entrance Hall/Corridor
EB: Services Entrance
C : Courtyard
IW: Iwan
GL : Gallery
T : Roof Terrace / Balcony
G : Guest Room (Reception)
LV: Family Living Room
B : Intimate Spaces (Bedrooms)
S : Services (Kitchen, Toilets, Storage)
P : Passage / Transitional Space
DV: Double Volume

Hierarchy and Depth of Spaces
(according to the orientation, and type of spaces)
(Researcher)

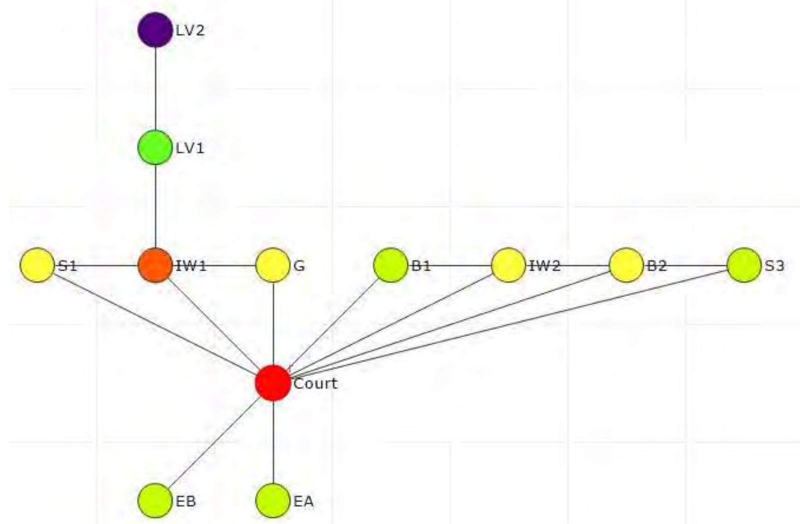




Space Syntax Analysis
Diagrams produced by Researcher using AGRAPH Online software
(https://www.ntnu.no/ab/spacesyntax)



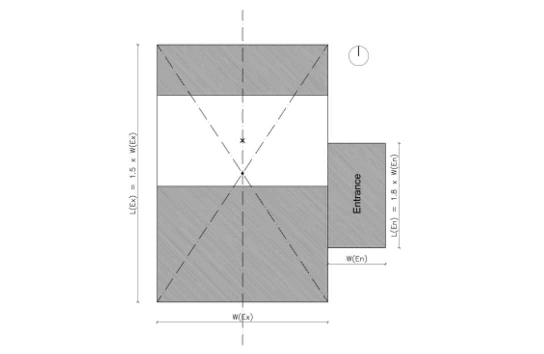
Depth of Spaces from the Main Entrance



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-2

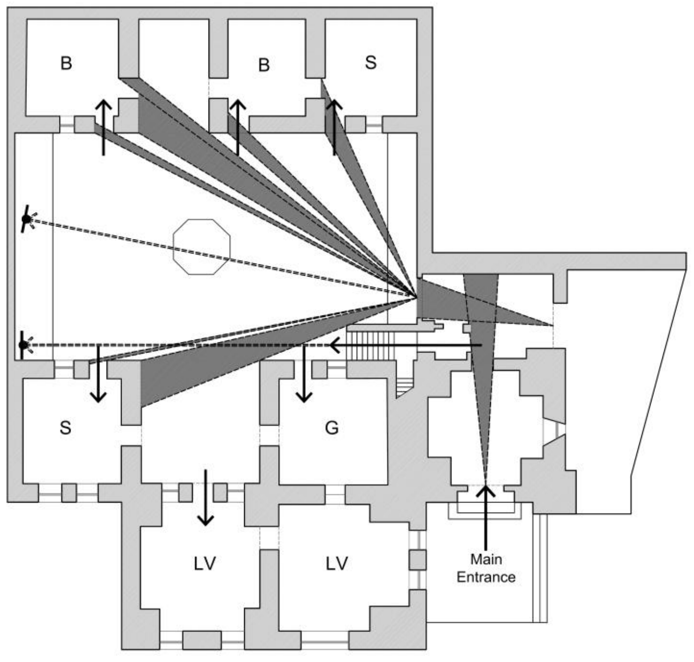
Typology and Geometric Properties of the House
(Researcher)



Typology	Recatngular layout with one courtyard adjacent to the East and West sides of the house
Exterior layout	1: 1.50
Courtyard	1 : 1.75 37 % of the total area of the house
Distance (D) between the center of the exterior layout (●) and the center of the courtyard (x)	Dx = 0 Dy = 1/5 W(Ex)
Thickness of exterior walls	80 cm
Height of spaces located on the ground floor	510 – 635 cm

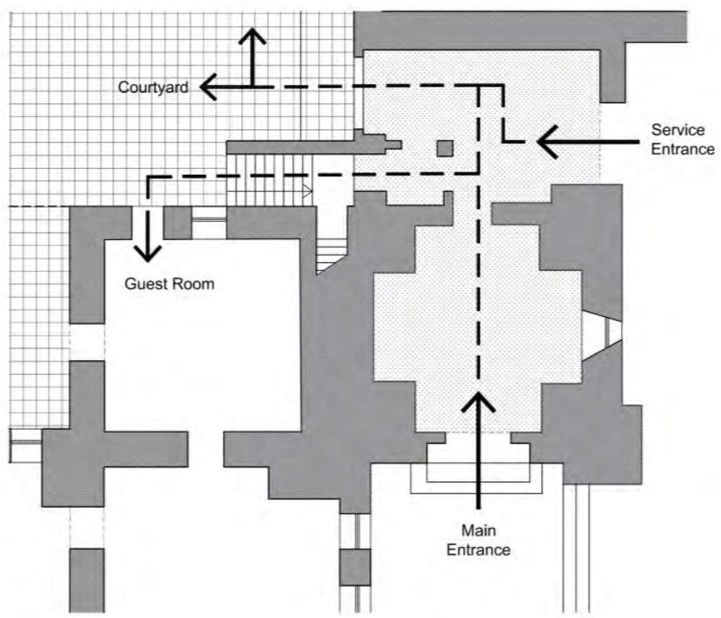
	Dominant Users (Male / Female)	Percentage of area of this space related to the total area of the house	Percentage of area of this space related to the floor area where it is located	Proportion of the area of this space, to the area of the courtyard	Proportion of Spaces
Courtyard	M+F	37 %	37 %	1 : 1	1 : 1.75
Iwan	M+F	9 %	9 %	0.25 : 1	1 : 1.05 , 1 : 1.62
Guest Room	M	5 %	5 %	0.13 : 1	1 : 1.25
Living Rooms	M+F	12 %	12 %	0.32 : 1	1 : 1.03 , 1 : 1.08
Bedrooms	M+F	7 %	7 %	0.20 : 1	1 : 1.25 , 1 : 1.05
Services (kitchen and storage) (Toilets)	F M+F	8 %	8 %	0.22 : 1	

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.

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
Court	14	1.27	0.05	18.33	4.91	9.00
B1	23	2.09	0.21	4.58	0.44	2.00
S1	21	1.90	0.18	5.50	0.36	2.00
IW1	18	1.63	0.12	7.85	1.61	4.00
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
Min	14.00	1.27	0.05	2.20	0.11	
Mean	**22.83**	**2.07**	**0.21**	**5.89**	**1.00**	
Max	36.00	3.27	0.45	18.33	4.91	

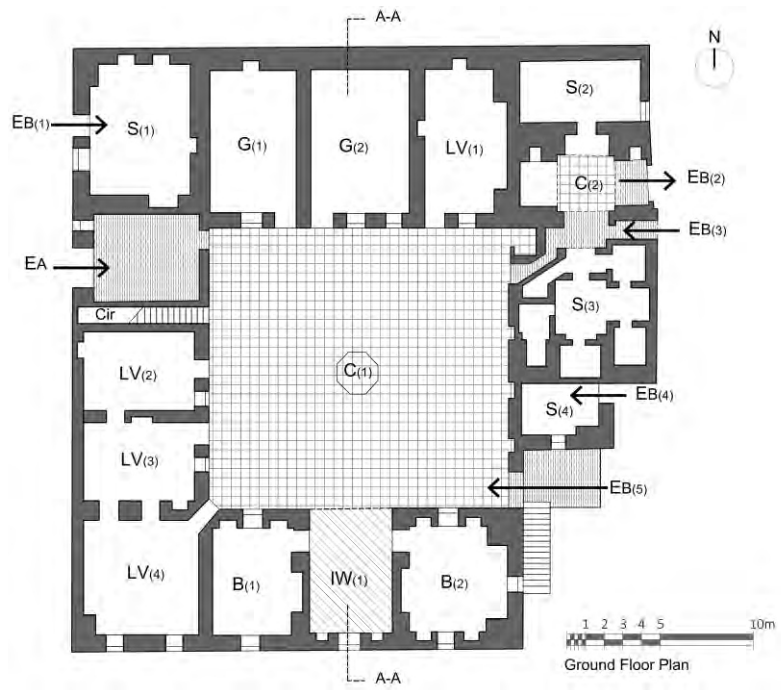
Integration Values:
Courtyard > Iwan > Guest Room > Services > Bedrooms > Living Rooms

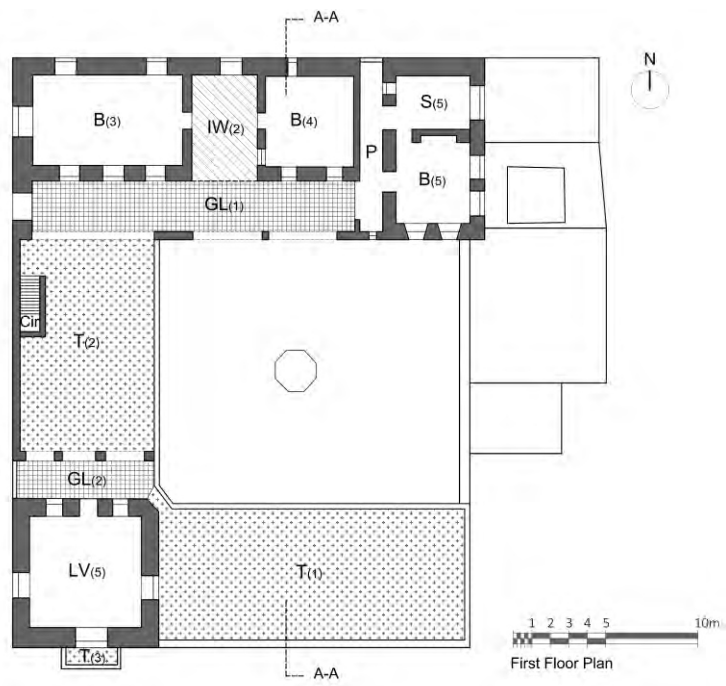
Lowest Integration Values:
- Living areas (private zones)

Highest Integration and Control Values:
- Courtyard
- Iwan

The Social Logic of the Spatial Arrangement of a Courtyard House in Lebanon	Region	Middle East	Country	Syria	Case No.	ME-L-3

Architectural Plans for a Courtyard House, Lebanon
(Redrawn by Researcher, after (Ragette, 2016, 173))

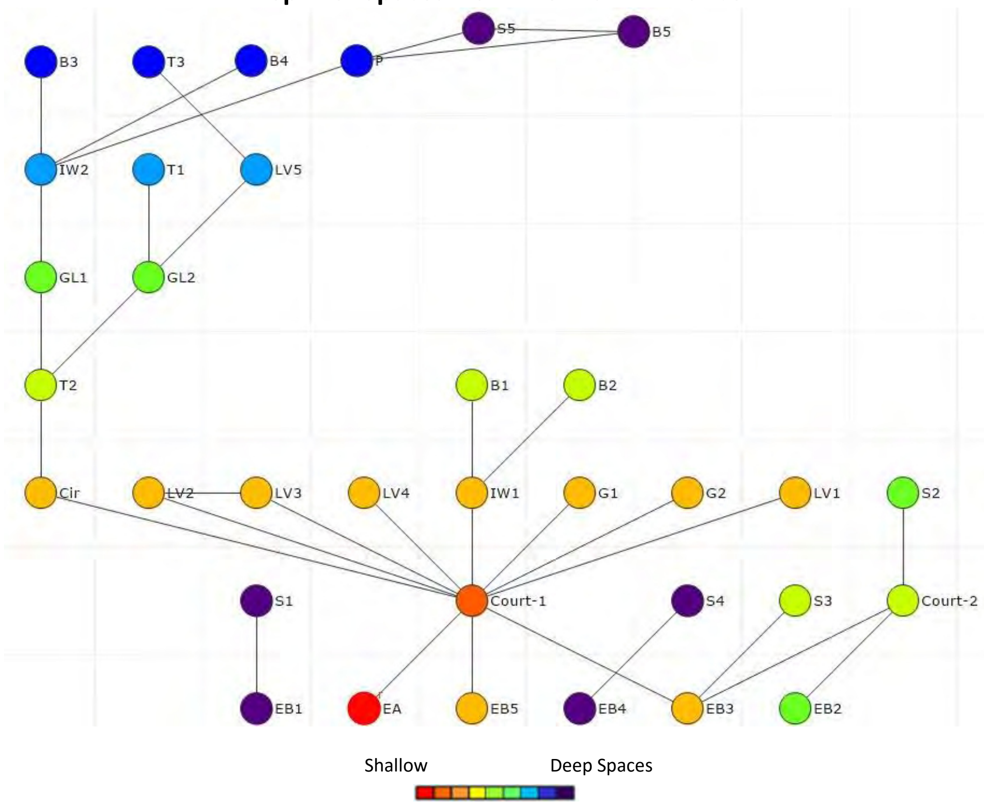




EA: Main Entrance Hall/Corridor
EB: Services Entrance
C : Courtyard
IW: Iwan
GL : Gallery
T : Roof Terrace / Balcony
G : Guest Room (Reception)
LV: Family Living Room
B : Intimate Spaces (Bedrooms)
S : Services (Kitchen, Toilets, Storage)
P : Passage / Transitional Space
DV: Double Volume

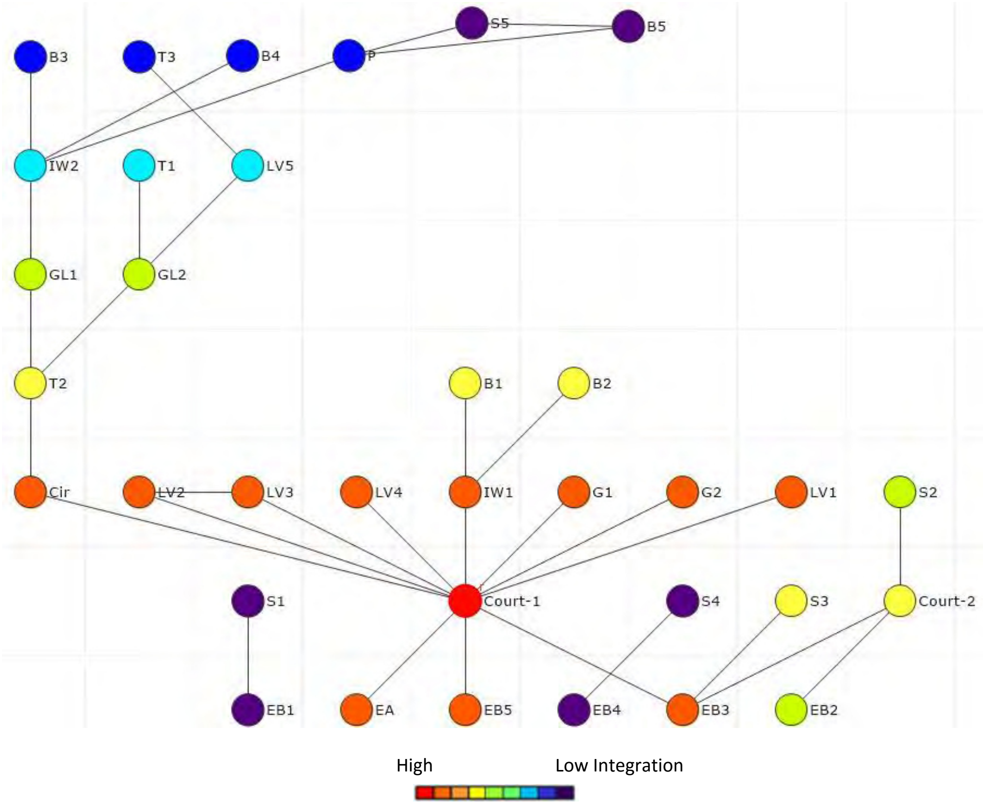
Space Syntax Analysis
Diagrams produced by Researcher using AGRAPH Online software
(https://www.ntnu.no/ab/spacesyntax)

Depth of Spaces from the Main Entrance



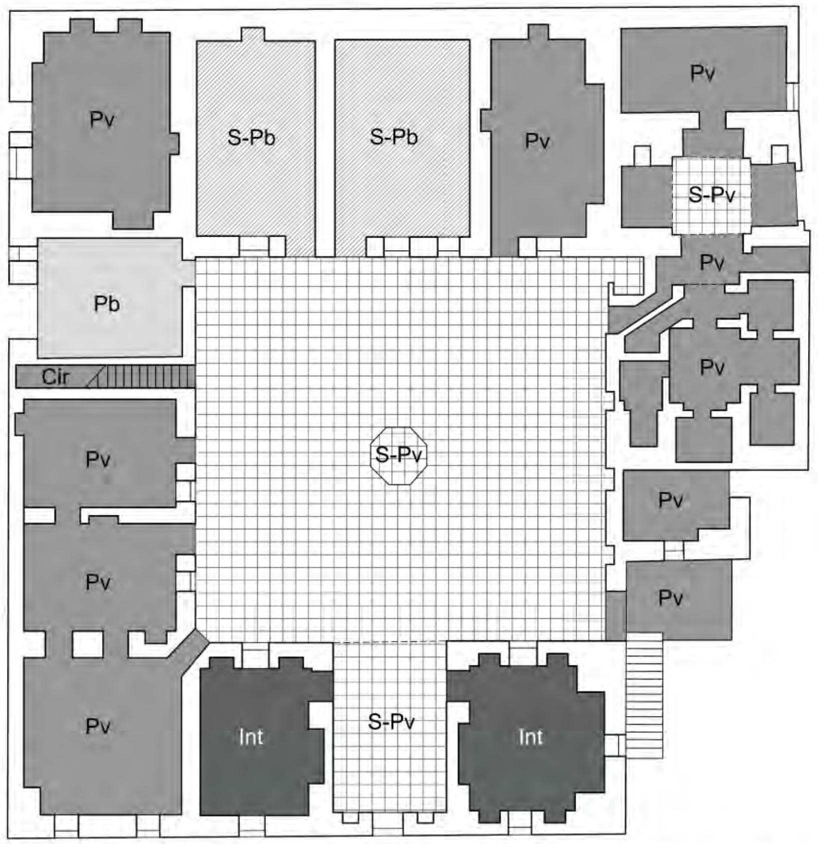
Integration of Spaces with the Courtyard

(the courtyard has the greatest control value)

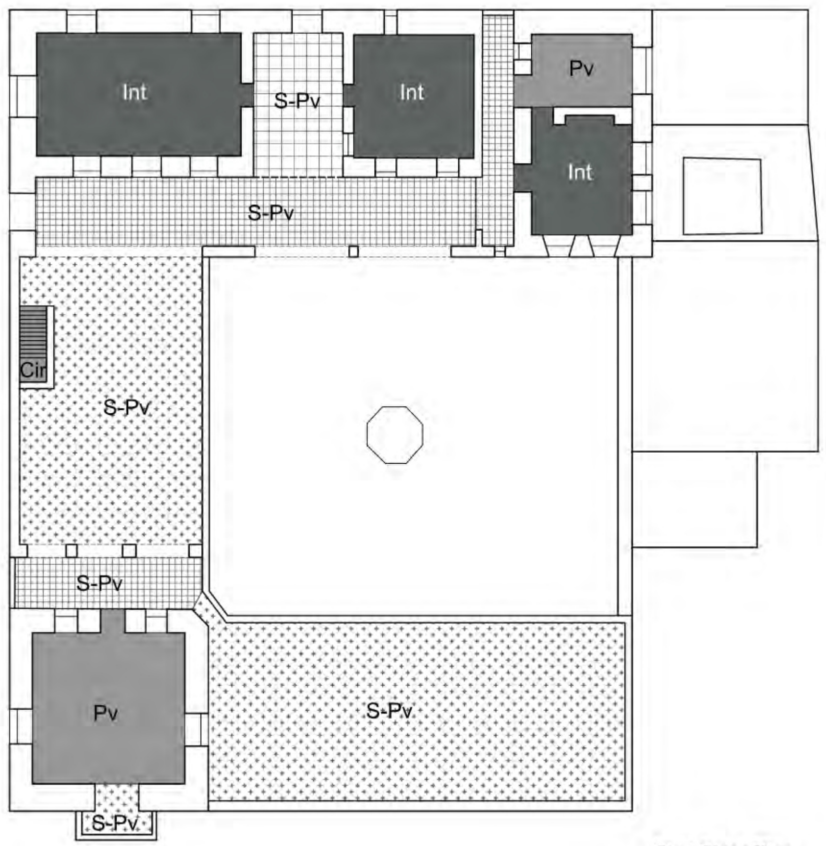


The Social Logic of the Spatial Arrangement of a Courtyard House in Lebanon	Region	Middle East	Country	Syria	Case No.	ME-L-3

Hierarchy and Depth of Spaces (according to the orientation, and type of spaces)
(Researcher)

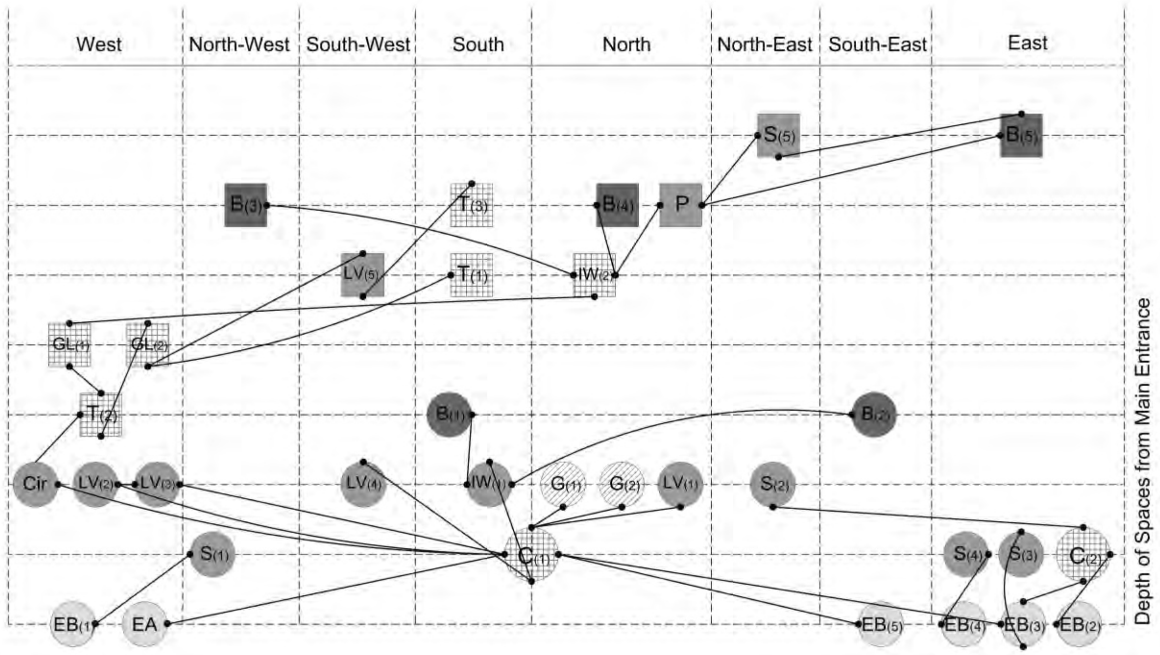


Ground Floor Plan



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)



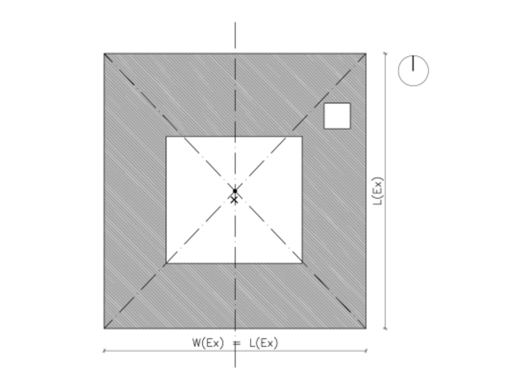
Spaces located on the Ground Floor

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	Region	Middle East	Country	Syria	Case No.	ME-L-3

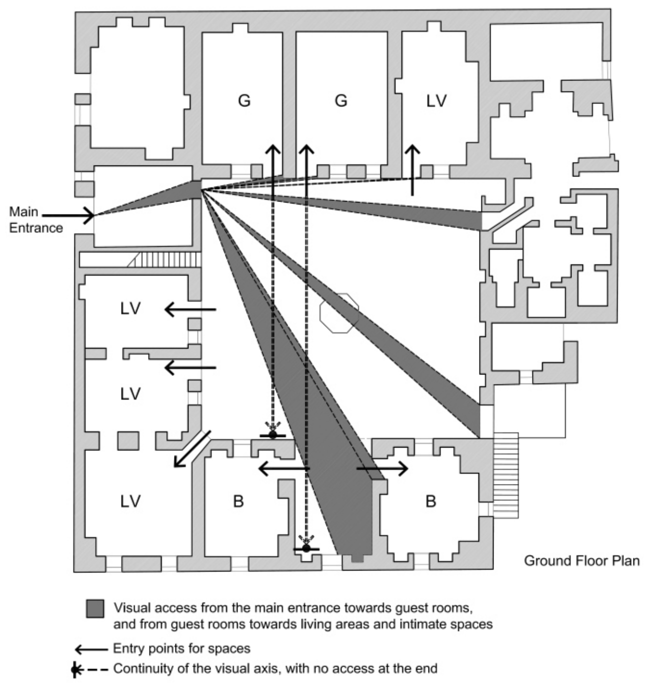
Typology and Geometric Properties of the House
(Researcher)



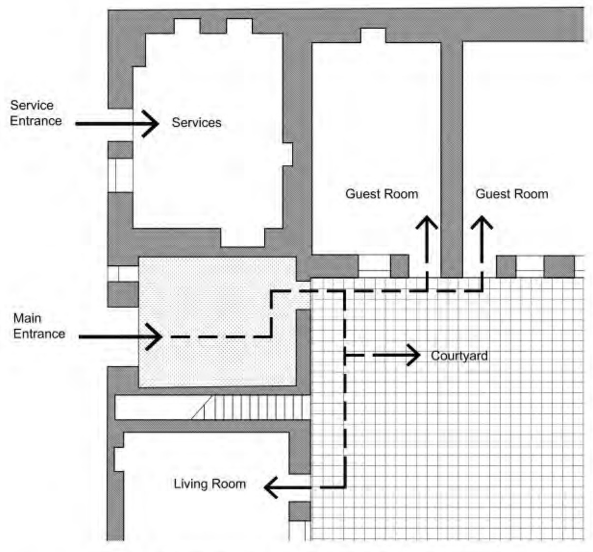
Typology	Recatngular layout with main courtyard at the center of the house, and a small service court
Exterior layout	1: 1
Courtyard	1 : 1.05
	19 % of the total area of the house, 29% from the GF
Distance (D) between the center of the exterior layout (●) and the center of the courtyard (x)	Center of the Courtyard ≈ Center of the House
Thickness of exterior walls	60-80 cm
Height of Guest/Living spaces on the Ground Floor	360 cm
Height of Bedrooms on the First Floor	4 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
			G	1st		
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 M+F	9 %	14 %	3 %	0.53 : 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 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.

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	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	

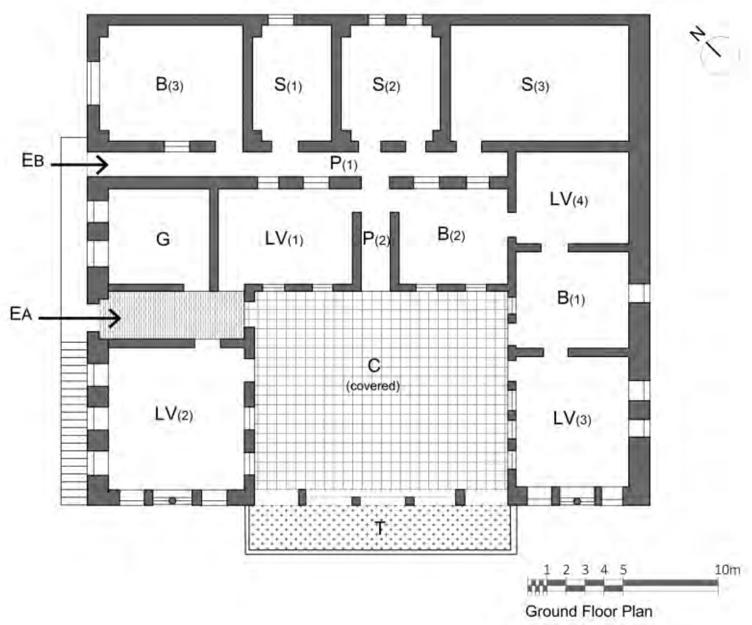
Integration Values:
Main Courtyard > Main Entrance and Service Entrance > Gallery and Iwan > Living Rooms > Guest Room > Bedrooms > Services (Kitchen, Storage, and Toilets) > Terraces

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

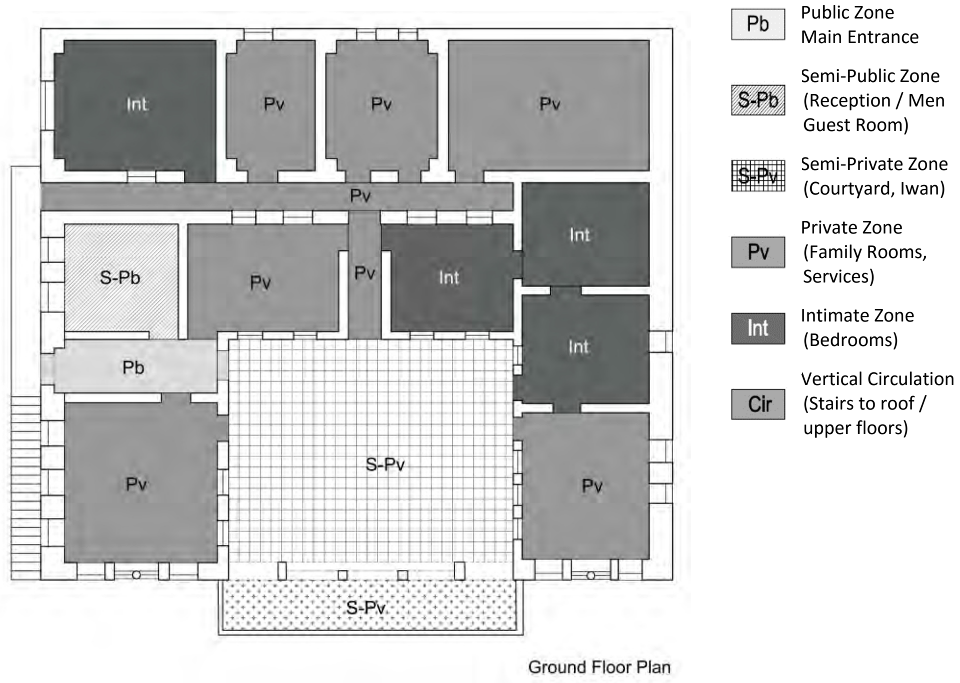
Architectural Plans for a Courtyard House, Lebanon
(Redrawn by Researcher, after (Ragette, 2016, 175))

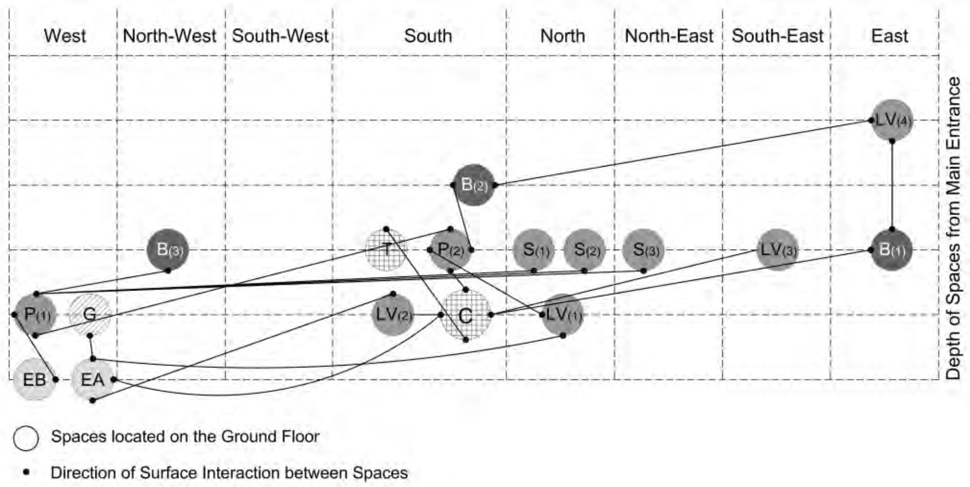


EA: Main Entrance Hall/Corridor
EB: Services Entrance
C : Courtyard
IW: Iwan
GL : Gallery
T : Roof Terrace / Balcony

G : Guest Room (Reception)
LV: Family Living Room
B : Intimate Spaces (Bedrooms)
S : Services (Kitchen, Toilets, Storage)
P : Passage / Transitional Space
DV: Double Volume

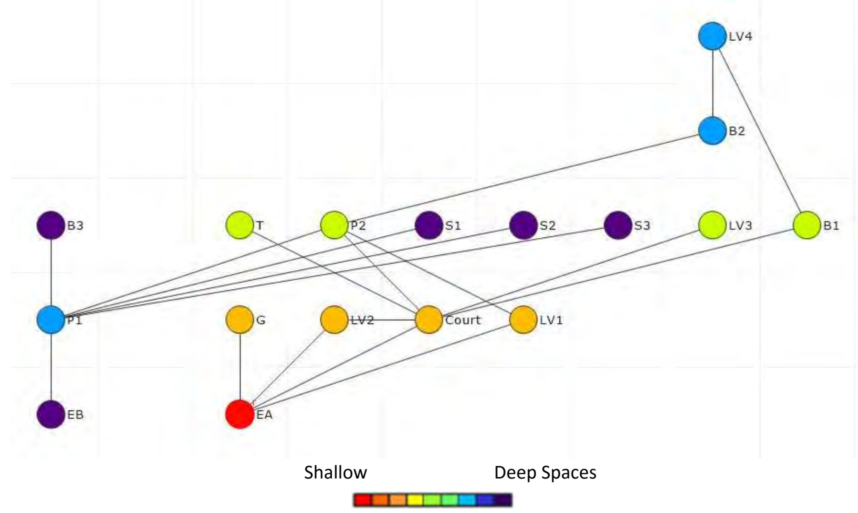
Hierarchy and Depth of Spaces
(according to the orientation, and type of spaces)
(Researcher)



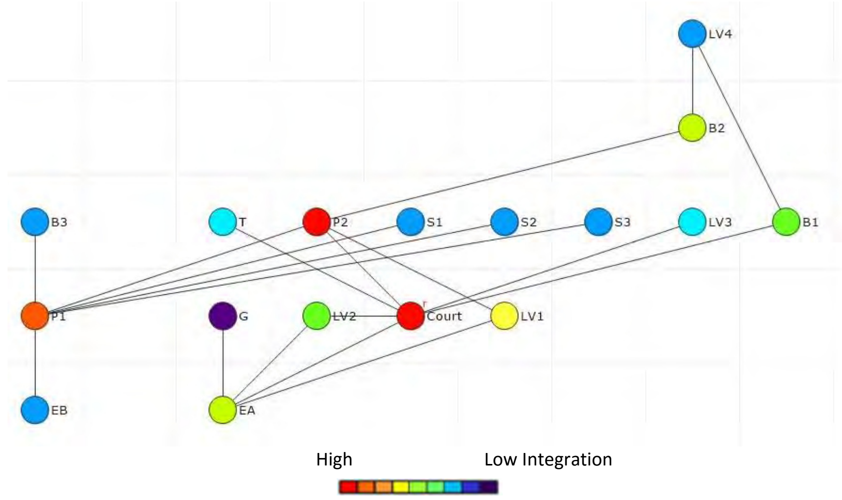


Space Syntax Analysis
Diagrams produced by Researcher using AGRAPH Online software
(https://www.ntnu.no/ab/spacesyntax)

Depth of Spaces from the Main Entrance

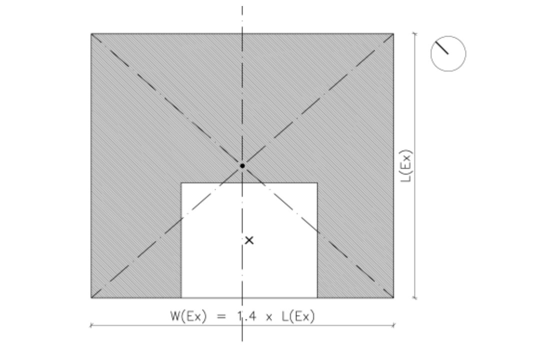


Integration of Spaces with the Courtyard
(the courtyard has the greatest control value)



The Social Logic of the Spatial Arrangement of a Courtyard House in Lebanon	Region	Middle East	Country	Lebanon	Case No.	ME-L-4

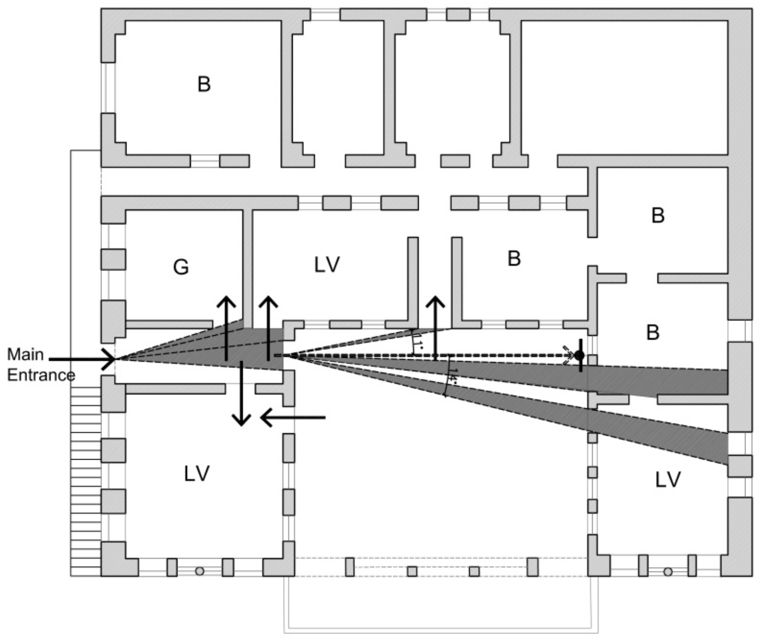
Typology and Geometric Properties of the House
(Researcher)



Typology	Recatngular layout with one courtyard adjacent to the south side of the house
Exterior layout	1: 1.4
Courtyard	1 : 1.28 20 % of the total area of the house
Distance (D) between the center of the exterior layout (●) and the center of the courtyard (x)	Dx = 0 Dy = - (1/4 W(Ex))
Thickness of exterior walls	55-100 cm
Height of spaces located on the ground floor	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
Courtyard	M+F	20 %	20 %	1 : 1	1 : 1.28
Terraces	M+F	5 %	5 %	0.24 : 1	
Guest Room	M	4 %	4 %	0.20 : 1	1 : 1.08
Living Rooms	M+F	23 %	23 %	1.17 : 1	1 : 1.05 , 1 : 1.22 , 1 : 1.15 , 1 : 1.4
Bedrooms	M+F	15 %	15 %	0.76 : 1	1 : 1.15 , 1 : 1.22
Services (kitchen and storage) (Toilets)	F M+F	8 %	8 %	0.40 : 1	

Visual Analysis from the Main Entrance towards inside the House
(Researcher)

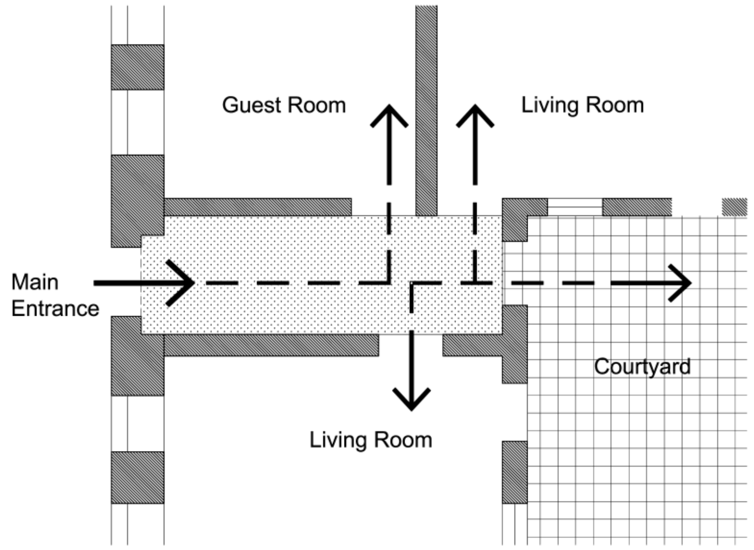


Visual access from the main entrance towards guest rooms, and from guest rooms towards living areas and intimate spaces

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 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	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	

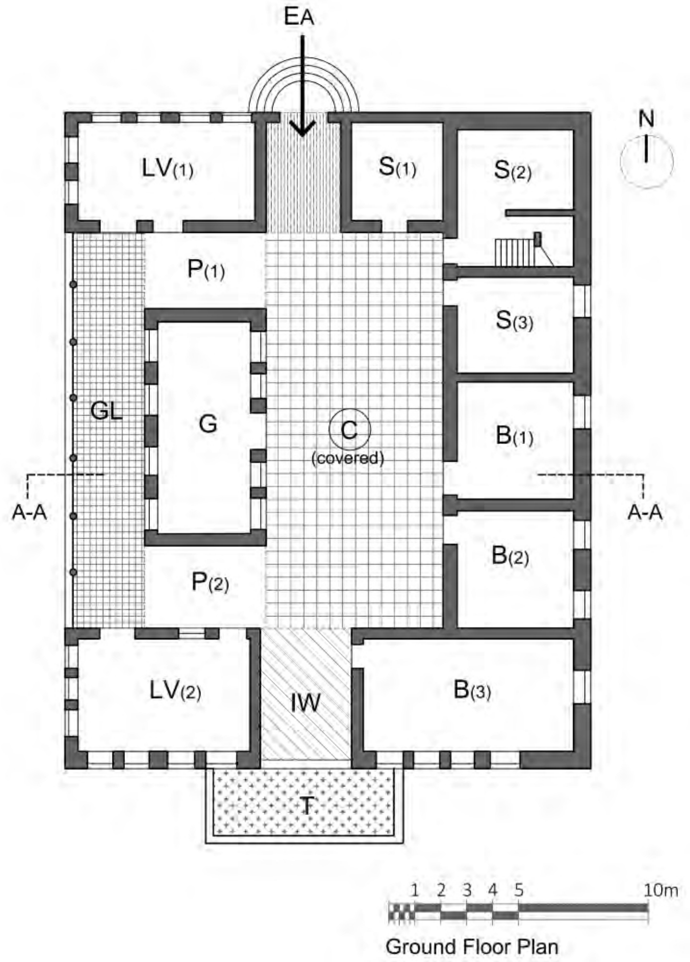
Integration Values:
Passage (corridor) > Courtyard > Living Room > Entrance > Bedrooms > Services (Kitchen, Storage, and Toilets) > Guest Room

Lowest Integration Values:
- Guest room
- Services

Highest Integration and Control Values:
- Courtyard
- Passage (corridors) as transitional spaces
- Living room

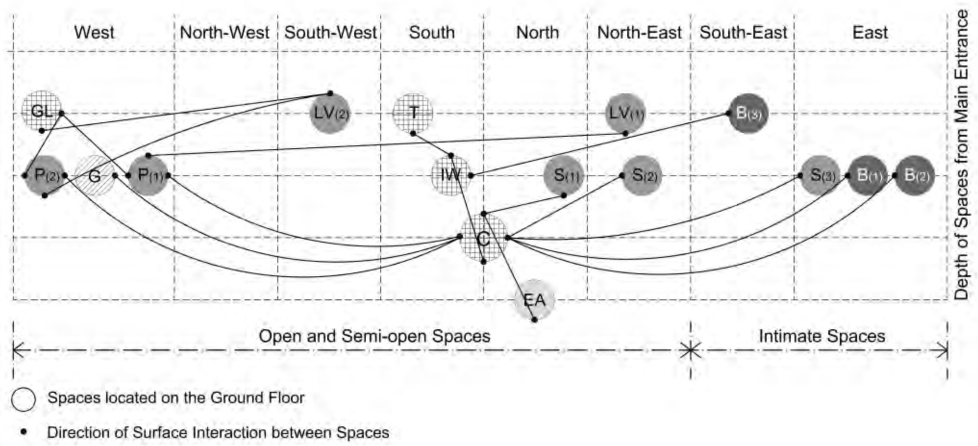
The Social Logic of the Spatial Arrangement of a Courtyard House in Lebanon	Region	Middle East	Country	Lebanon	Case No.	ME-L-5

Architectural Plans for a Courtyard House, Lebanon (Redrawn by Researcher, after (Ragette, 2016, 177))	Hierarchy and Depth of Spaces (according to the orientation, and type of spaces) (Researcher)	Space Syntax Analysis Diagrams produced by Researcher using AGRAPH Online software (https://www.ntnu.no/ab/spacesyntax)

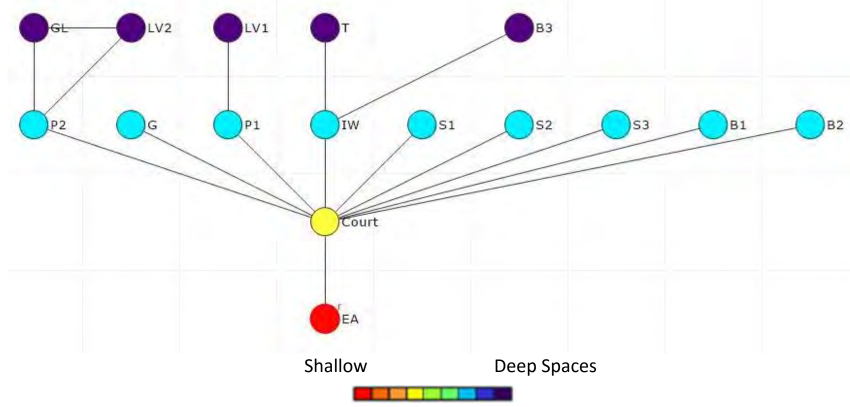


EA: Main Entrance Hall/Corridor
EB: Services Entrance
C : Courtyard
IW: Iwan
GL : Gallery
T : Roof Terrace / Balcony

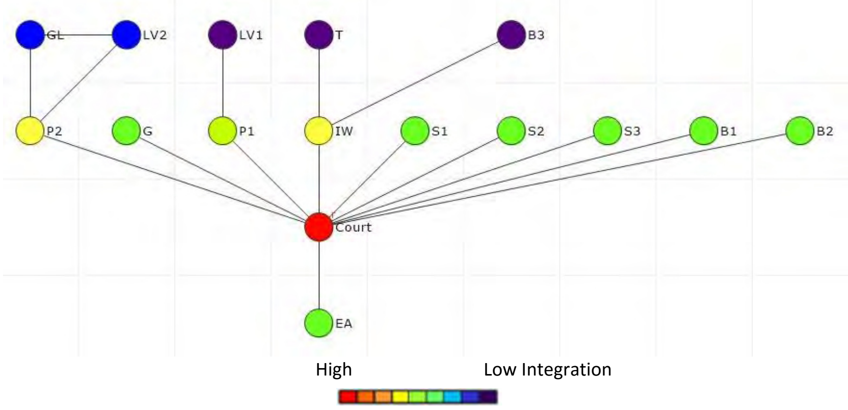
G : Guest Room (Reception)
LV: Family Living Room
B : Intimate Spaces (Bedrooms)
S : Services (Kitchen, Toilets, Storage)
P : Passage / Transitional Space
DV: Double Volume



Depth of Spaces from the Main Entrance

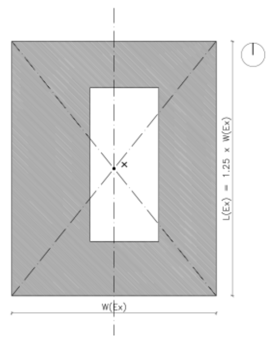


Integration of Spaces with the Courtyard
(the courtyard has the greatest control value)



The Social Logic of the Spatial Arrangement of a Courtyard House in Lebanon	Region	Middle East	Country	Lebanon	Case No.	ME-L-5

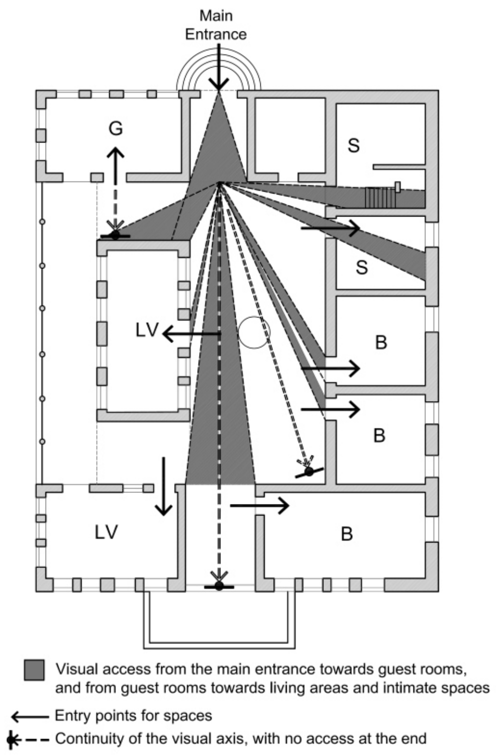
Typology and Geometric Properties of the House
(Researcher)



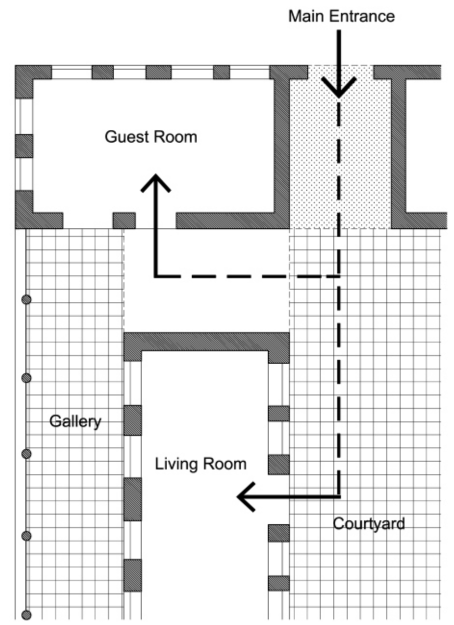
Typology	Recatngular layout with one courtyard at the center of the house
Exterior layout	1: 1.25
Courtyard	1 : 2.25
	22 % of the total area of the house
Distance (D) between the center of the exterior layout (●) and the center of the courtyard (x)	Center of the house ≈ center of the courtyard
Thickness of exterior walls	40-65 cm
Height of spaces located on the ground floor	345 - 610 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
Courtyard	M+F	22 %	22 %	1 : 1	1 : 2.25
Iwan	M+F	4 %	4 %	0.17 : 1	1 : 1.45
Gallery	M+F	9 %	9 %	0.40 : 1	
Terrace	M+F	5 %	5 %	0.21 : 1	1 : 2.15
Guest Room	M	6 %	6 %	0.29 : 1	1 : 2.25
Living Rooms	M+F	12 %	12 %	0.55 : 1	1 : 1.5 , 1 : 1.8
Bedrooms	M+F	16 %	16 %	0.74 : 1	1 : 1.87 , 1 : 1
Services (kitchen and storage) (Toilets)	F M+F	9 %	9 %	0.43 : 1	

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)



Entry passage for guests, separated visually from the courtyard and family zones

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
Court	20	1.33	0.04	21.00	8.16	10.00
P1	32	2.13	0.16	6.17	1.10	2.00
G	34	2.26	0.18	5.52	0.10	1.00
P2	30	2.00	0.14	7.00	1.10	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
IW	30	2.00	0.14	7.00	2.10	3.00
T	44	2.93	0.27	3.62	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
Min	20.00	1.33	0.04	3.38	0.10	
Mean	**35.62**	**2.37**	**0.19**	**6.12**	**1.00**	
Max	46.00	3.06	0.29	21.00	8.16	

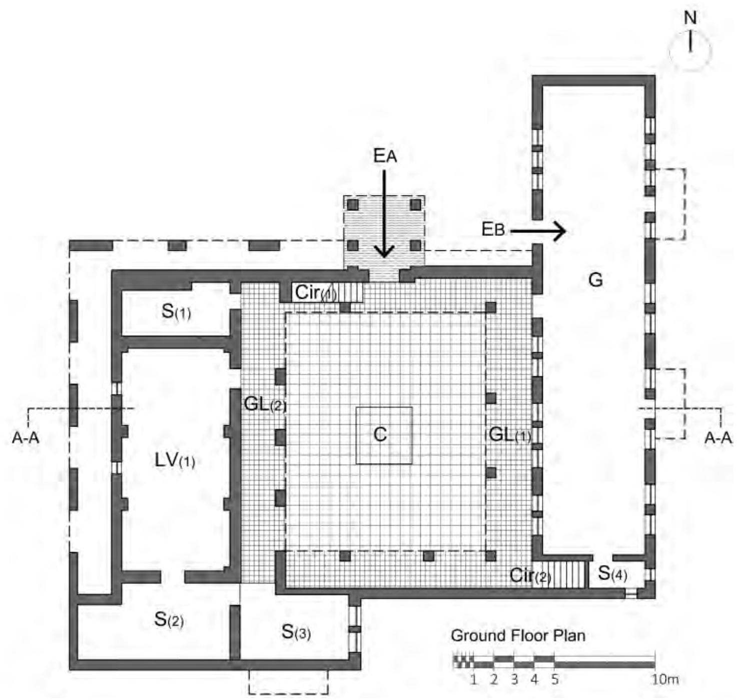
Integration Values:
Courtyard > Passage (corridor) > Iwan > Guest Room, Entrance, Services, Gallery > Living Rooms > Bedrooms

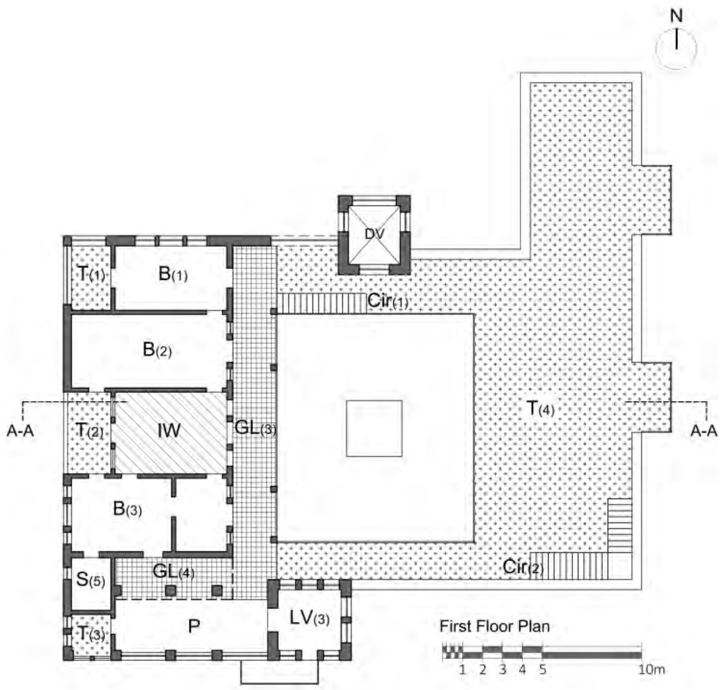
Lowest Integration Values:
- Living room
- Bedrooms
- Gallery and Terraces

Highest Integration and Control Values:
- Courtyard
- Passage (corridors) as transitional spaces
- Iwan (semi-open spaces)

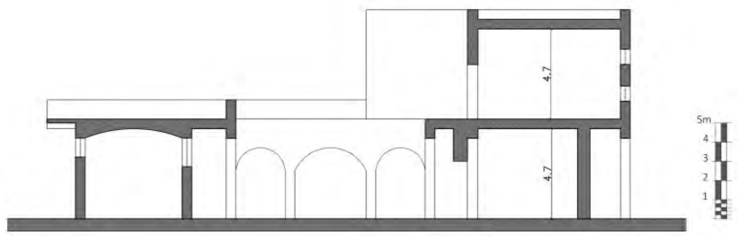
The Social Logic of the Spatial Arrangement of a Courtyard House in Jerash, Jordan	Region	Middle East	Country	Jordan	Case No.	ME-J-1

Architectural Plans for a Courtyard House, Jordan (Redrawn by Researcher, after (??????))	**Space Syntax Analysis** Diagrams produced by Researcher using AGRAPH Online software (https://www.ntnu.no/ab/spacesyntax)



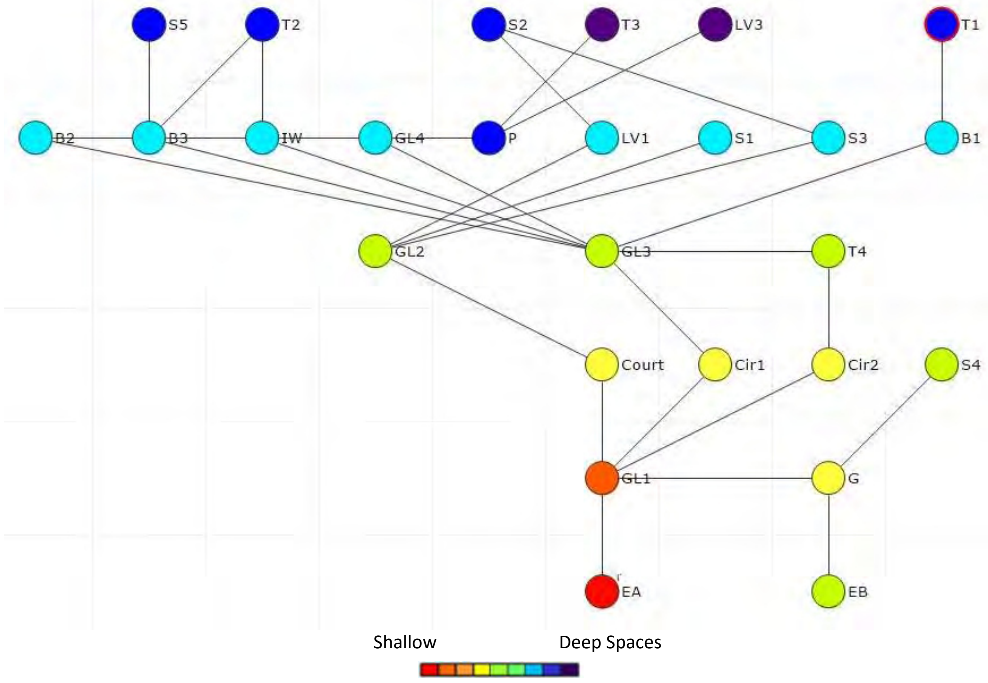


EA: Main Entrance Hall/Corridor
EB: Services Entrance
C : Courtyard
IW: Iwan
GL : Gallery
T : Roof Terrace / Balcony
G : Guest Room (Reception)
LV: Family Living Room
B : Intimate Spaces (Bedrooms)
S : Services (Kitchen, Toilets, Storage)
P : Passage / Transitional Space
DV: Double Volume

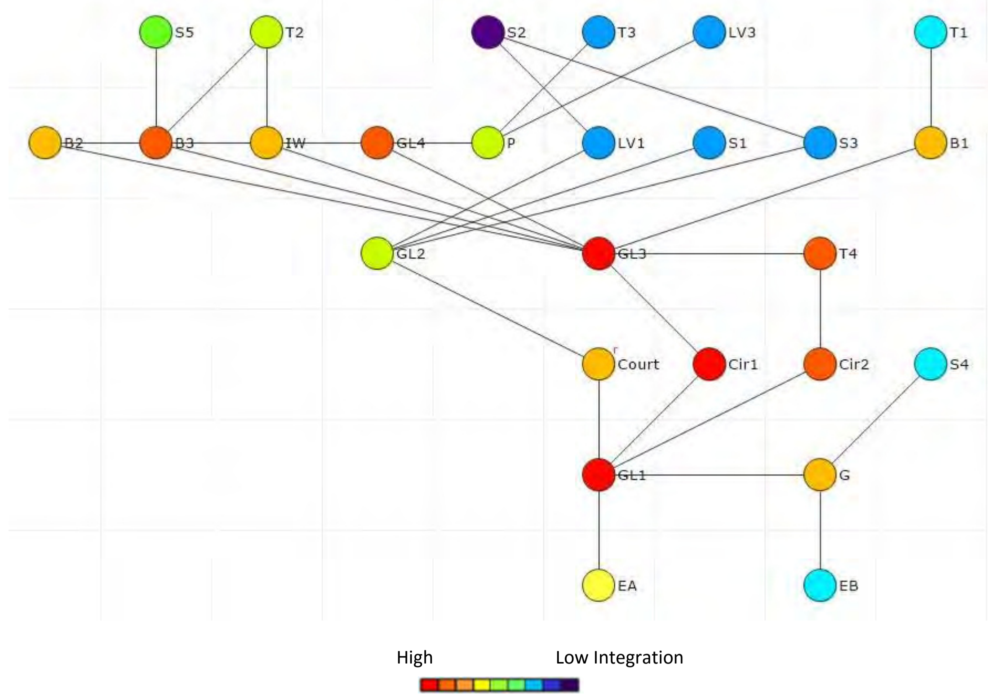


Sec. (A-A)

Depth of Spaces from the Main Entrance

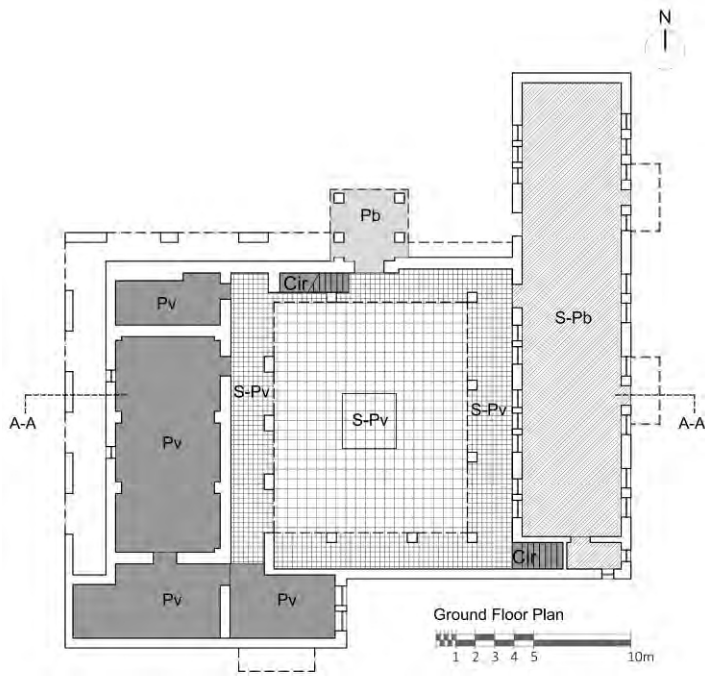


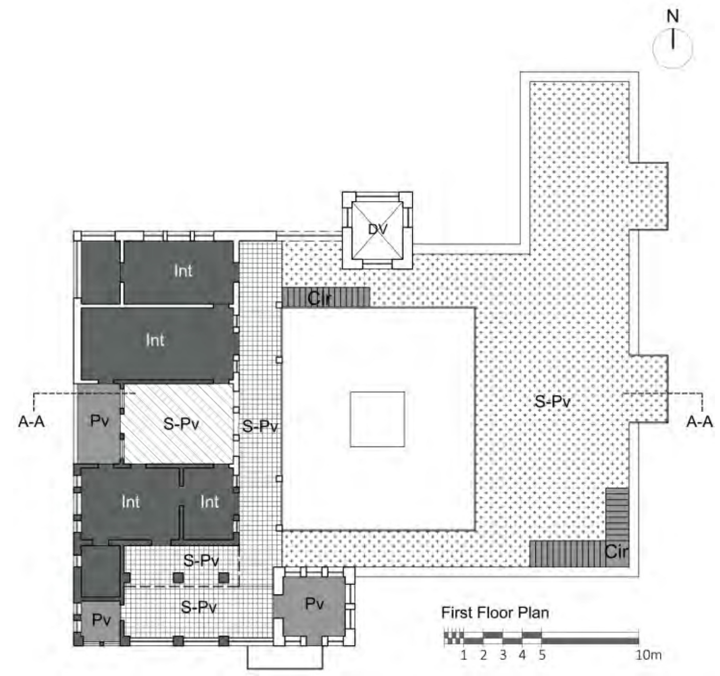
Integration of Spaces with the Courtyard
(the courtyard has the greatest control value)



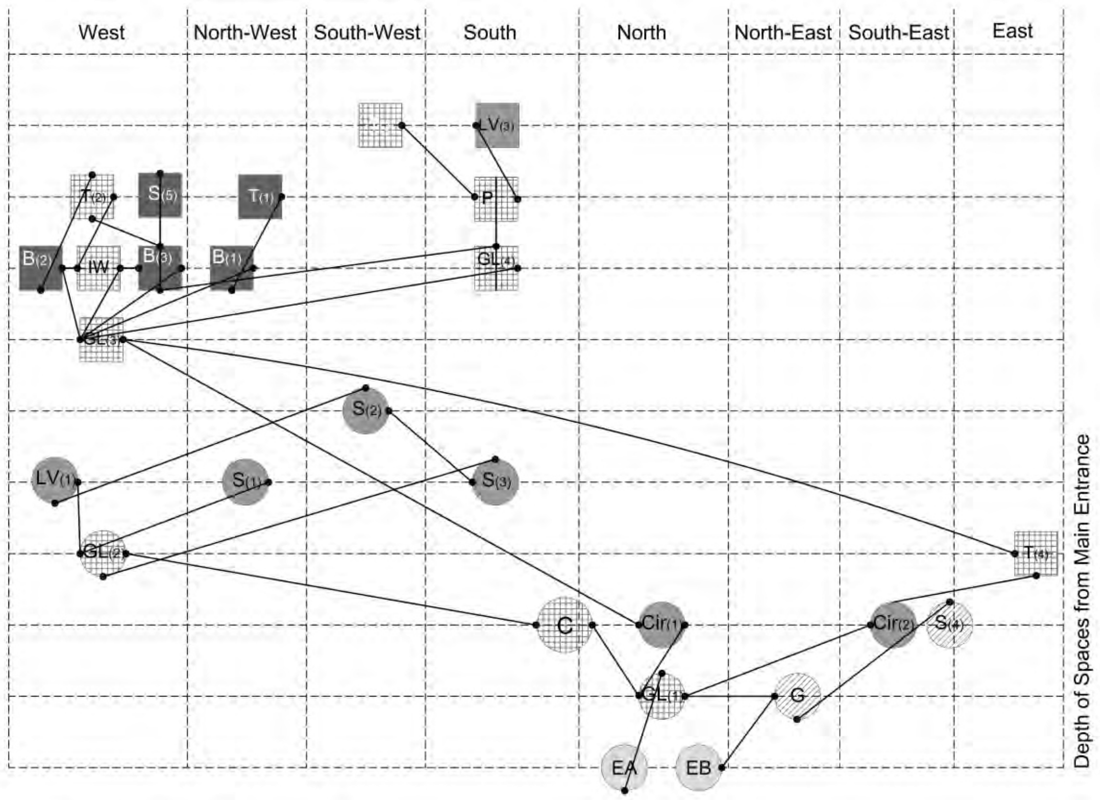
The Social Logic of the Spatial Arrangement of a Courtyard House in Jerash, Jordan	Region	Middle East	Country	Jordan	Case No.	ME-J-1

Hierarchy and Depth of Spaces (according to the orientation, and type of spaces)
(Researcher)





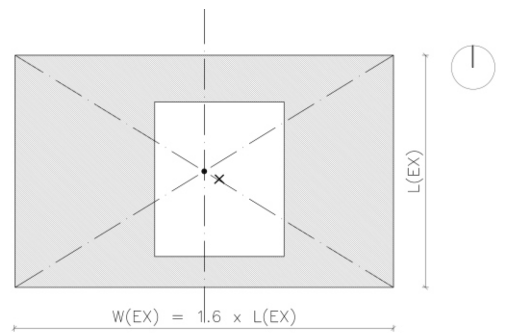
- Pb — Public Zone (Main Entrance)
- S-Pb — Semi-Public Zone (Reception / Men Guest Room)
- S-Pv — Semi-Private Zone (Courtyard, Iwan)
- Pv — Private Zone (Family Rooms, Services)
- Int — Intimate Zone (Bedrooms)
- Cir — Vertical Circulation (Stairs to roof / upper floors)



- 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

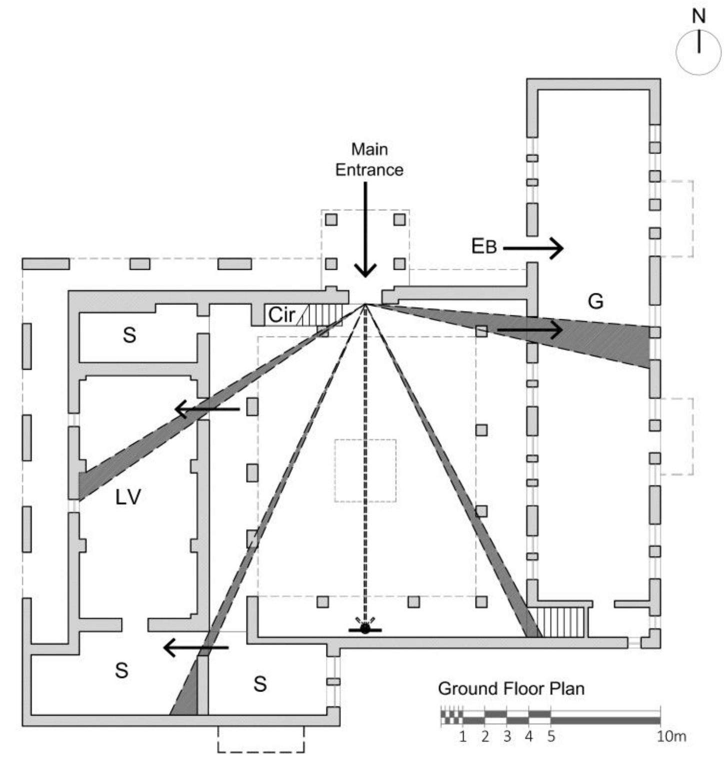
Typology and Geometric Properties of the House
(Researcher)



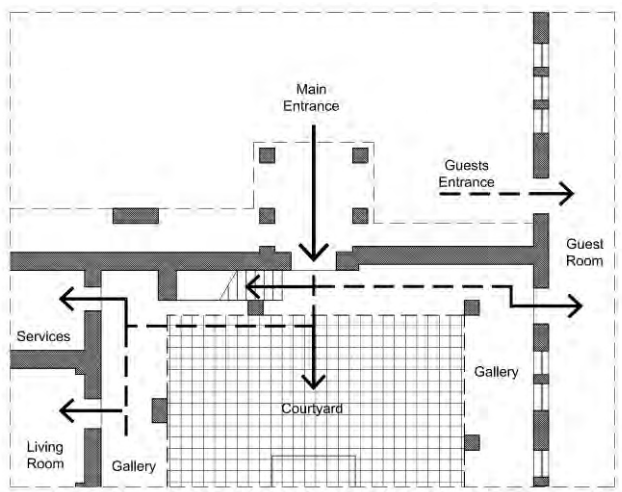
Typology	Recatngular layout with one courtyard at the center of the house
Exterior layout	1: 1.6
Courtyard	1 : 1.2
	13 % of the total area of the house, 25 % of the GF
Distance (D) between the center of the exterior layout (●) and the center of the courtyard (x)	Center of the Courtyard ≈ Center of the House
Thickness of exterior walls	50 cm
Height of Guest/Living spaces on the Ground Floor	470 cm
Height of Bedrooms on the First Floor	470 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
			G	1st		
Courtyard	M+F	13 %	25 %	-	1 : 1	1 : 1.2
Iwan	M+F	3 %	-	7 %	0.25 : 1	1 : 1.3
Gallery	M+F	16 %	20 %	12 %	1.23 : 1	
Terraces	M+F	26 %	-	56 %	2 : 1	
Guest Rooms	M	14 %	26 %	-	1.05 : 1	1 : 4.6
Living Rooms	M+F	8 %	13 %	3 %	0.60 : 1	1 : 2
Bedrooms	M+F	9 %	-	18 %	0.66 : 1	1 : 1.3 , 1: 1.8 , 1 : 2.2
Services (kitchen and storage) (Toilets)	F 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	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	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)

<u>Appendix (4-B-8)</u>

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
AVG	***765***	***189***	***250***			***974***	***1093***	***798***	***82%***	***176***	***18%***	***974***
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
AVG	***786***	***348***				***855***	***936***	***669***	***78%***	***187***	***22%***	***855***
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
AVG	***460***					***460***	***554***	***382***	***83%***	***78***	***17%***	***460***
JOR-1	566	258				824	1060	706	86%	118	14%	824
AVG	***566***	***258***				***824***	***1060***	***706***	***47%***	***784***	***53%***	***1490***
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
AVG	***401***	***336***	***189***			***813***	***839***	***725***	***89%***	***88***	***11%***	***813***
AVG	**598**	**296**	**209**			**785**	**896**	**649**	**83%**	**136**	**17%**	**785**

	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
AVG		0%	47	4%	119	11%	42	4%	93	9%	61	6%		10	1%	15	1%	34	3%	1060
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
AVG	10	1%	53	7%	81	10%	51	6%	94	12%	108	14%		20	2%	21	3%	29	4%	795
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
AVG		0%	95	18%	94	18%	17	3%	90	17%	40	8%	22	11	2%	5	1%	35	7%	527
JOR-1		0%	145	16%	236	26%	23	3%	78	9%	69	8%		15	2%		0%	42	5%	916
AVG		0%	145	16%	236	26%	23	3%	78	9%	69	8%		15	2%		0%	42	5%	916
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
AVG	13	2%	99	16%	26	4%	40	6%	93	15%	79	13%	16	17	3%	3	0%	51	8%	627
AVG	**12**	**1%**	**88**	**10%**	**111**	**13%**	**35**	**4%**	**90**	**10%**	**71**	**8%**	**19**	**15**	**2%**	**11**	**1%**	**38**	**4%**	**885**

						Main Court				Service Court				Iwan-1				
Case	**Distance (Court - Center) x**	**y**	**Distance (Court2 - Center) x**	**y**	**Thick. Of Walls**	**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	***1.51***	***0.81***	***2.20***	***0.15***	***82***	***11.97***	***24.53***	***0.69***		***18.20***	***15.00***	***1.21***		***5.98***	***5.05***	***1.19***		***0.47***
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	***0.83***	***-0.43***			***83***	***14.15***	***12.77***	***1.15***		***3.00***	***3.00***	***1.00***		***6.45***	***4.88***	***1.35***		***0.37***
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	***2.89***	***-0.93***			***76***	***8.47***	***8.33***	***1.04***						***5.40***	***3.00***	***1.80***		
JOR-1	-0.28	-0.78			50	10.00	11.85	0.84	CEN.					5.70	4.30	1.33	W	
AVG	***-0.28***	***-0.78***			***50***	***10.00***	***11.85***	***0.84***						***5.70***	***4.30***	***1.33***		
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	***-0.98***	***0.95***	***3.95***	***5.58***	***70***	***9.61***	***7.61***	***1.28***		***3.92***	***3.58***	***1.09***		***4.39***	***3.73***	***1.23***		***0.43***
AVG	**0.79**	**-0.08**	**3.07**	**2.87**	**72**	**10.84**	**13.02**	**1.20**		**8.37**	**7.19**	**1.16**		**5.58**	**4.19**	**1.33**		**1.27**

		Iwan-2						Main Liv			
Case	**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	***0.42***	***4.70***	***4.90***	***1.04***	***0.27***			***8.65***	***4.30***	***2.09***	
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		***6.20***	***3.92***	***1.59***	***0.24***			***7.12***	***5.97***	***1.29***	
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	***0.44***							***5.18***	***4.45***	***1.17***	
JOR-1	0.48							11.05	5.40	2.05	W
AVG	***0.48***							***11.05***	***5.40***	***2.05***	
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	***0.69***	***4.20***	***5.30***	***1.48***	***0.70***	***0.69***		***7.82***	***3.37***	***2.35***	
AVG	**2.03**	**5.03**	**4.71**	**1.07**	**1.21**	**0.69**		**7.97**	**4.70**	**1.70**	

	Guest						Rooms				X(Rooms) / X(Court)		Y(Rooms) / Y(Court)		
Case	x	y	prop.	direction	M/F/M+F	No. of Guest Rooms	E	W	N	S	E	W	N	S	x(court)/X (L)
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
AVG	***6.52***	***4.83***	***1.38***				***4.62***	***6.47***	***4.15***	***5.97***	***0.39***	***0.54***	***0.20***	***0.29***	***0.52***
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
AVG	***6.29***	***4.66***	***1.39***				***5.24***	***7.13***	***8.53***	***7.14***	***0.45***	***0.62***	***0.71***	***0.56***	***0.53***
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
AVG	***4.93***	***4.33***	***1.17***				***2.02***	***9.37***	***8.02***	***5.38***	***0.31***	***1.17***	***1.08***	***0.57***	***0.43***
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
AVG	***23.30***	***5.10***	***4.57***				***9.40***	***8.65***	***2.30***	***2.30***	***0.94***	***0.87***	***0.19***	***0.19***	***0.36***
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
AVG	***6.38***	***3.34***	***1.92***				***5.53***	***4.28***	***5.24***	***6.49***	***0.61***	***0.46***	***0.66***	***0.89***	***0.49***
AVG	**9.48**	**4.45**	**2.13**				**5.36**	**7.18**	**5.65**	**5.46**	**0.54**	**0.73**	**0.57**	**0.50**	**0.47**

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
AVG	***376***	***343***	***140***			***582***	***620***	***525***	***90%***	***57***	***10%***	***582***
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
AVG	***401***	***189***				***439***	***495***	***343***	***78%***	***97***	***22%***	***439***
MOR-1	925	798				1723	1723	1586	92%	137	8%	1723
MOR-2	162	162	120			444	486	409	92%	35	8%	444
AVG	***544***					***1084***	***1126***	***998***	***92%***	***86***	***8%***	***1084***
ALG-1	1188	1089	1045			3322	3322	3040	92%	282	8%	3322
ALG-2	65	48				113	128	106	94%	7	6%	113
AVG	***627***	***569***	***1045***			***1718***	***1733***	***1573***	***92%***	***145***	***8%***	***1718***
AVG	**487**	**367**	**593**			**956**	**993**	**859**	**88%**	**96**	**12%**	**956**

	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%
AVG		***0%***		***0%***	***38***	***8%***	***42***	***8%***	***86***	***17%***	***75***	***15%***		***17***	***3%***	***11***	***2%***
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%
AVG		***0%***	***39***	***3%***	***56***	***1%***	***17***	***2%***	***43***	***12%***	***45***	***15%***	***18***	***21***	***6%***	***8***	***0%***
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%
AVG		***0%***	***401***	***15%***	***42***	***7%***		***0%***	***210***	***21%***	***98***	***23%***	***44***	***19***	***3%***	***4***	***1%***
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%
AVG		***0%***	***96***	***9%***	***15***	***7%***		***0%***	***167***	***11%***	***473***	***26%***	***6***	***36***	***8%***		***0%***
AVG		**0%**	**179**	**7%**	**38**	**6%**	**30**	**3%**	**126**	**15%**	**173**	**20%**	**23**	**23**	**5%**	**8**	**1%**

Case	Corridor & Stairs		Total	Distance (Court - Center) x , y		Distance (Court2 - Center) x , y		Thick. Of Walls	Main Court x	Main Court y	Main Court prop.	Main Court direction	Service Court x	Service Court y	Service Court prop.	Service Court 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				
AVG	***69***	***13%***	***510***	***-0.41***	***-2.78***	***-8.83***	***3.71***	***60***	***7.98***	***7.29***	***1.19***		***3.85***	***4.50***	***0.86***	
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.				
AVG	***41***	***5%***	***336***	***1***	***1.55***	***0***	***-0.50***	***66***	***10.35***	***8.49***	***1.34***					
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
AVG	***46***	***6%***	***847***	***0***	***0***			***75***	***11.28***	***12.43***	***0.92***		***8.20***	***1.90***	***4.32***	
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				
AVG	***169***	***9%***	***1244***	***0.63***	***0.22***			***55***	***6.88***	***6.90***	***0.93***					
AVG	**81**	**8%**	**734**	**1.60**	**-1.47**	**-8.83**	**3.21**	**64.05**	**9.12**	**8.78**	**1.10**		**6.03**	**3.20**	**2.59**	

	Iwan-1						Iwan-2						Main Liv			
Case	**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	***4.20***	***4.20***	***1.00***	***0.64***			***5.20***	***2.45***	***2.12***		***0.57***		***5.15***	***4.32***	***1.24***	
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	***4.73***	***4.20***	***1.32***	***0.55***	***1.34***								***8.30***	***3.40***	***2.58***	
MOR-1													19.60	5.35	3.66	E
MOR-2													5.40	1.90	2.84	N
AVG													***12.50***	***3.63***	***3.25***	
ALG-1													11.10	7.40	1.50	N
ALG-2													4.25	2.20	1.93	E
AVG													***7.68***	***4.80***	***1.72***	
AVG	**4.47**	**4.20**	**1.16**	**0.59**	**1.34**		**5.20**	**2.45**	**2.12**		**0.57**		**8.41**	**4.04**	**2.20**	

	Guest						Rooms				X(Rooms)/X(Main-Court)		Y(Rooms)/Y(Main-Court)		
Case	x	y	prop.	direction	M/F/M+F	No. of Guest Rooms	E	W	N	S	E	W	N	S	x(MC) / X(L)
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
AVG	***6.73***	***4.18***	***1.60***				***8.98***	***4.70***	***8.00***	***2.49***	***1.15***	***0.61***	***1.11***	***0.36***	*0.37*
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
AVG	***7.38***	***3.26***	***2.22***				***4.44***	***6.02***	***4.95***	***5.32***	***0.44***	***0.60***	***0.60***	***0.65***	*0.50*
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
AVG	***12.35***	***3.38***	***3.86***				***6.40***	***6.25***	***7.65***	***6.30***	***0.54***	***0.54***	***0.73***	***0.52***	*0.47*
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
AVG	***8.53***	***2.78***	***3.11***				***7.58***	***2.18***	***7.80***	***6.03***	***1.32***	***0.19***	***1.13***	***1.01***	*0.41*
AVG	**8.74**	**3.40**	**2.70**				**6.85**	**4.79**	**7.10**	**5.03**	**0.86**	**0.49**	**0.89**	**0.64**	**0.44**

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
AVG	***355***	***168***					***523***	***669***	***417***	***80%***	***106***	***20%***	***523***
UAE	1185	867					2052	2060	1773	86%	279	14%	2052
AVG	***1185***	***867***					***2052***	***2060***	***1773***	***86%***	***279***	***14%***	***2052***
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
AVG	***395***	***191***	***150***				***539***	***709***	***467***	***87%***	***72***	***13%***	***539***
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
AVG	***734***						***734***	***800***	***613***	***83%***	***121***	***17%***	***734***
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
AVG	***138***	***140***	***138***	***162***	***162***	***65***	***610***	***695***	***587***	***96%***	***23***	***4%***	***610***
AVG	**561**	**342**	**144**	**162**	**162**	**65**	**892**	**987**	**771**	**86%**	**120**	**14%**	**892**

	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	***16***	***3%***	***53***	***10%***	***115***	***22%***	***280***	***53%***	***61***	***12%***	***525***	***53***	***8%***	***53***	***8%***	***106***	***16%***		***0%***
UAE	33	2%	62	4%	440	28%	789	51%	228	15%	1552	53	3%	281	18%	279	17%		0%
AVG	***33***	***2%***	***62***	***4%***	***440***	***28%***	***789***	***51%***	***228***	***15%***	***1552***	***53***	***3%***	***281***	***18%***	***279***	***17%***	***0***	***0%***
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	***20***	***5%***	***64***	***15%***	***108***	***25%***	***182***	***42%***	***60***	***14%***	***434***	***46***	***9%***	***57***	***11%***	***41***	***8%***		***0%***
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	***26***	***4%***	***79***	***13%***	***223***	***36%***	***154***	***25%***	***141***	***23%***	***623***	***49***	***7%***	***43***	***6%***	***99***	***13%***	***45***	***6%***
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	***14***	***3%***	***40***	***10%***	***53***	***13%***	***244***	***62%***	***43***	***11%***	***392***	***26***	***5%***	***48***	***10%***	***23***	***5%***		
AVG	**22**	**3%**	**60**	**10%**	**188**	**25%**	**330**	**47%**	**106**	**15%**	**705**	**45**	**6%**	**96**	**10%**	**109**	**12%**	**23**	**2%**

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		***0%***		***0%***	***146***	***22%***		***0%***	***61***	***9%***	***60***	***9%***		***16***	***2%***		***0%***	***177***	***26%***	***672***
UAE		0%	200	13%	8	1%		0%	203	13%	318	20%		17	1%	21	1%	218	14%	1598
AVG		***0%***	***200***	***13%***	***8***	***1%***		***0%***	***203***	***13%***	***318***	***20%***		***17***	***1%***	***21***	***1%***	***218***	***14%***	***1598***
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	***32***	***6%***	***56***	***11%***	***169***	***32%***		***0%***	***59***	***11%***	***79***	***15%***	***25***	***20***	***4%***	***13***	***2%***	***58***	***11%***	***524***
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	***68***	***9%***	***79***	***11%***	***198***	***27%***		***0%***	***55***	***7%***	***20***	***3%***	***21***	***26***	***4%***	***10***	***1%***	***50***	***7%***	***742***
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					***85***	***18%***			***43***	***9%***	***145***	***30%***	***21***	***13***	***3%***			***100***	***21%***	***482***
AVG	**50**	**4%**	**112**	**8%**	**121**	**20%**			**84**	**10%**	**124**	**15%**	**22**	**18**	**3%**	**15**	**1%**	**121**	**16%**	**804**

Case	Distance (Court - Center) x , y		Distance (Court2 - Center) x , y		Thick. Of Walls	Main Court				Service Court				Main Liv			
						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	***-1.48***	***-1.48***			***40***	***10.25***	***11.75***	***0.87***						***5.10***	***3.25***	***1.57***	
UAE	1.84	0.39			65	15.5	15.5	1.00	CEN.					9.35	5.9	1.58	W
AVG	***1.84***	***0.39***			***65***	***15.50***	***15.50***	***1.00***						***9.35***	***5.90***	***1.58***	
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	***0.55***	***0.10***			***48***	***6.65***	***6.15***	***1.09***		***7.65***	***3.75***	***1.99***		***6.27***	***4.41***	***1.52***	
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	***-2.10***	***1.39***	***8.90***	***-7.27***	***37***	***10.03***	***9.83***	***1.02***		***6.60***	***10.25***	***0.64***		***6.47***	***5.97***	***1.21***	
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	***-0.19***	***0.00***			***75***	***6.80***	***4.03***	***2.55***						***7.13***	***3.08***	***2.31***	
AVG	**-0.28**	**0.08**	**8.90**	**-7.27**	**52.83**	**9.85**	**9.45**	**1.31**		**7.13**	**7.00**	**1.32**		**6.86**	**4.52**	**1.64**	

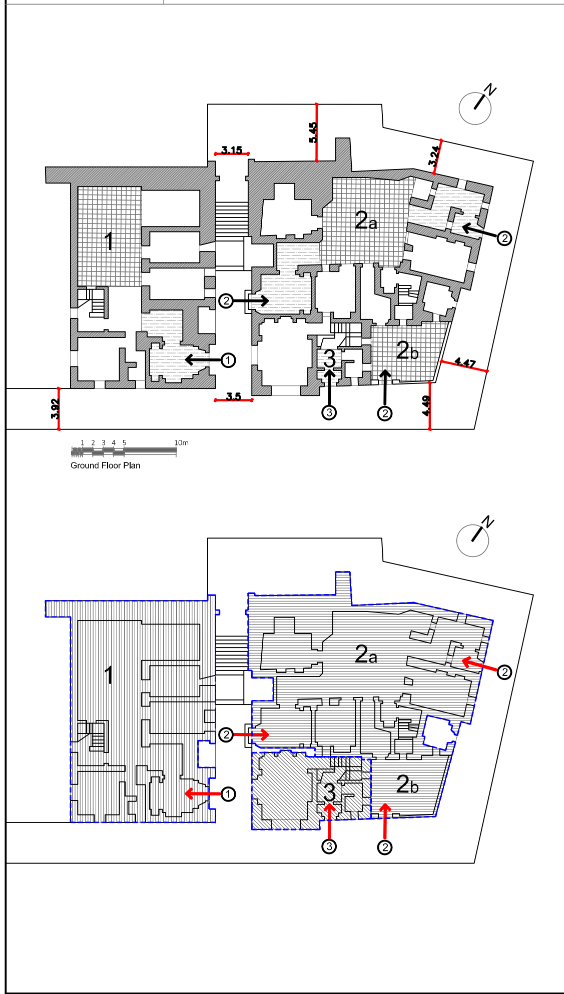
	Guest						Rooms				X(Rooms) / X(Court)		Y(Rooms) / Y(Court)		
Case	**x**	**y**	**prop.**	**direction**	**M/F/M+F**	**No. of Guest Rooms**	**E**	**W**	**N**	**S**	**E**	**W**	**N**	**S**	**x(MC) / X(L)**
OMA	10.75	2.85	3.77	E	M	2	3.65	6.4	6.6	3.3	0.36	0.62	0.56	0.28	0.50
AVG	***10.75***	***2.85***	***3.77***				***3.65***	***6.40***	***6.60***	***3.30***	***0.36***	***0.62***	***0.56***	***0.28***	*0.50*
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	***13.10***	***3.95***	***3.32***				***11.80***	***14.60***	***5.50***	***6.15***	***0.76***	***0.94***	***0.35***	***0.40***	***0.37***
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	***7.69***	***5.40***	***1.64***				***4.85***	***8.84***	***7.42***	***6.56***	***0.85***	***1.41***	***1.22***	***1.08***	***0.33***
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	***6.80***	***4.55***	***1.48***				***7.73***	***4.51***	***11.58***	***8.77***	***0.77***	***0.45***	***1.16***	***0.88***	*0.45*
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	***8.45***	***2.98***	***2.88***				***3.95***	***4.05***	***3.60***	***4.45***	***0.81***	***0.85***	***1.07***	***1.30***	***0.46***
AVG	**9.36**	**3.95**	**2.62**				**6.40**	**7.68**	**6.94**	**5.85**	**0.71**	**0.86**	**0.87**	**0.79**	**0.42**

Appendix (4-B-9)

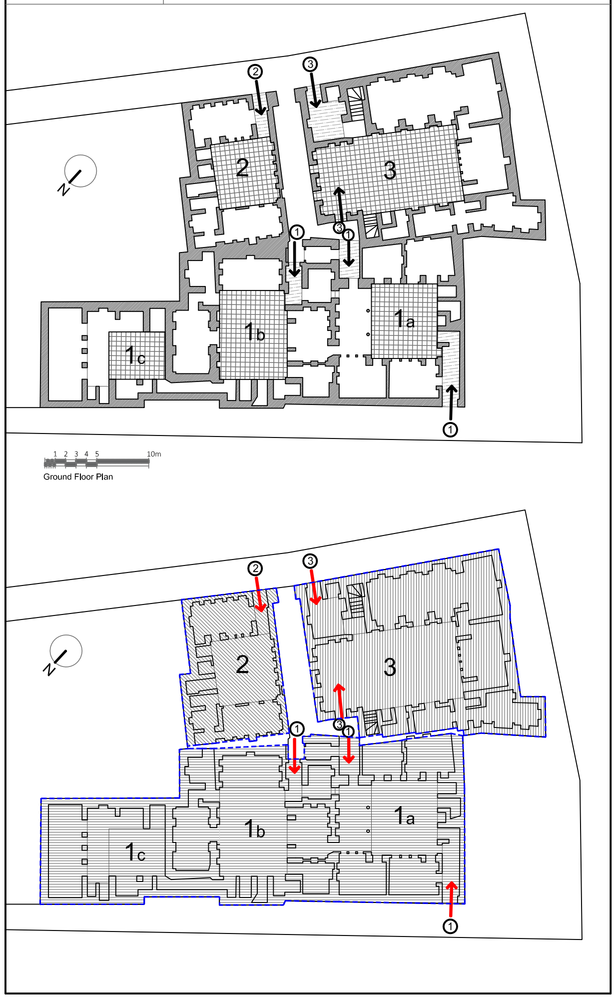
As-built Plans for the Selected Traditional Neighbourhoods

As-Built Plans for Neighborhoods / Clusters of Houses (4 cases)

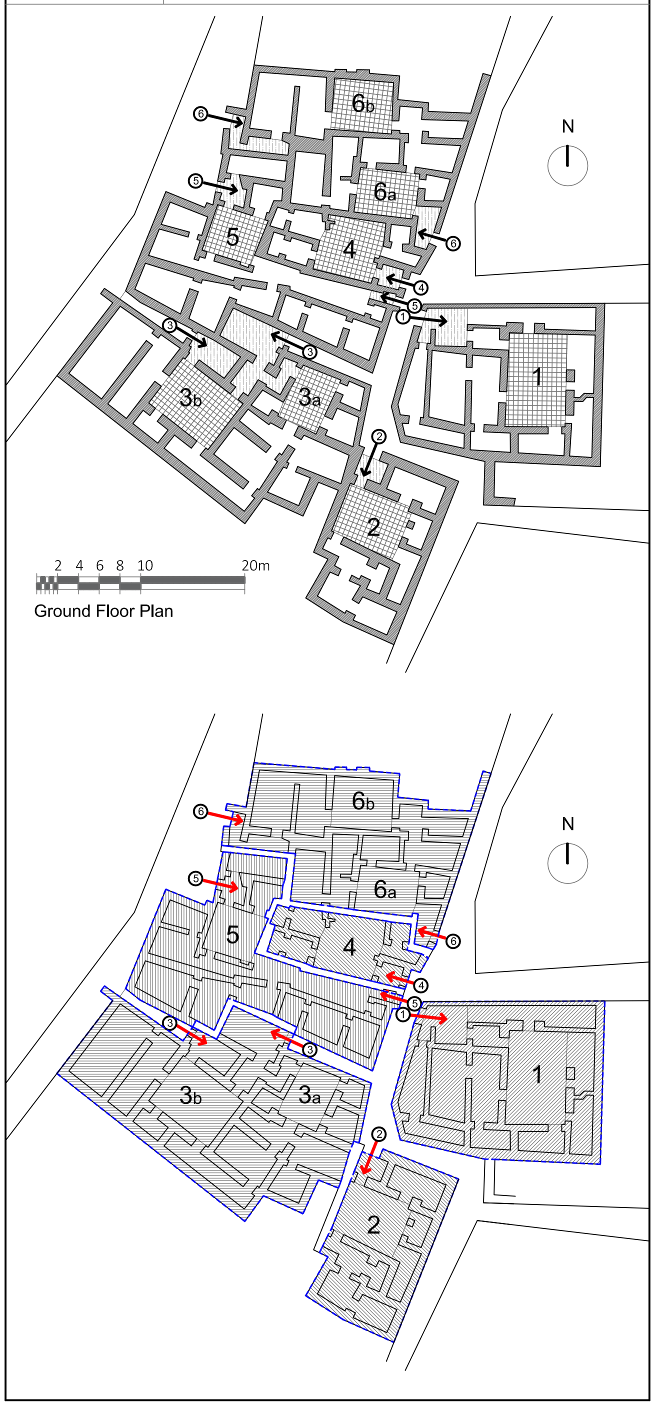
CLUS-1 | A three-house cluster, Cairo, Egypt. (redrawn by the author, after Ragette, 2016, 148)



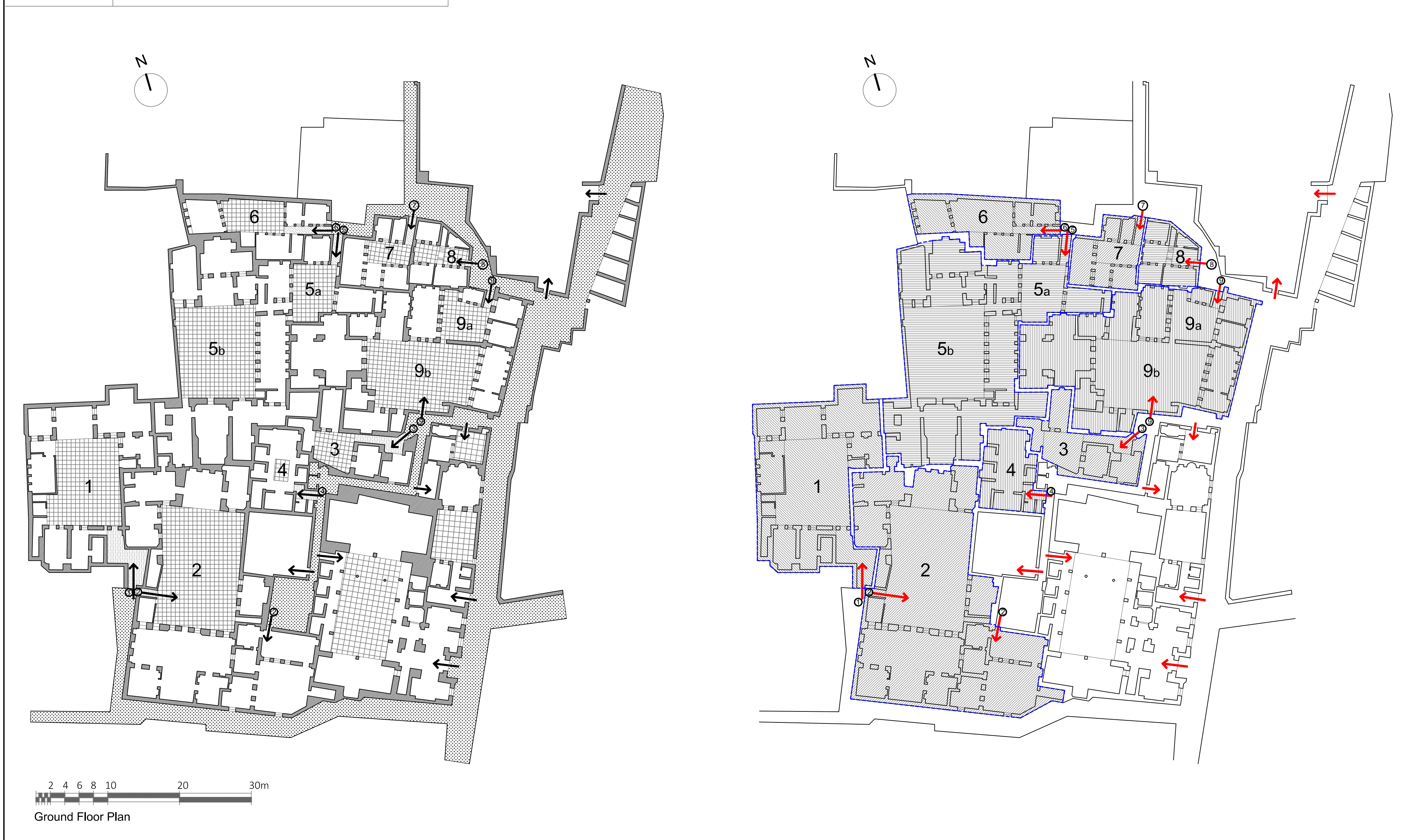
CLUS-2 | A five-courtyard compound, Baghdad, Iraq. (redrawn by the author, after Ragette, 2016, 191)



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)

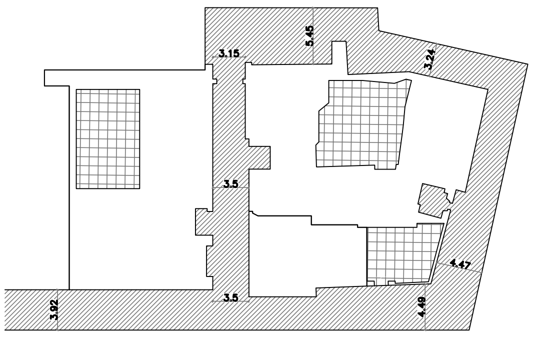
Analysing Aspects of Social Sustainability for the Selected Traditional Neighbourhoods

Social Indicators: Hierarchy of Open Spaces / Accessibility / Safety and Security

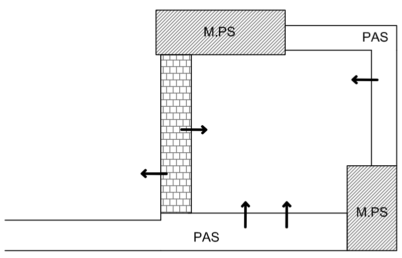
Strategies:

- Main Public Space ⟶ Alleys ⟶ '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^o 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

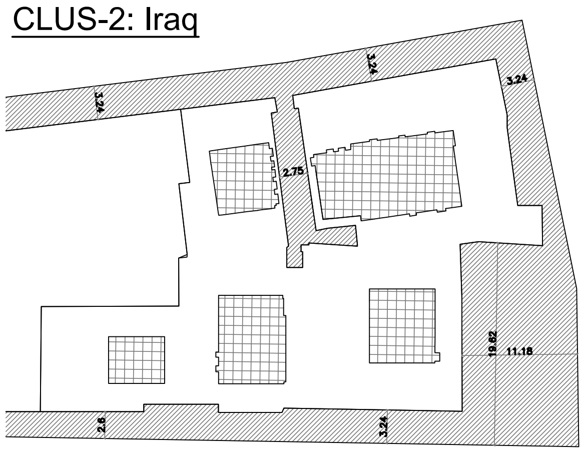


Public Spaces
Private Courtyards
Built-up Area

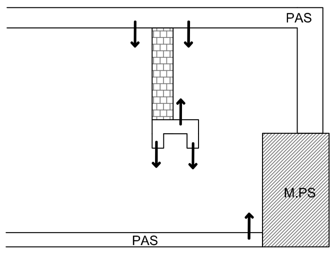


Main Public Spaces (M.PS) (3.15 m ≤ $width_{(M.PS)}$ ≤ 3.95 m)
'Semi-Private' Open Spaces (PV.S) ($width_{(PV.S)}$ = 3.50 m)
Alleys and Passageways (PAS) (4.45 m ≤ $width_{(PAS)}$ ≤ 5.45 m)
⟶ Entrances of Residential Units

CLUS-2: Iraq

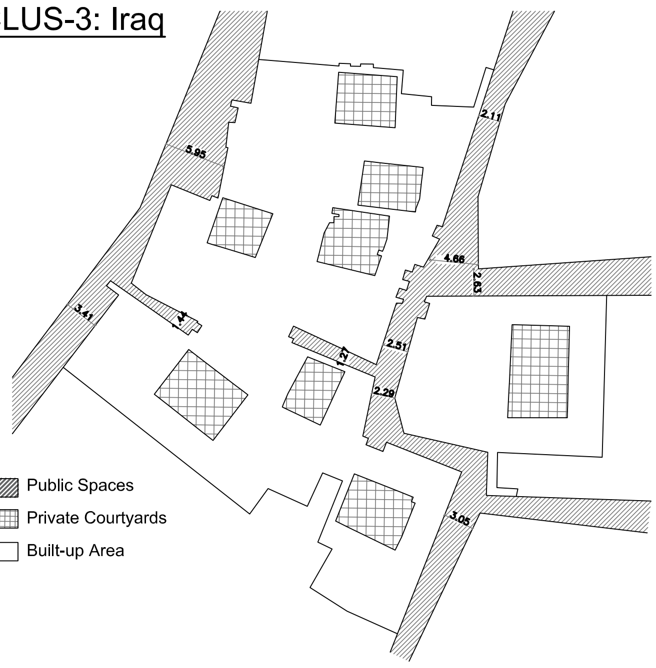


Public Spaces
Private Courtyards
Built-up Area

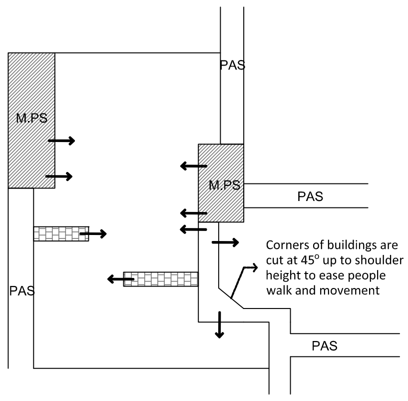


Main Public Spaces (M.PS) ($width_{(M.PS)}$ = 11.25 m)
'Semi-Private' Open Spaces (PV.S) ($width_{(PV.S)}$ = 2.75 m)
Alleys and Passageways (PAS) (2.60 m ≤ $width_{(PAS)}$ ≤ 3.25 m)
⟶ Entrances of Residential Units

CLUS-3: Iraq

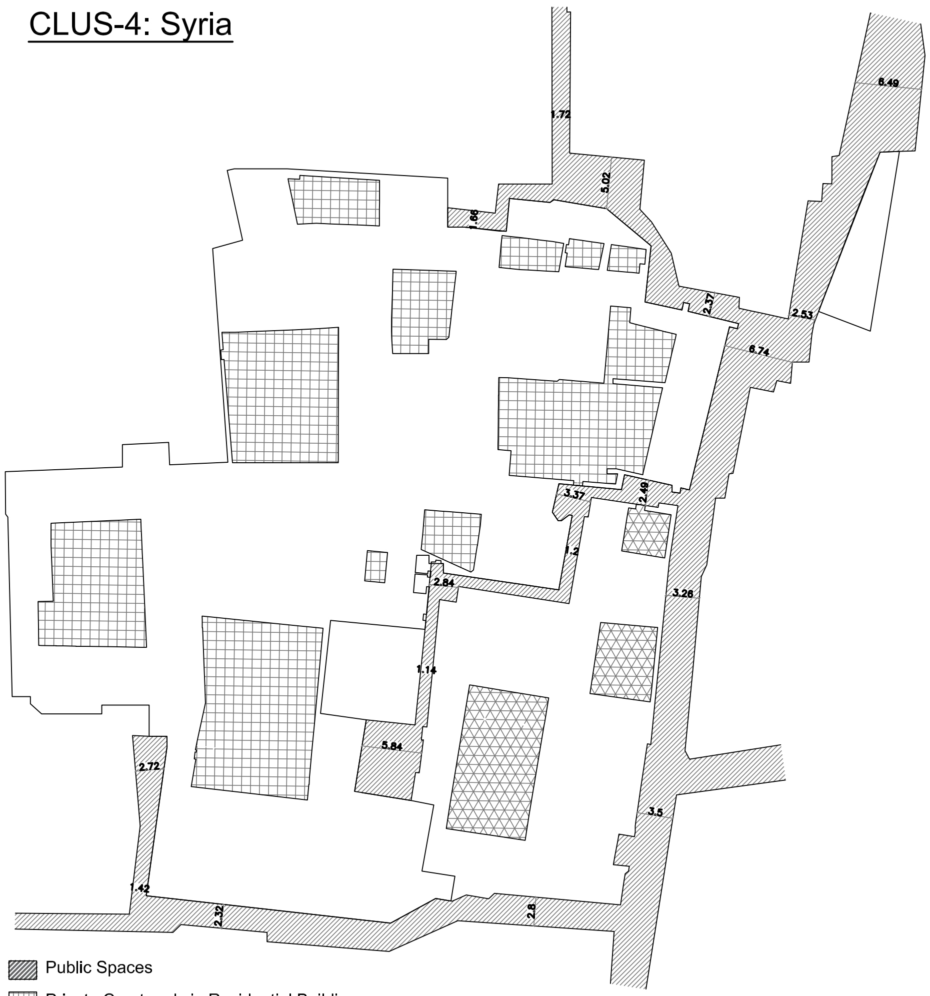


Public Spaces
Private Courtyards
Built-up Area

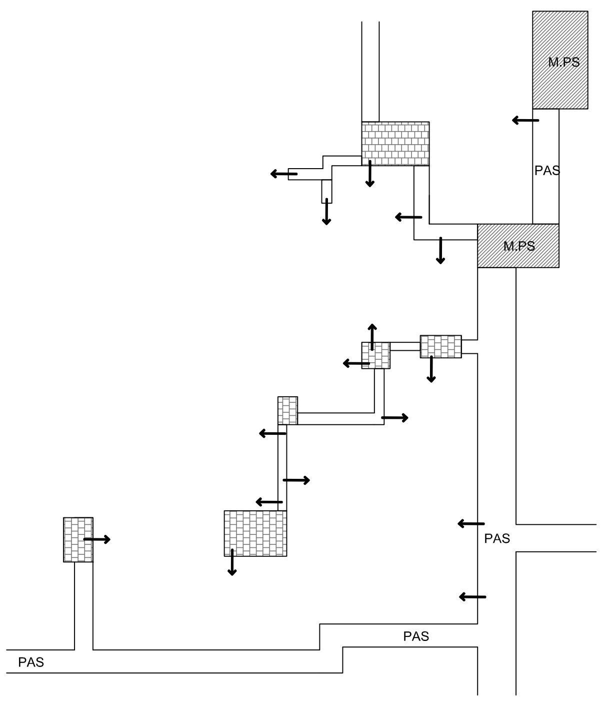


Main Public Spaces (M.PS) (4.35 m ≤ $width_{(M.PS)}$ ≤ 5.95 m)
'Semi-Private' Open Spaces (PV.S) (1.25 m ≤ $width_{(PV.S)}$ ≤ 1.45 m)
Alleys and Passageways (PAS) (2.25 m ≤ $width_{(PAS)}$ ≤ 3.40 m)
⟶ Entrances of Residential Units

CLUS-4: Syria



Public Spaces
Private Courtyards in Residential Buildings
Private Courtyards in Non-Residential Buildings
Built-up Area



Main Public Spaces (M.PS) (5.00 m ≤ $width_{(M.PS)}$ ≤ 8.75 m)
'Semi-Private' Open Spaces (PV.S) (1.15 m ≤ $width_{(PV.S)}$ ≤ 5.85 m)
Alleys and Passageways (PAS) (2.30 m ≤ $width_{(PAS)}$ ≤ 3.50 m)
⟶ Entrances of Residential Units

Social Indicators: Density and Crowding / Social Interaction / Thermal Comfort

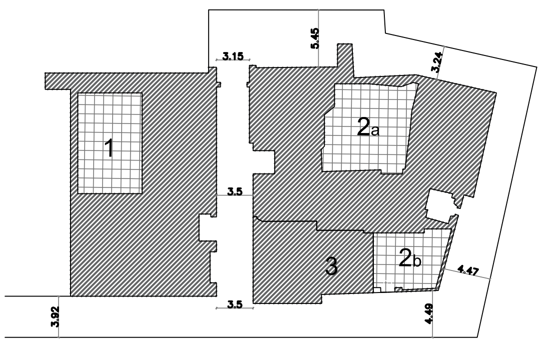
Strategies:

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

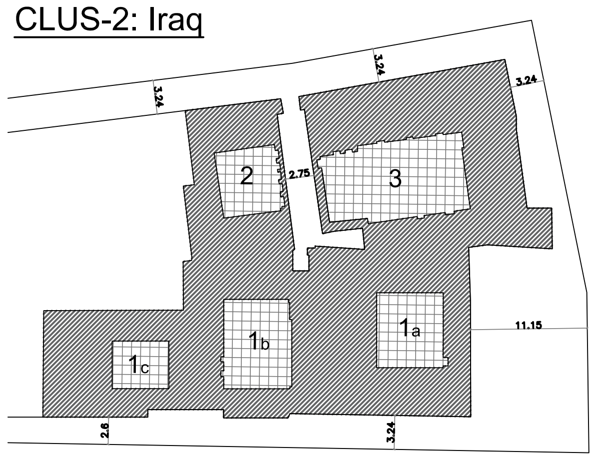
CLUS-1: Egypt



Total Area of the Cluster = 1185 m^2
Total Area of Public Spaces = 454 m^2
The Percent of Public Spaces relative to the Total Area of the Cluster = 38.3 %

Total Area of Houses = 731 m^2
Total Area of Covered Spaces = 569 m^2
Total Area of Private Courtyards = 162 m^2
The Percent of Private Courtyards relative to the Total Area of Houses = 22.2 %

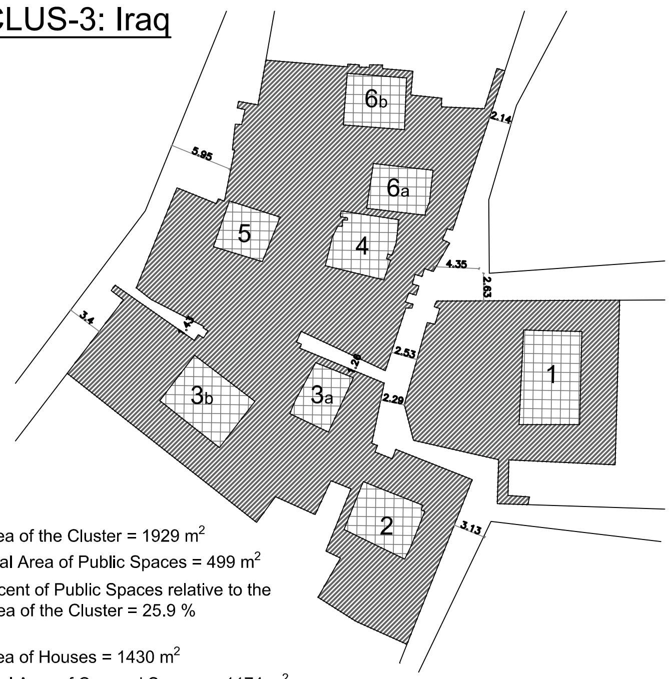
CLUS-2: Iraq



Total Area of the Cluster = 1642 m^2
Total Area of Public Spaces = 622 m^2
The Percent of Public Spaces relative to the Total Area of the Cluster = 37.9 %

Total Area of Houses = 1020 m^2
Total Area of Covered Spaces = 757 m^2
Total Area of Private Courtyards = 263 m^2
The Percent of Private Courtyards relative to the Total Area of Houses = 25.8 %

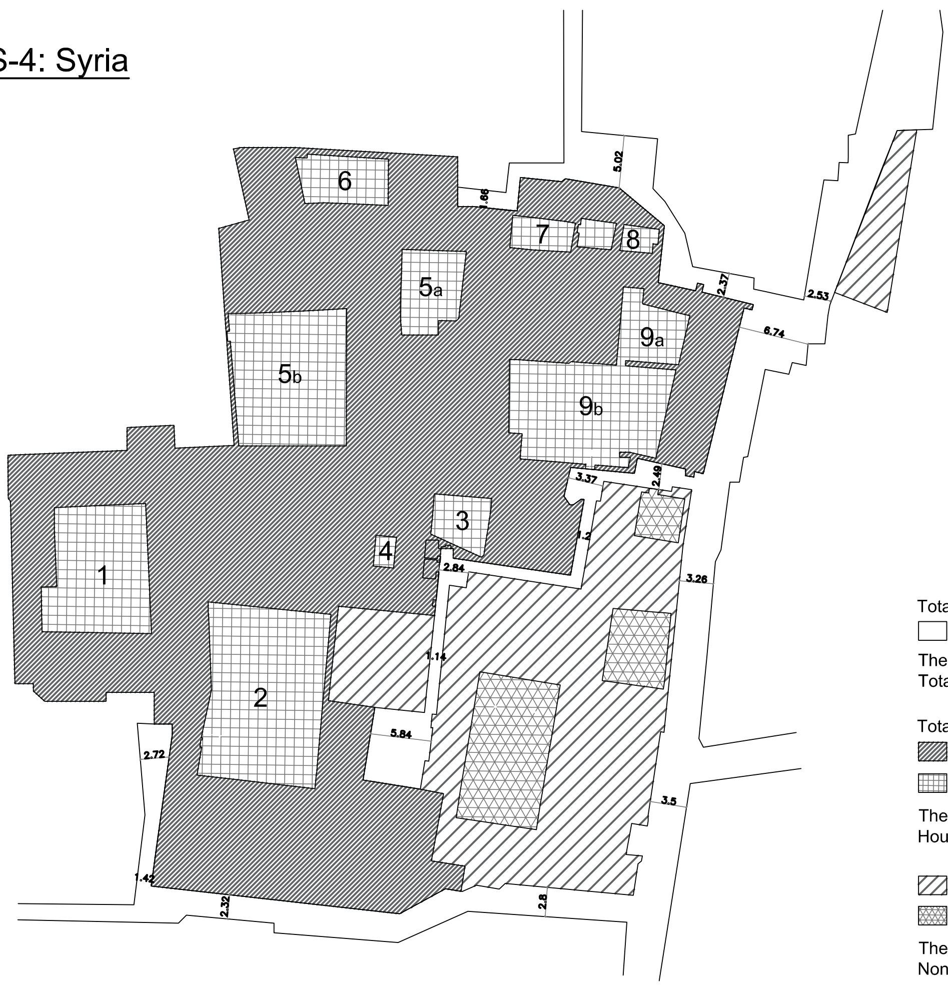
CLUS-3: Iraq



Total Area of the Cluster = 1929 m^2
Total Area of Public Spaces = 499 m^2
The Percent of Public Spaces relative to the Total Area of the Cluster = 25.9 %

Total Area of Houses = 1430 m^2
Total Area of Covered Spaces = 1174 m^2
Total Area of Private Courtyards = 256 m^2
The Percent of Private Courtyards relative to the Total Area of Houses = 17.9 %

CLUS-4: Syria



Total Area of the Cluster = 4525 m^2
Total Area of Public Spaces = 929 m^2
The Percent of Public Spaces relative to the Total Area of the Cluster = 20.5 %

Total Area of Houses = 2757 m^2
Total Area of Covered Spaces for Houses = 1998 m^2
Total Area of Private Courtyards in Houses = 759 m^2
The Percent of Private Courtyards relative to the Total Area of Houses = 27.5 %

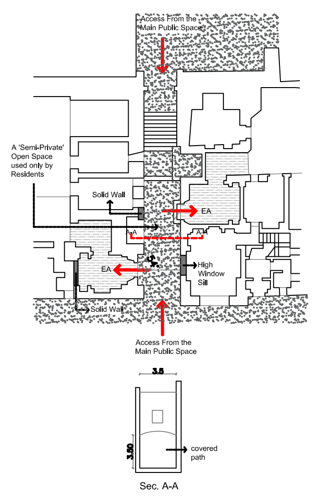
Total Area of Non-Residential Activities = 839 m^2
Total Area of Courtyards in Non-Residential Activities = 168 m^2
The Percent of Private Courtyards relative to the Total Area of Non-Residential Activities = 20.0 %

Social Indicator: Visual Privacy

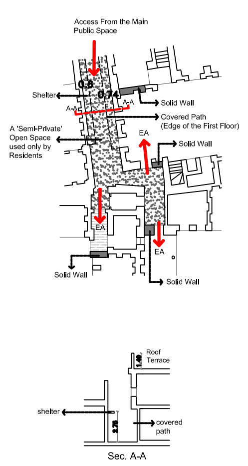
Strategies:

- 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.

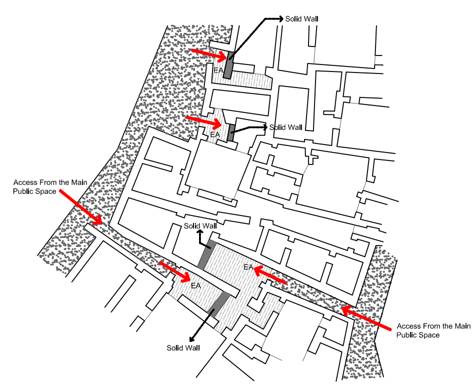
CLUS-1: Egypt



CLUS-2: Iraq



CLUS-3: Iraq



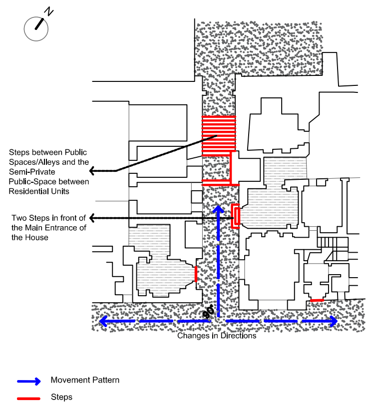
CLUS-4: Syria

Social Indicator: Hygiene / Accessibility

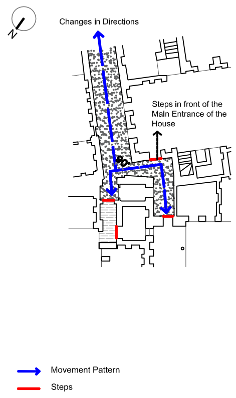
Strategies:

- 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

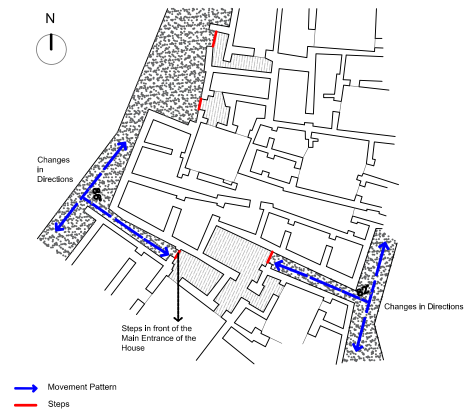
CLUS-1: Egypt



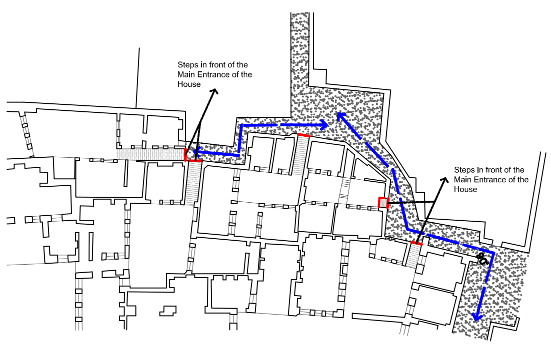
CLUS-2: Iraq

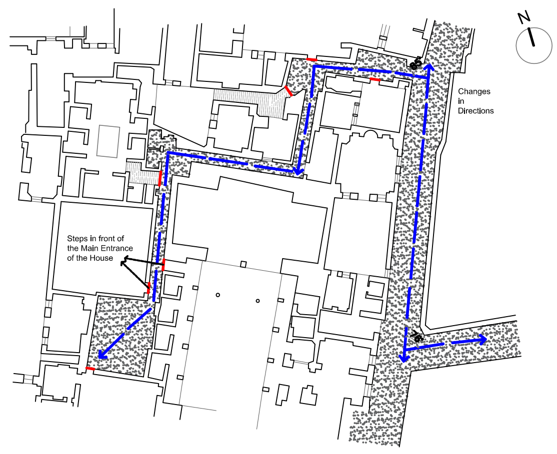


CLUS-3: Iraq



CLUS-4: Syria



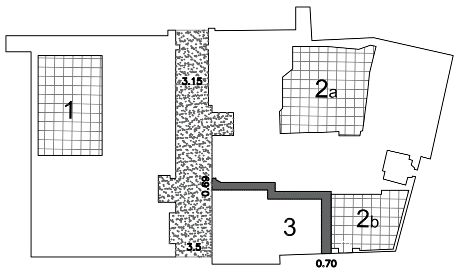


Social Indicator: Acoustical Privacy

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

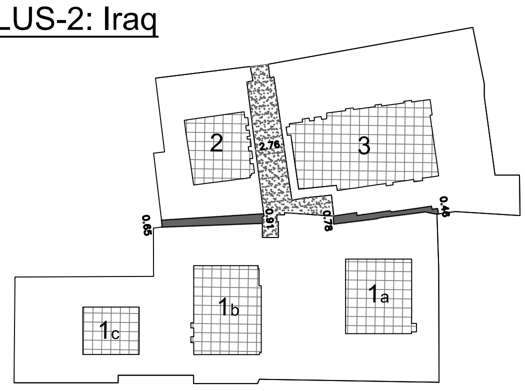


Shared Surface between Adjacent Houses (thickness = 70 cm)

Private Courtyards

Alleys between Houses (w = 3.15 to 3.50 m)

CLUS-2: Iraq

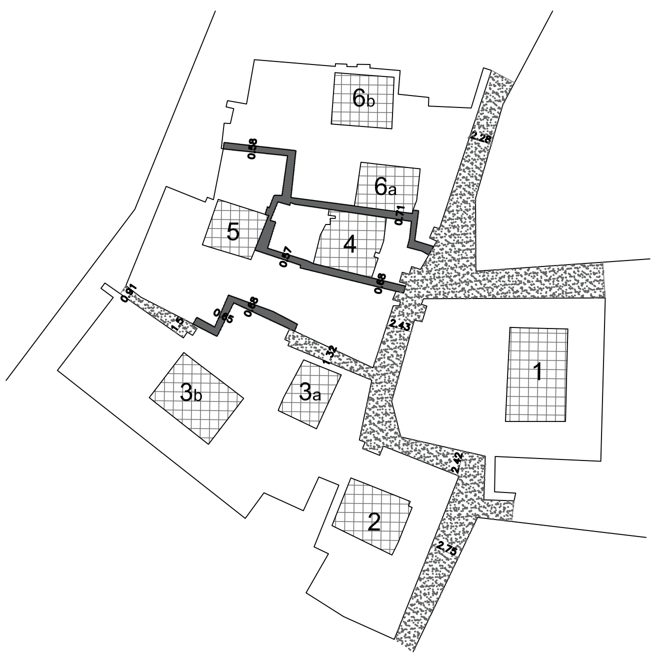


Shared Surface between Adjacent Houses (thickness = 46 to 91 cm)

Private Courtyards

Alleys between Houses (w = 2.76 m)

CLUS-3: Iraq

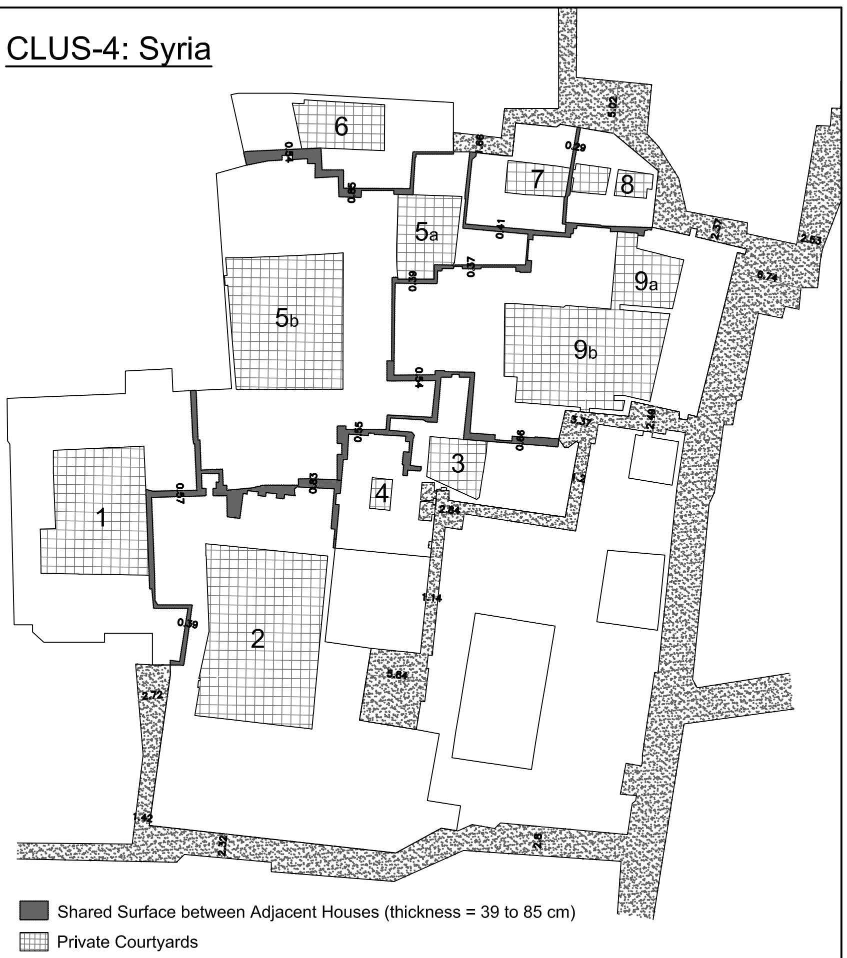


Shared Surface between Adjacent Houses (thickness = 57 to 71 cm)

Private Courtyards

Alleys between Houses (w = 0.91 to 2.75 m)

CLUS-4: Syria



Shared Surface between Adjacent Houses (thickness = 39 to 85 cm)

Private Courtyards

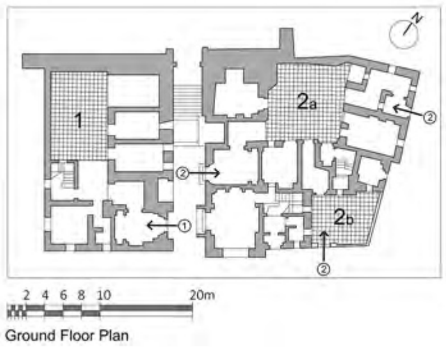
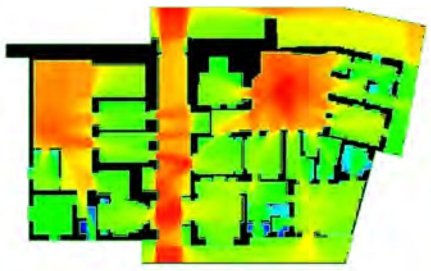
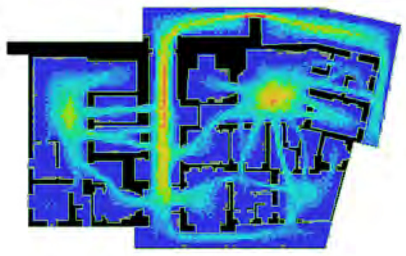
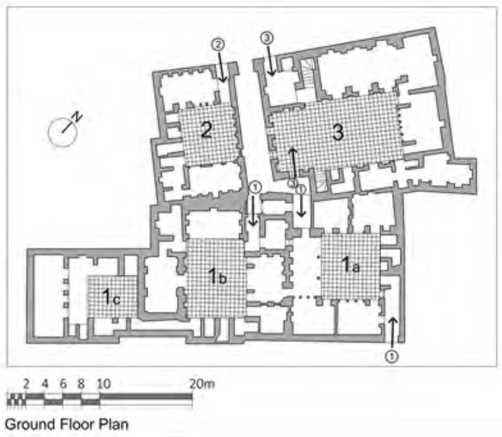
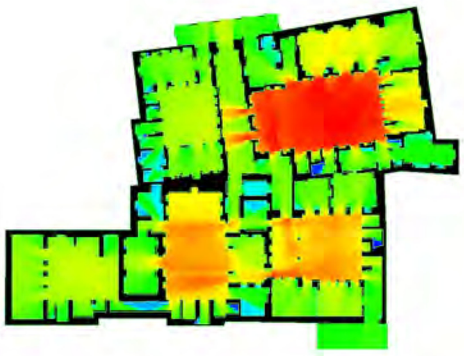
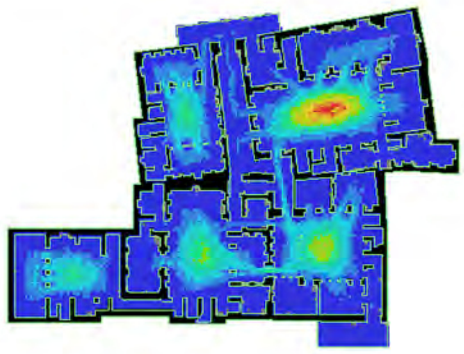
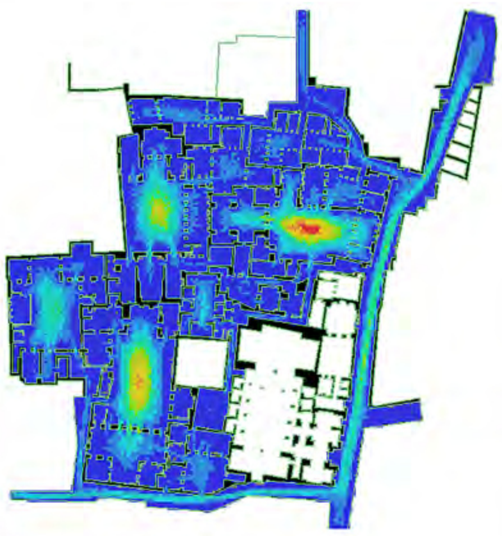
Alleys between Houses (w = 1.14 to 2.80 m)

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 (Number of points that are directly connected to other spaces)	Agent Analysis (Pattern of movement and frequent use of spaces, released from the public gathering space)
CLUS-1 (Egypt)			
CLUS-2 (Iraq)			
CLUS-3 (Iraq)			
CLUS-4 (Syria) Key: Maximum Amount Minimum Amount			

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		
CLUS-1 (Egypt)	 2 4 6 8 10 20m Ground Floor Plan	House (1) 	House (2) 	
CLUS-2 (Iraq)	 2 4 6 8 10 20m Ground Floor Plan	House (1) 	House (2) 	House (3) 
CLUS-3 (Iraq)	 2 4 6 8 10 20m Ground Floor Plan	House (1) 	House (2) 	House (3) 
		House (4) 	House (5) 	House (6) 

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
CLUS-4 (Syria)		 

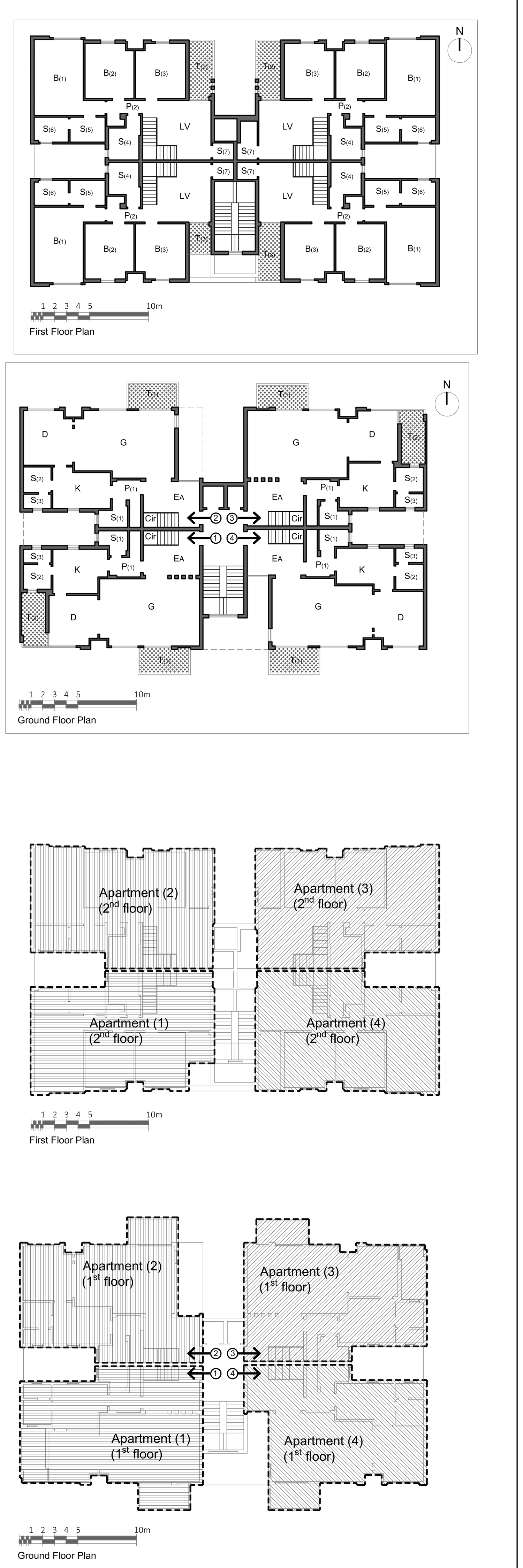
Appendix (4-B-13)

As-built Plans for the Selected Contemporary Apartment Buildings

As-Built Plan - Contemporary Apartment Buildings (5 cases)

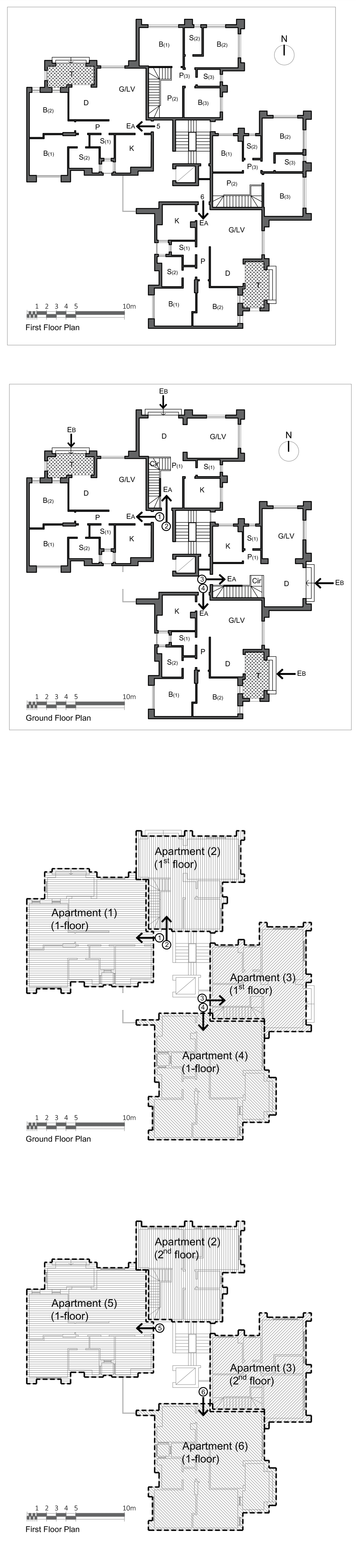
APR-1

West town residences, Cairo, Egypt.
(redrawn by the author, after
http://www.nileestate.com)



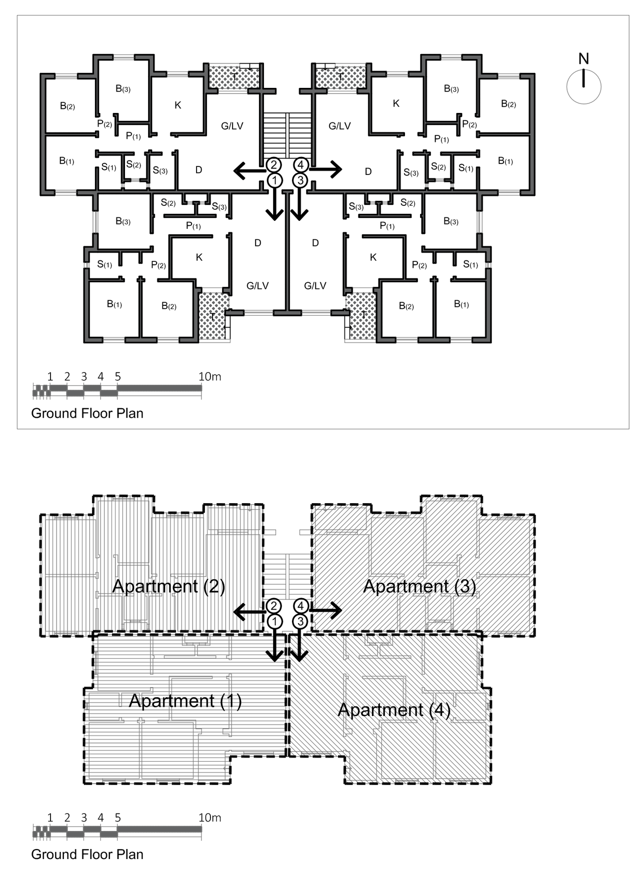
APR-2

The village gate project, Egypt.
(redrawn by the author, after
http://www.mlseg.info)



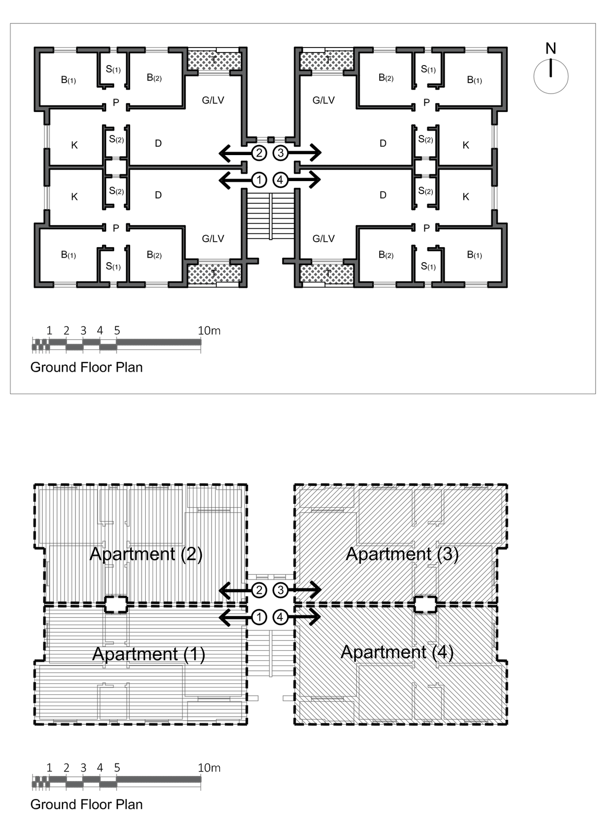
APR-3

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)

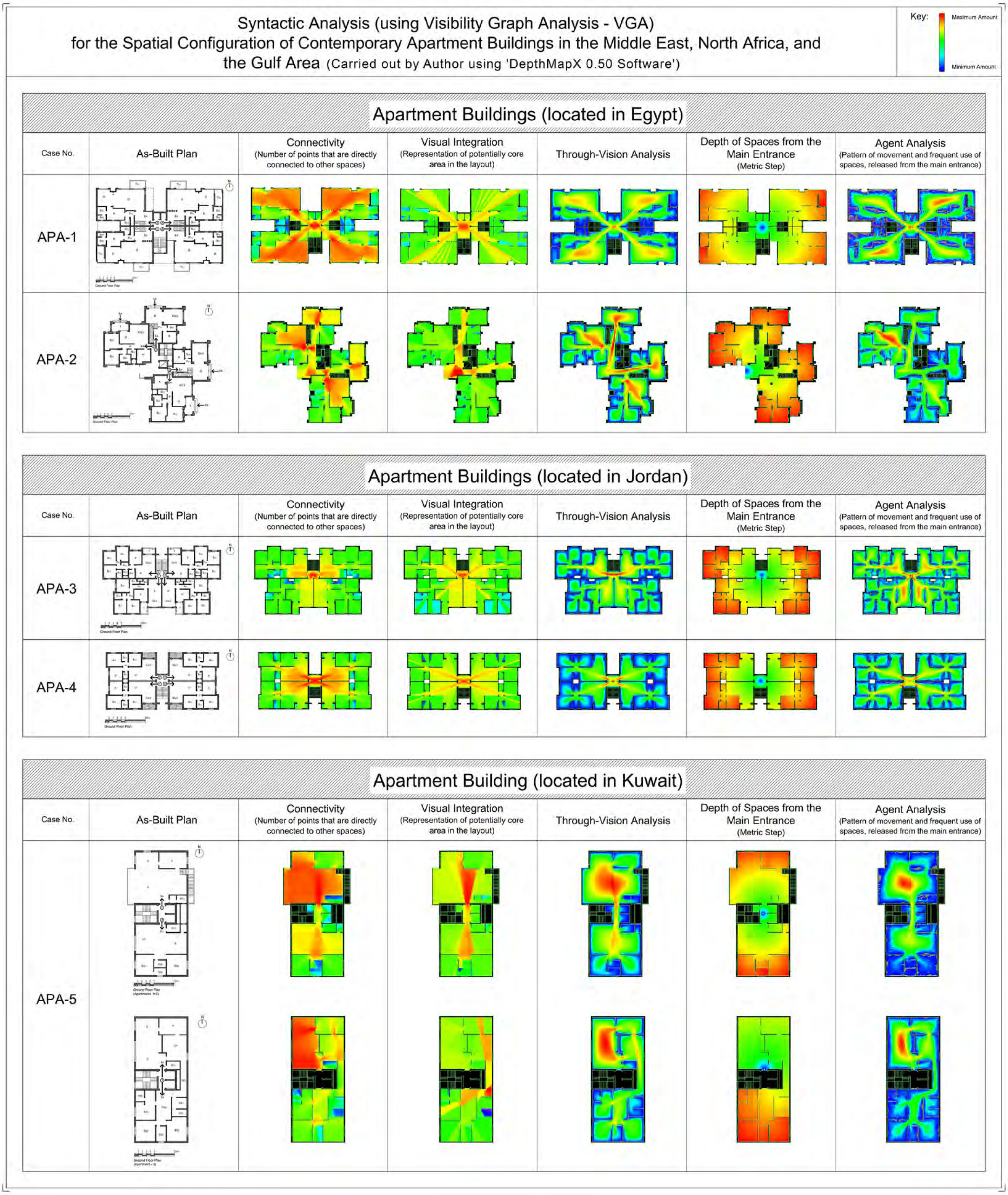


APR-5

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')
Key:
Maximum Amount
Minimum Amount
Apartment Buildings (located in Egypt)
Case No.
As-Built Plan
Connectivity
(Number of points that are directly connected to other spaces)
Visual Integration
(Representation of potentially core area in the layout)
Through-Vision Analysis
Depth of Spaces from the Main Entrance
(Metric Step)
Agent Analysis
(Pattern of movement and frequent use of spaces, released from the main entrance)
APA-1
APA-2
Apartment Buildings (located in Jordan)
APA-3
APA-4
Apartment Building (located in Kuwait)
APA-5

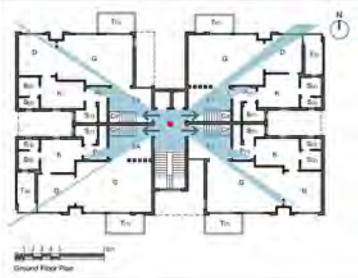
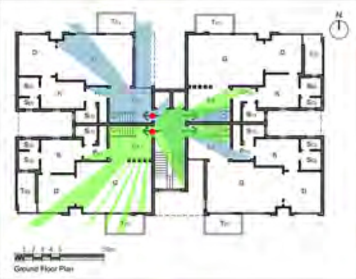
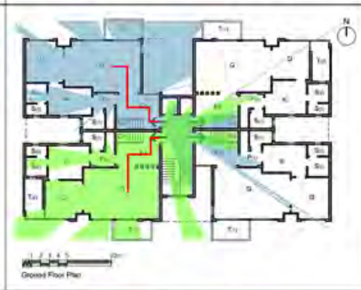
Appendix (4-B-15)

Isovist Analysis for the Selected Contemporary Apartment Buildings

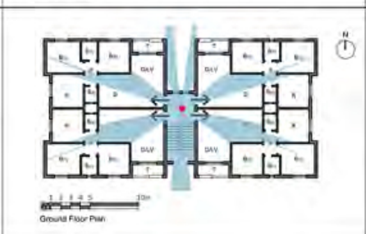
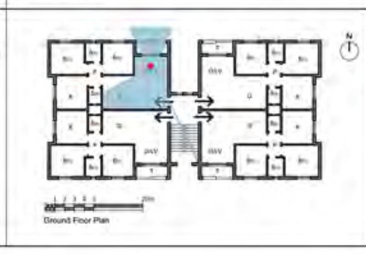
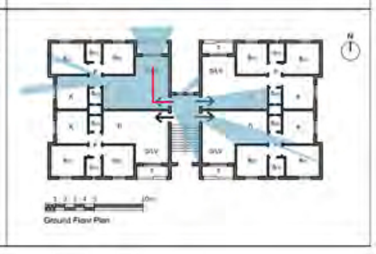
Visibility Study for the Main Floor from Different Points Inside Contemporary Apartment Buildings in the Middle East, North Africa, and the Gulf Area

(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

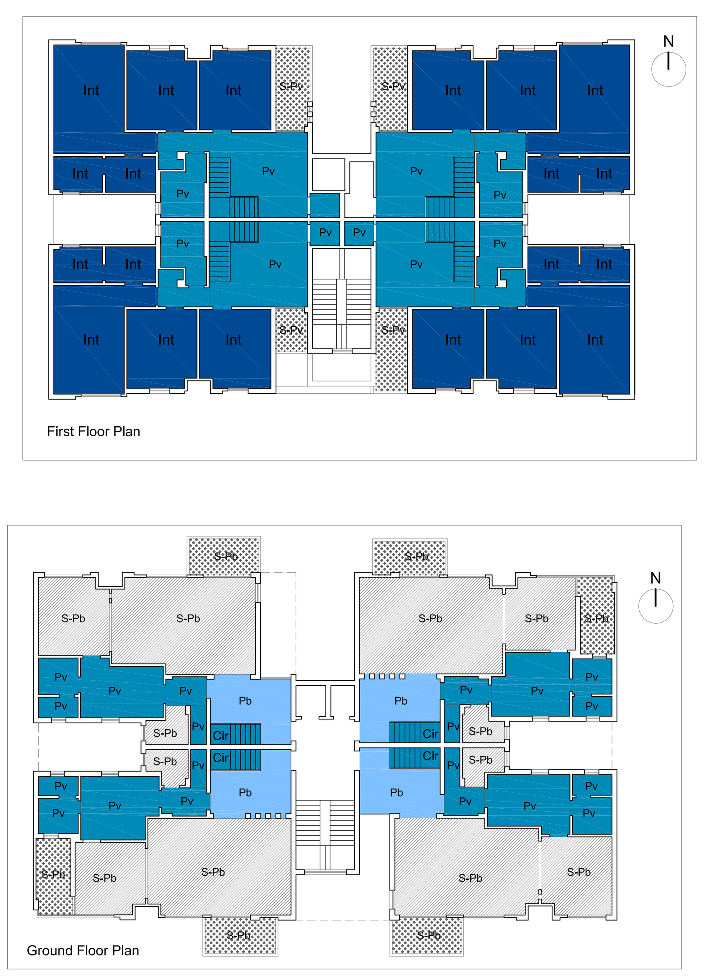
Hierarchy of Spaces

Contemporary Apartment Buildings (5 cases)

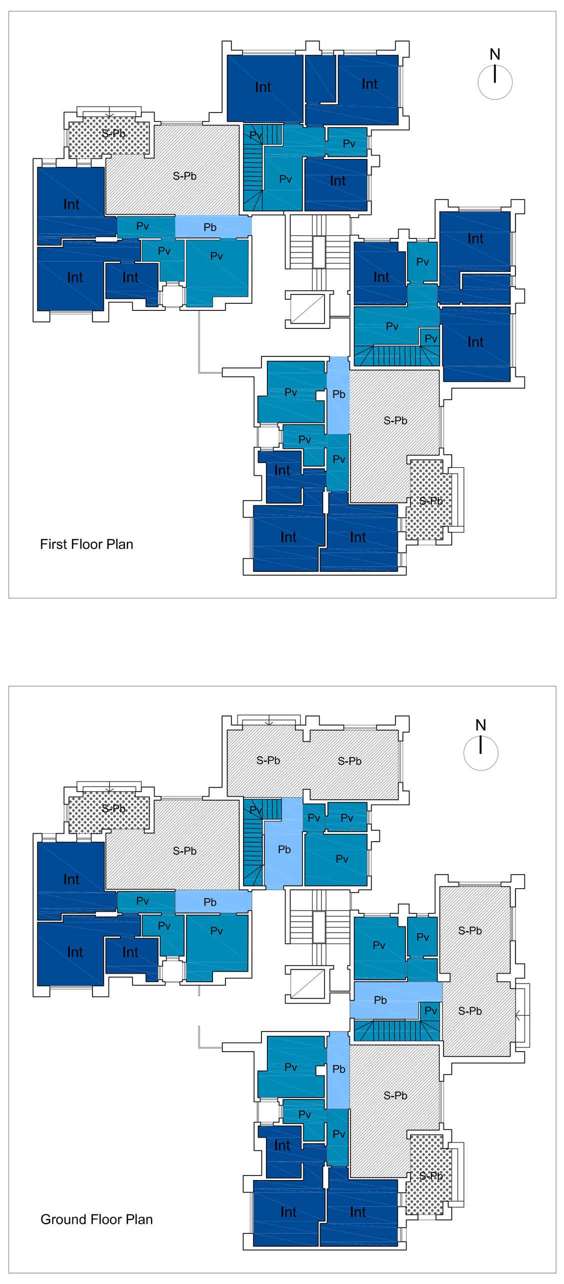
Key:

- Public Spaces (Pb)
  (Main Entry Hall)
- Semi-Public Spaces (S-Pb)
  (Guest Room, Toilet for Guests)
- 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)

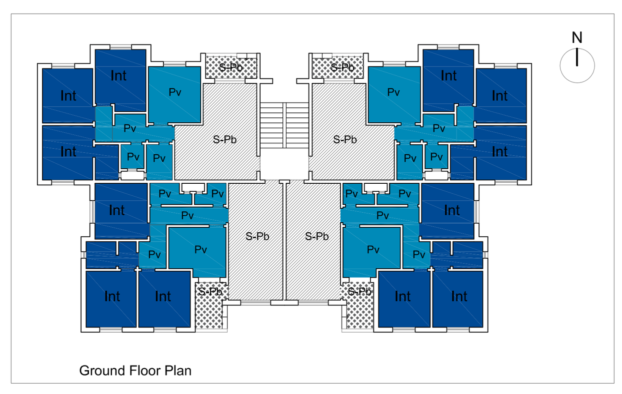
APR-1 EGYPT



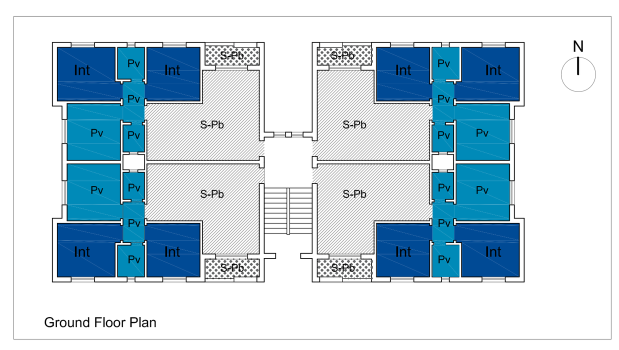
APR-2 EGYPT



APR-3 JORDAN



APR-4 JORDAN



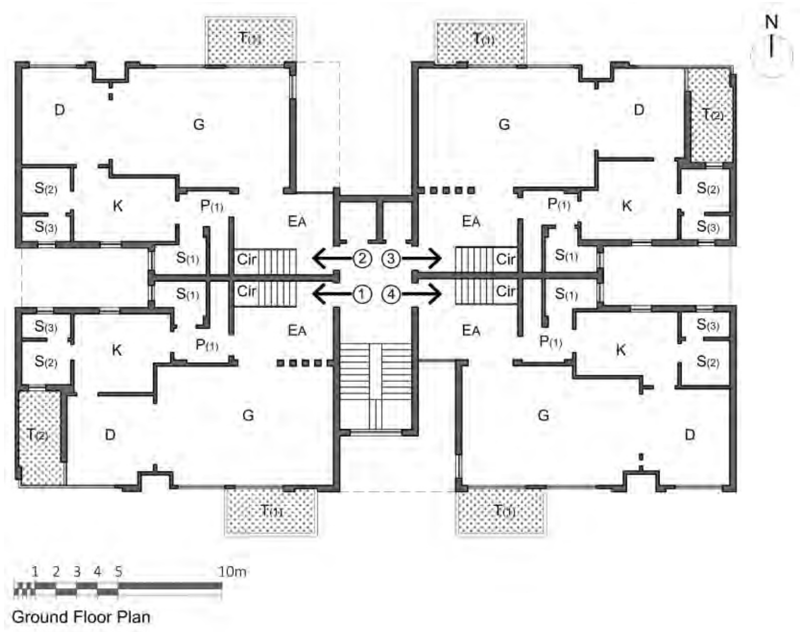
APR-5 KUWAIT

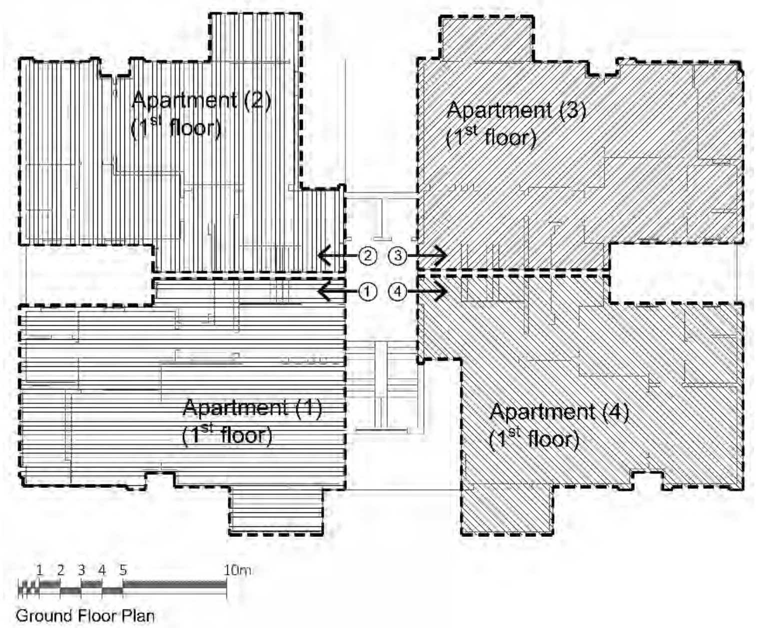
<u>Appendix (4-B-17)</u>

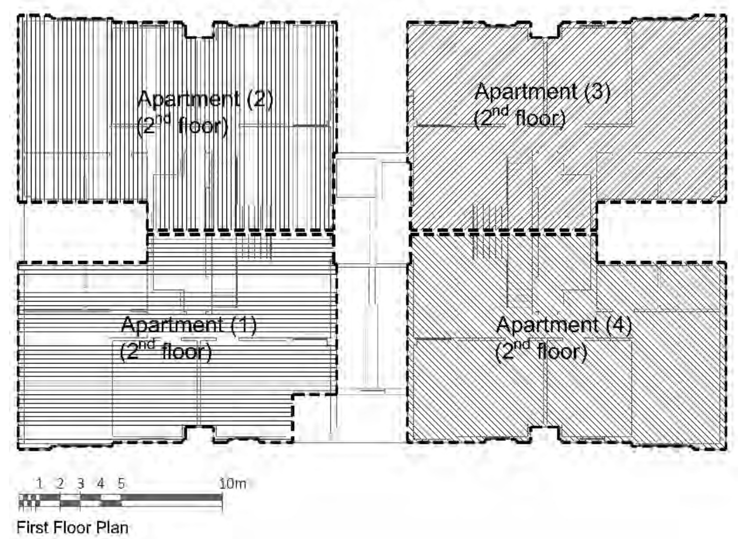
Syntactic Diagrams for the Selected Contemporary Apartment Buildings

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)



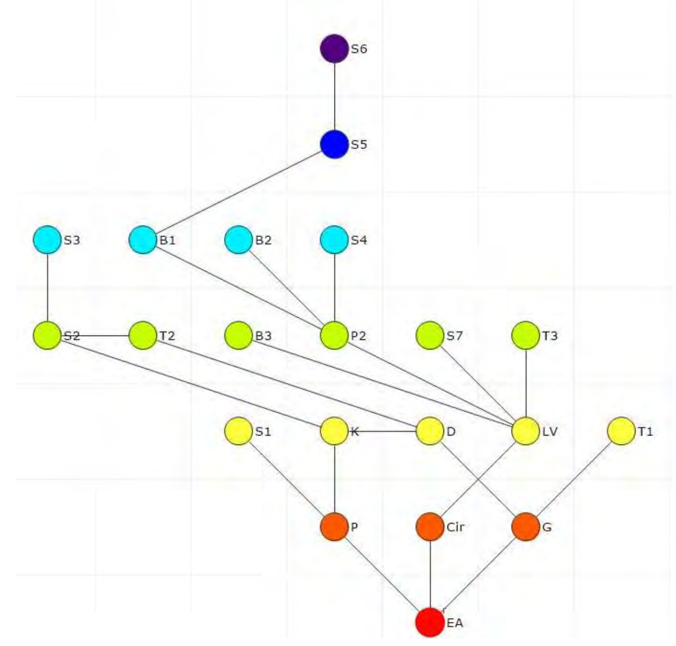




EA: Main Entrance Hall/Corridor
EB: Services Entrance
C : Courtyard
IW: Iwan
GL : Gallery
T : Roof Terrace / Balcony
G : Guest Room (Reception)
D : Dining Room
LV: Family Living Room
B : Intimate Spaces (Bedrooms)
K : Kitchen
S : Services (Toilets, Storage)
P : Passage / Transitional Space
DV: Double Volume

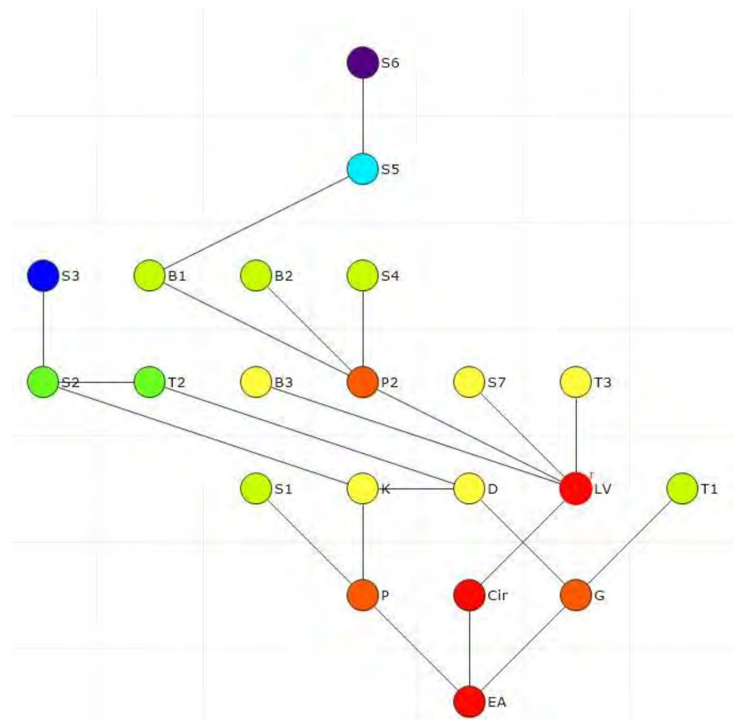
Space Syntax Analysis
Diagrams produced by Researcher using AGRAPH Online software
(https://www.ntnu.no/ab/spacesyntax)

Depth of Spaces



Shallow Deep Spaces

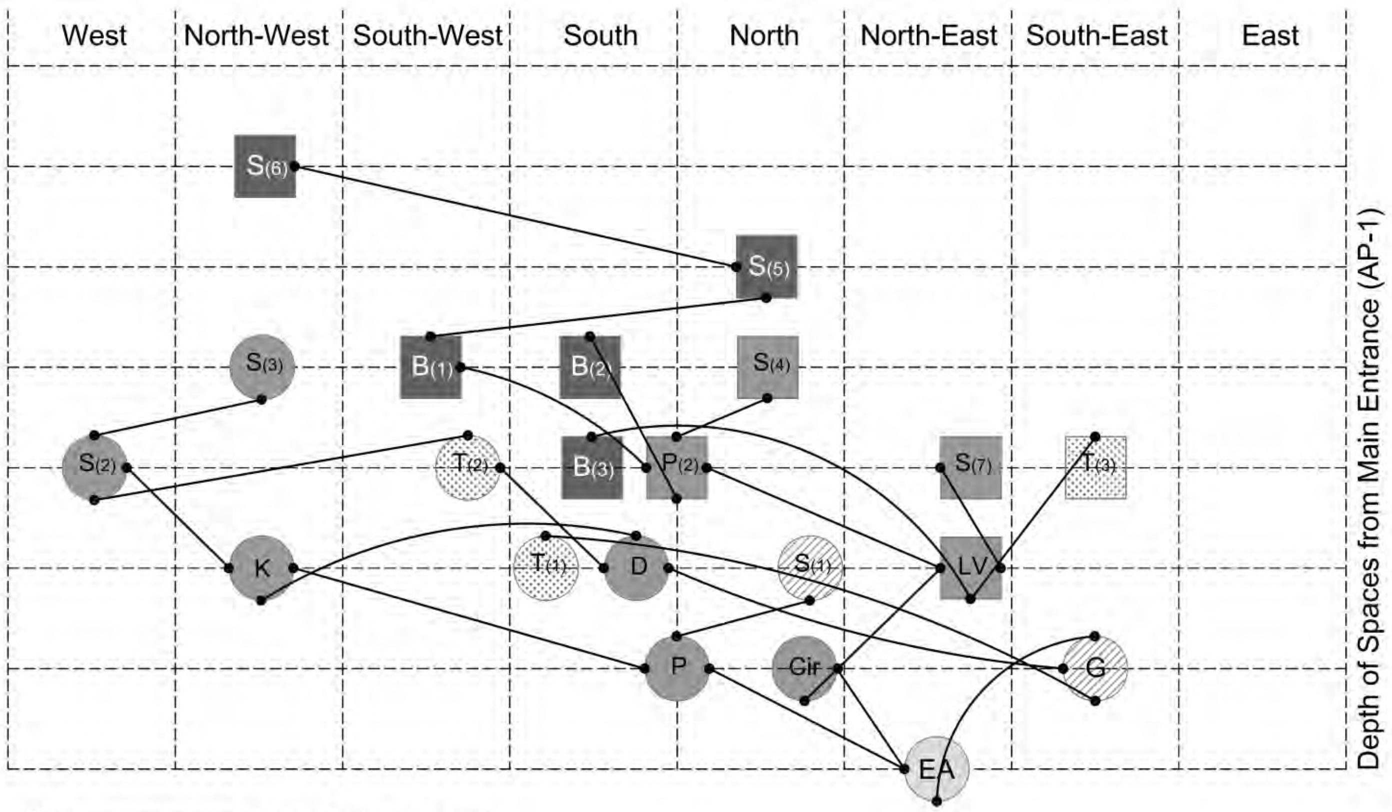
Integration of Spaces with the Living Room and the Entrance
(the courtyard has the greatest control value)



High Low Integration

The Social Logic of the Spatial Arrangement of an Apartment Building in Cairo, Egypt	Region	North Africa	Country	Egypt	Case No.	AP-1

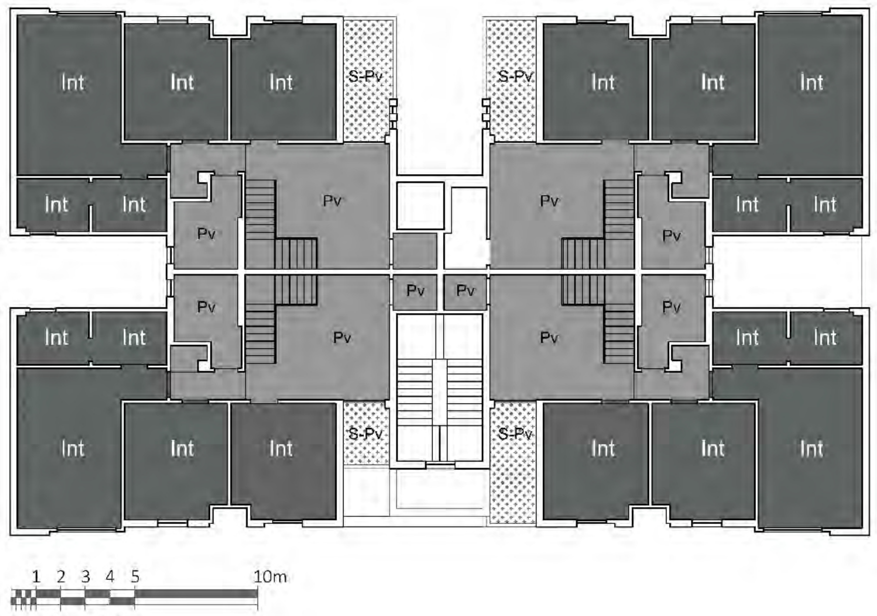
Hierarchy and Depth of Spaces (according to the orientation, and type of spaces)
(Researcher)



- Spaces located on the Ground Floor (circle)
- Spaces located on the First Floor (square)
- • Direction of Surface Interaction between Spaces

Ground 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)

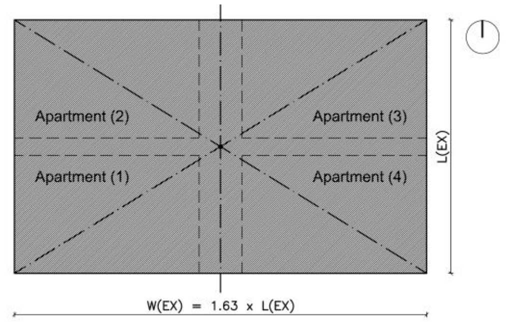


First Floor Plan

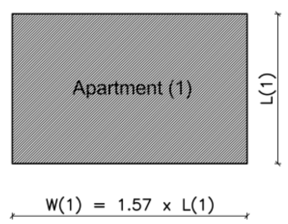
The Social Logic of the Spatial Arrangement of an Apartment Building in Cairo, Egypt

Region	North Africa	Country	Egypt	Case No.	AP-1

Typology and Geometric Properties of the Building and Apartments
(Researcher)

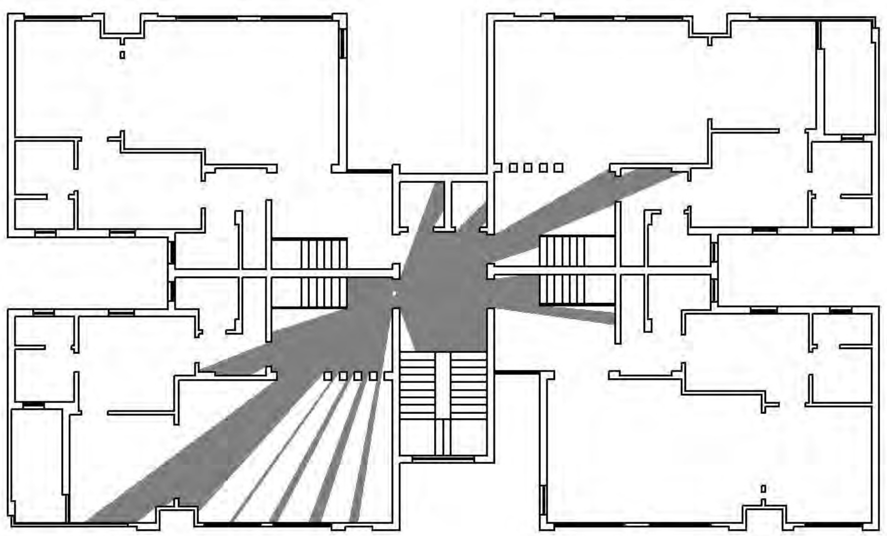


Typology	Recatngular layout
Exterior layout	1: 1.63
Each Apartment	1 : 1.57
	22.5% of the total area of the building
Thickness of exterior walls	30 cm
Height of Guest/Living spaces	

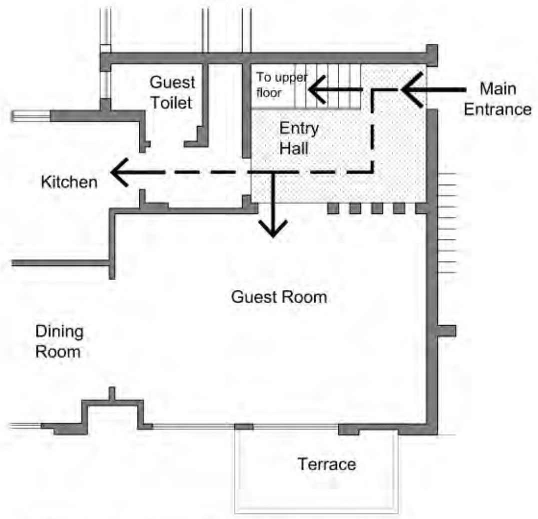


Spaces	Dominant Users (Male / Female)	Percentage of area of this space related to the total area of the apartment	Percentage of area of this space related to the floor area where it is located		Proportion of Spaces
			Ground	1st Floor	
Corridor	M+F	5.40 %	3.00 %	7.70 %	1 : 1.6 , 1 : 3
Terraces	M+F	8.00 %	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

Visual analysis from the main entrance towards guest rooms and private/intimate spaces (Produced by Syntax2D)
(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 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		

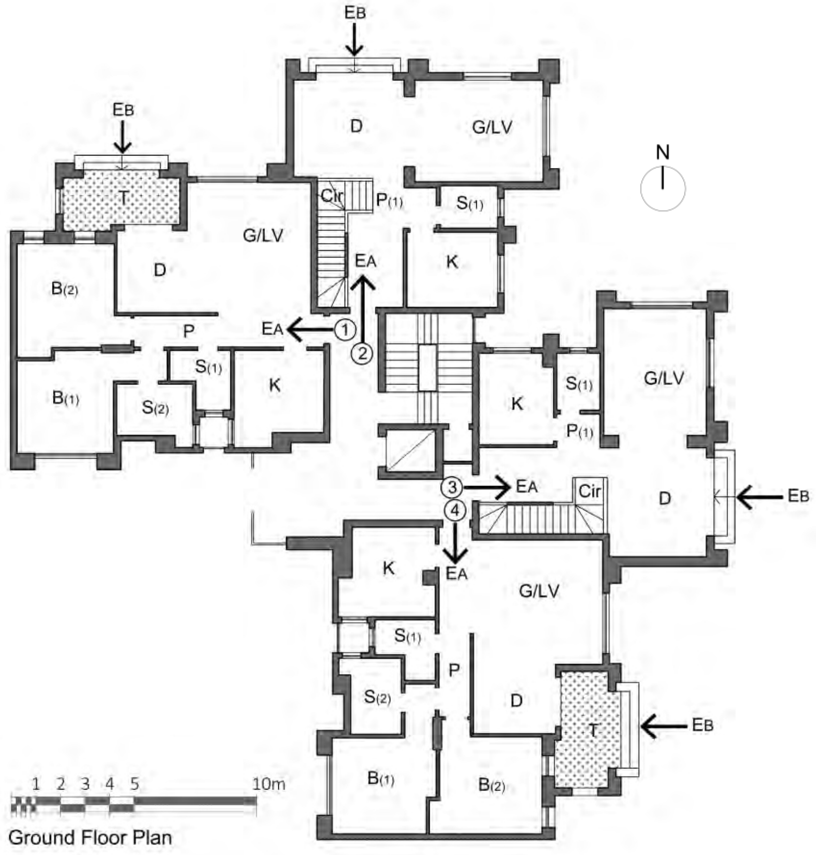
Spaces	TDn	MDn	RA	i	CV	NCn
Cir	57	2.85	0.19	5.13	0.53	2
EA	58	2.90	0.20	5.00	1.16	3
LV	58	2.90	0.20	5.00	3.75	5
P	67	3.35	0.24	4.04	1.66	3
P2	67	3.35	0.24	4.04	2.70	4
G	68	3.40	0.25	3.95	1.66	3
K	76	3.80	0.29	3.39	1.00	3
D	77	3.85	0.30	3.33	1.16	3
B3	77	3.85	0.30	3.33	0.20	1
S7	77	3.85	0.30	3.33	0.20	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		

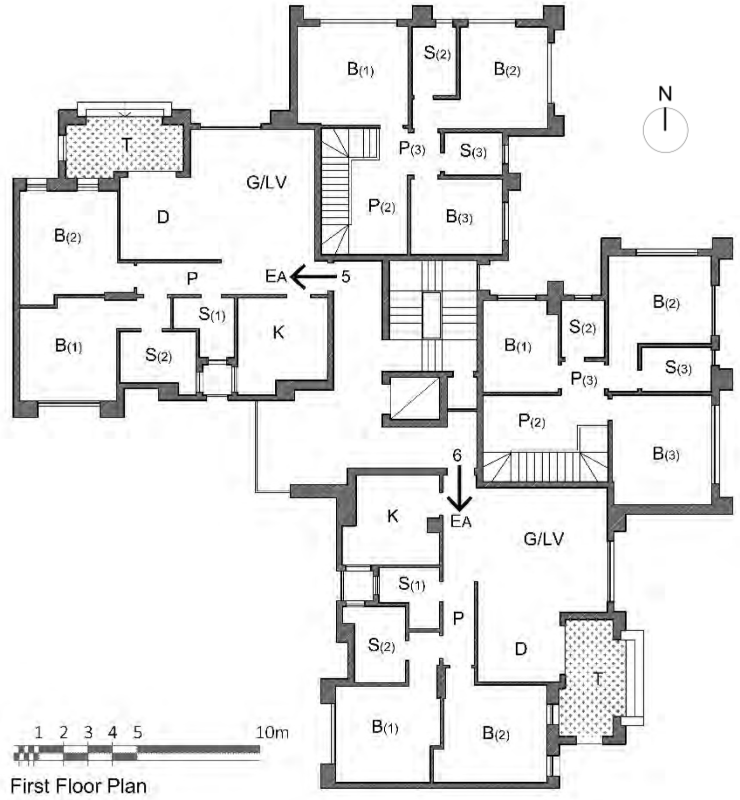
Integration Values:
Vertical Circulation > Entrance, Living Area > Corridors > Guest Room > Kitchen > Dining Room > Bedrooms > Terraces > Services (Toilets)

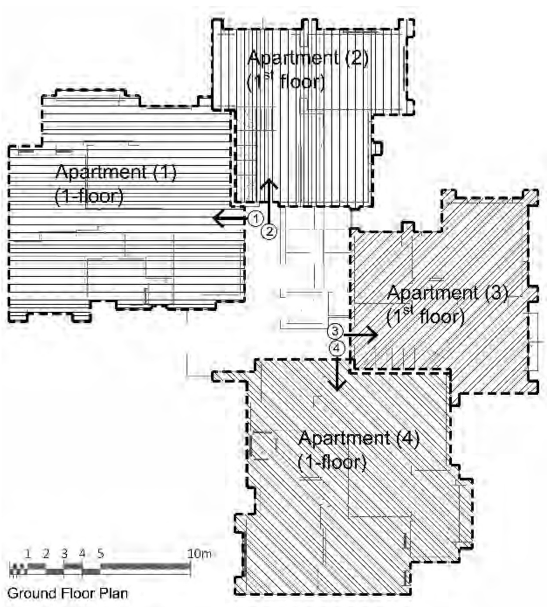
Lowest Integration Values:
- Services (Toilets)
- Terraces

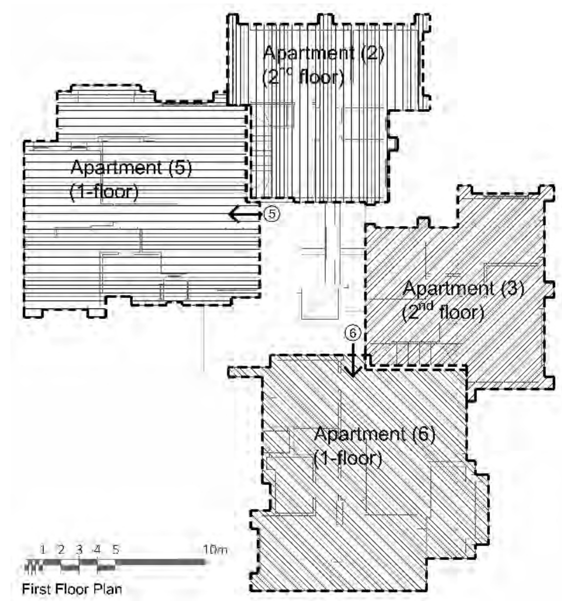
Highest Integration and Control Values:
- Vertical circulation (stairs)
- Entrance
- Corridors

The Social Logic of the Spatial Arrangement of an Apartment Building in Cairo, Egypt	Region	North Africa	Country	Egypt	Case No.	AP-2
Architectural Plans for an Apartment Building, 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)					



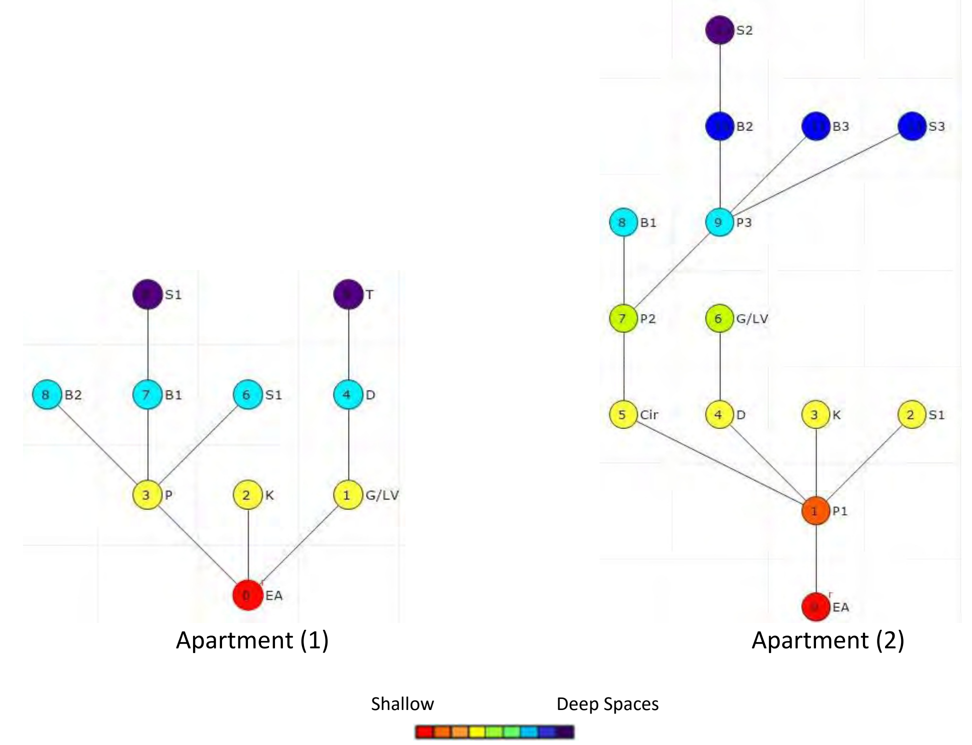




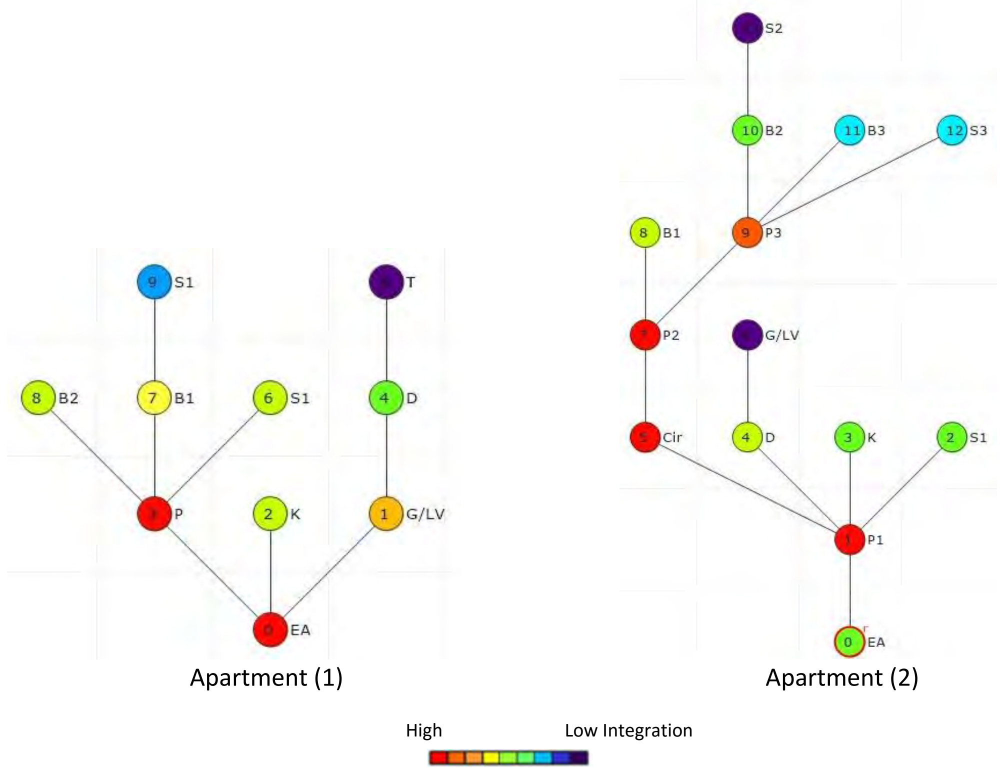


EA: Main Entrance Hall/Corridor
EB: Services Entrance
C : Courtyard
IW: Iwan
GL : Gallery
T : Roof Terrace / Balcony
G : Guest Room (Reception)
D : Dining Room
LV: Family Living Room
B : Intimate Spaces (Bedrooms)
K : Kitchen
S : Services (Toilets, Storage)
P : Passage / Transitional Space
DV: Double Volume

Depth of Spaces



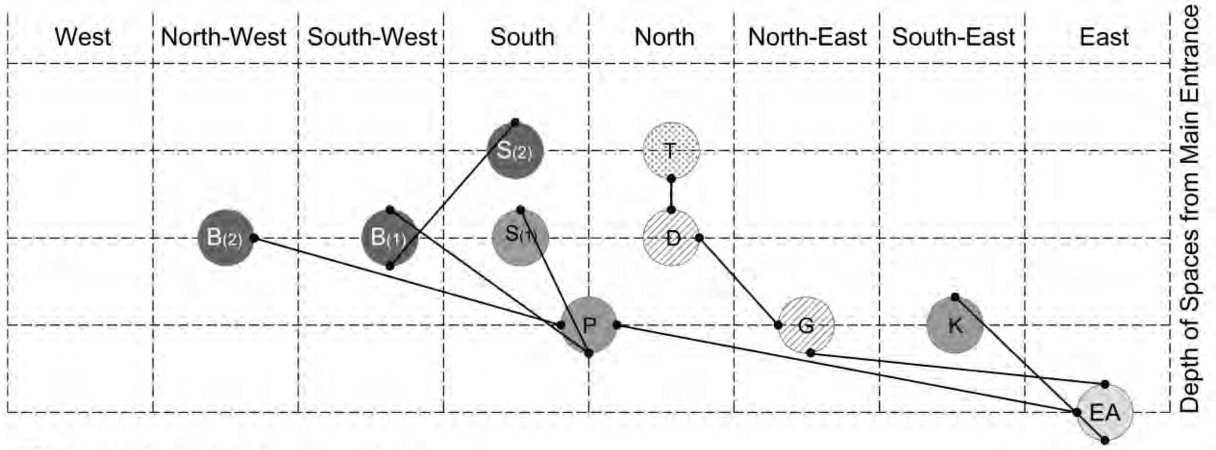
Integration of Spaces with the Living Room and the Entrance
(the courtyard has the greatest control value)



The Social Logic of the Spatial Arrangement of an Apartment Building in Cairo, Egypt	Region	North Africa	Country	Egypt	Case No.	AP-2

Hierarchy and Depth of Spaces (according to the orientation, and type of spaces)
(Researcher)

Hierarchy and Depth of Spaces for Apartment (1)

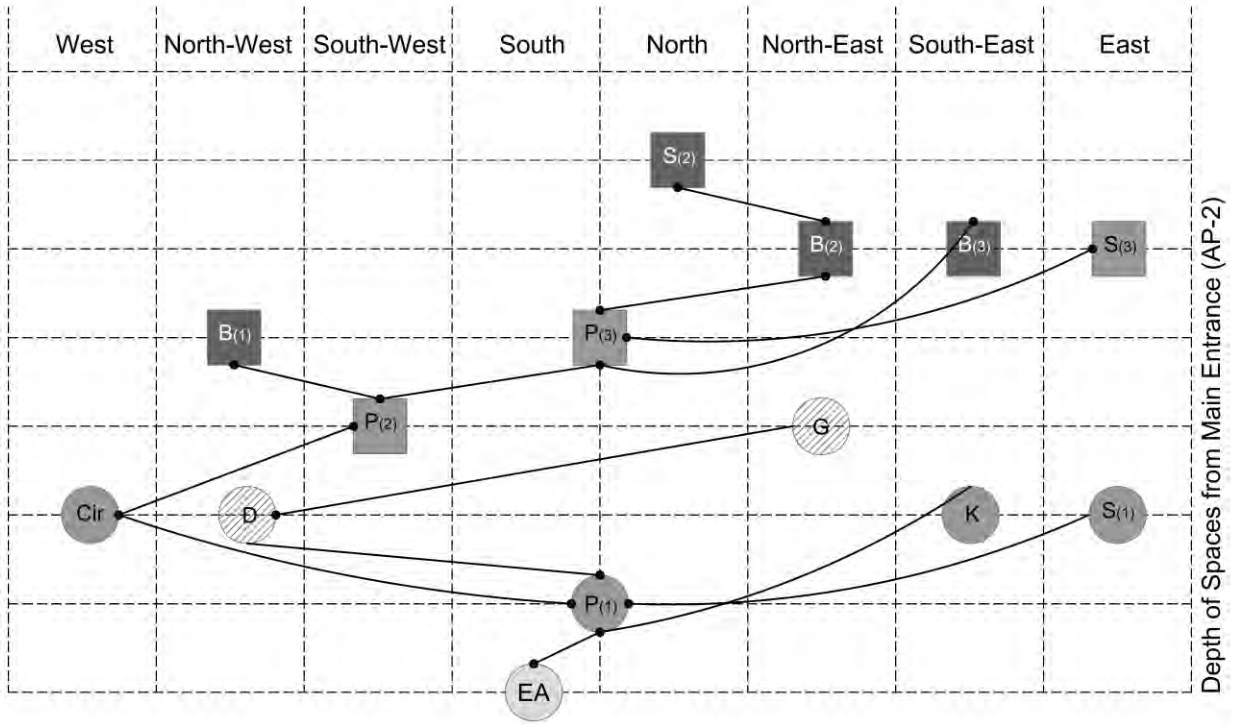


◯ Spaces located on the Ground Floor

• 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)

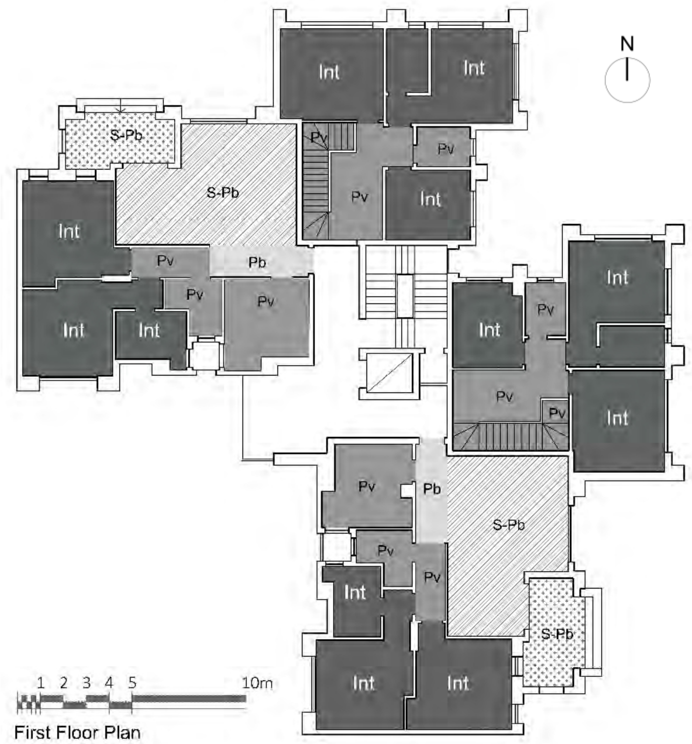
Hierarchy and Depth of Spaces for Apartment (2)



◯ Spaces located on the Ground Floor

☐ Spaces located on the First Floor

• Direction of Surface Interaction between Spaces



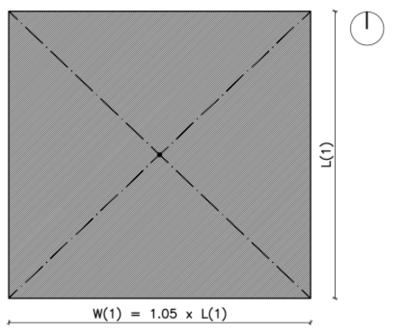
The Social Logic of the Spatial Arrangement of an Apartment Building in Cairo, Egypt	Region	North Africa	Country	Egypt	Case No.	AP-2

Typology and Geometric Properties of the Building and Apartments

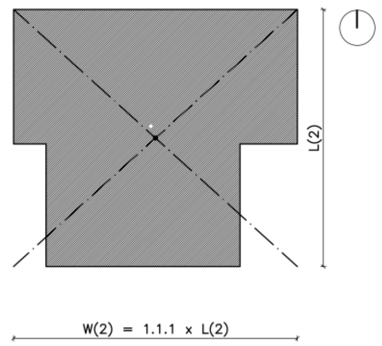
(Researcher)

Typology	Each apartment is a square
Apartment 1 (one-floor apartment)	1 : 1.05
	27 % of the total area of the floor
Apartment 2 (two-floors apartment)	1 : 1.10
	Each level = 17 % of the total area of the floor in the building
Thickness of exterior walls	30 cm
Height of Guest/Living spaces	

Geometric Pattern for Apartments 1 and 4
(1-floor apartments)



Geometric Pattern for Apartments 2 and 3
(2-floors apartments)



Type (1): one-floor apartment / **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	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**
Spaces			**Ground**	**1st 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

Integration of Spaces FOR Apartments (1, 4) using Space Syntax Theory

(Calculations produced by AGRAPH Online software)
(https://www.ntnu.no/ab/spacesyntax)

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:

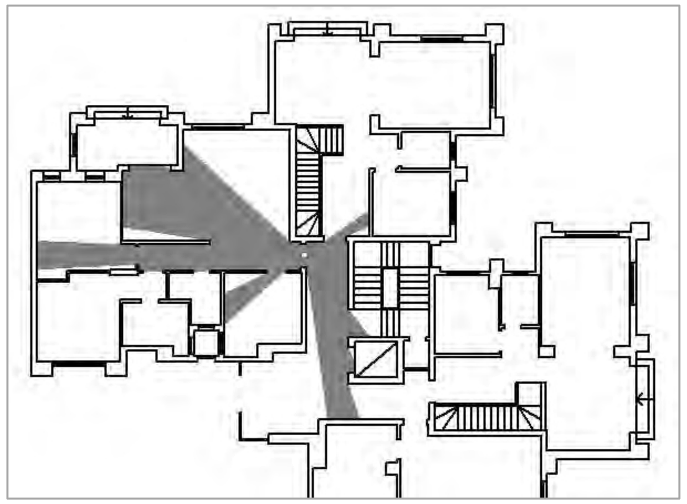
- Entrance
- Corridors

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)

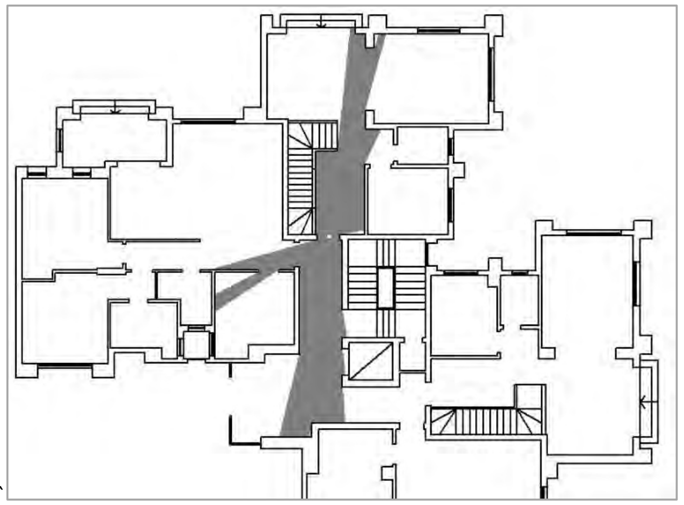
Visual analysis from the main entrance towards guest rooms and private/intimate spaces (Produced by Syntax2D)
(https://sourceforge.net/projects/syntax2d/?source=typ_redirect)

Visual Analysis for Apartment (1)



Generally, there is no direct visual connection between the entrance/guest room, and bedrooms

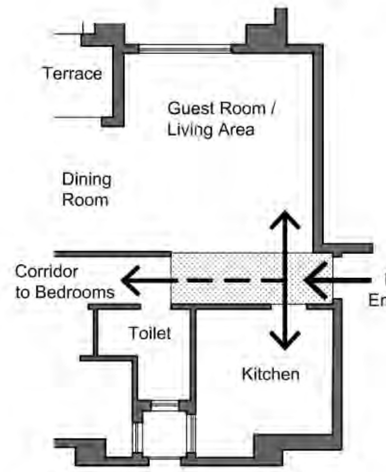
Visual Analysis for Apartment (2)



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

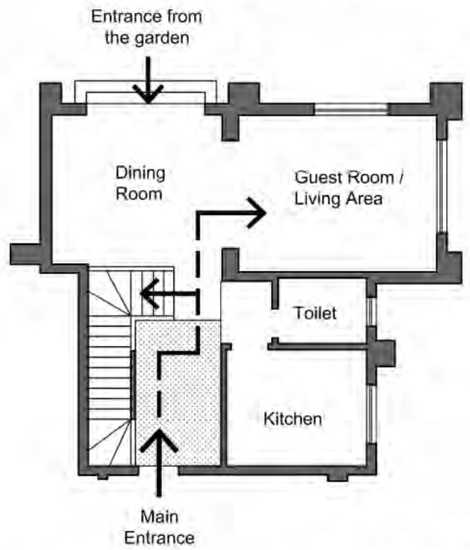
Pattern of movement from the entrance to other spaces (Researcher)

Circulation Pattern for Apartments 1 and 4
(1-floor apartments)



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.

Circulation Pattern for Apartments 2 and 3
(2-floors apartments)



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.

Integration of Spaces (for Apartments 2, 3) using Space Syntax Theory
(Calculations produced by AGRAPH Online software)
(https://www.ntnu.no/ab/spacesyntax)

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

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)

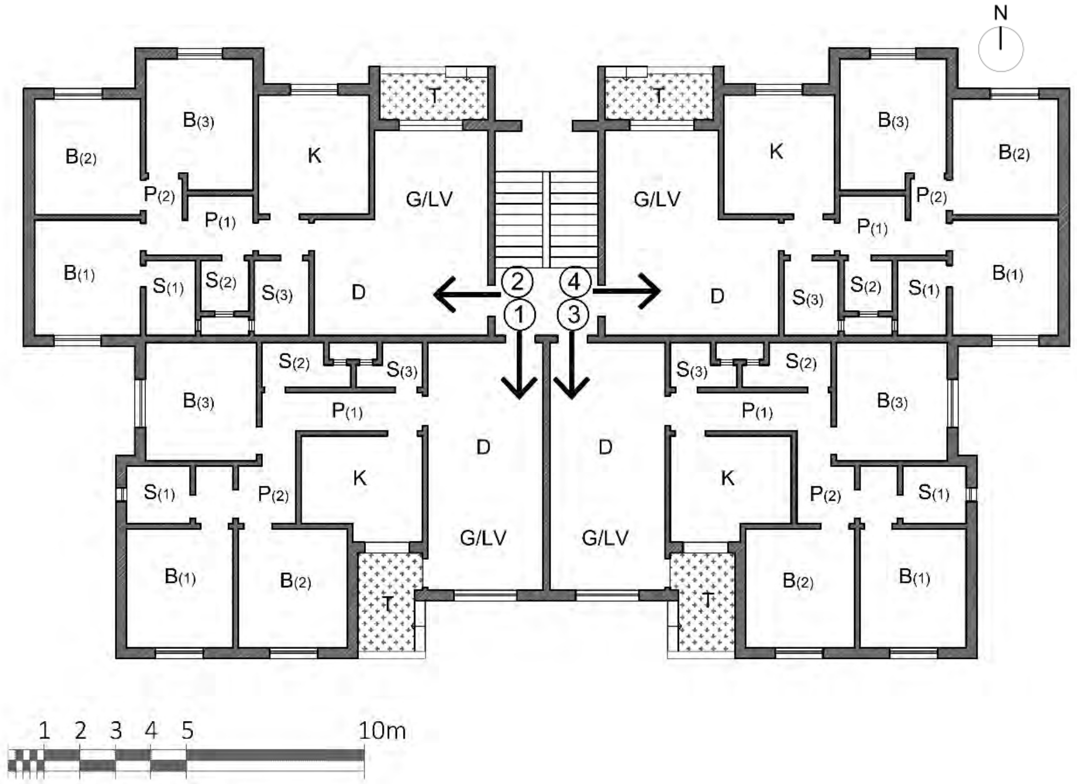
Lowest Integration Values:
- Services (Toilets)
- Guest Room

Highest Integration and Control Values:
- Vertical circulation (stairs)
- Corridors

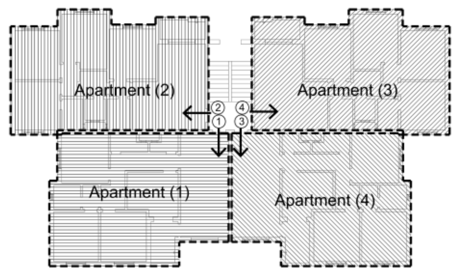
The Social Logic of the Spatial Arrangement of an Apartment Building in Amman, Jordan	Region	Middle East	Country	Jordan	Case No.	AP-3

Architectural Plans for an Apartment Building, Amman, Jordan

(Redrawn by Researcher, http://www.csbe.org (accessed 20/10/2016)



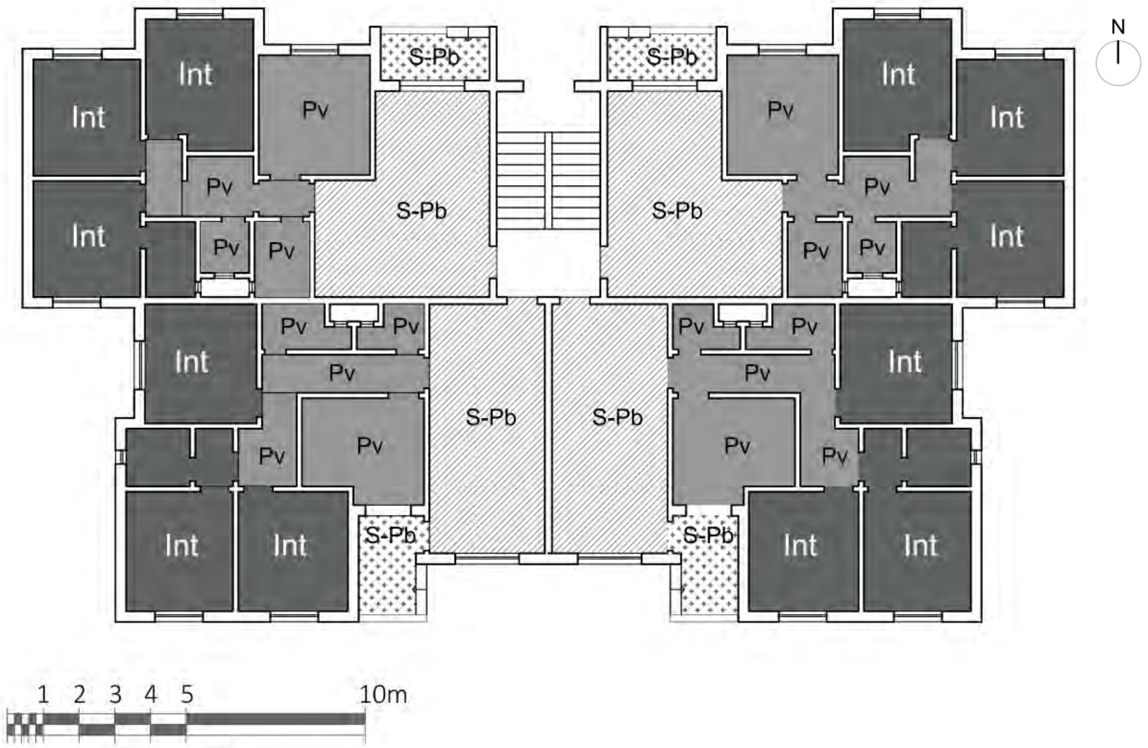
Ground Floor Plan



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

Hierarchy of Spaces

(Researcher)



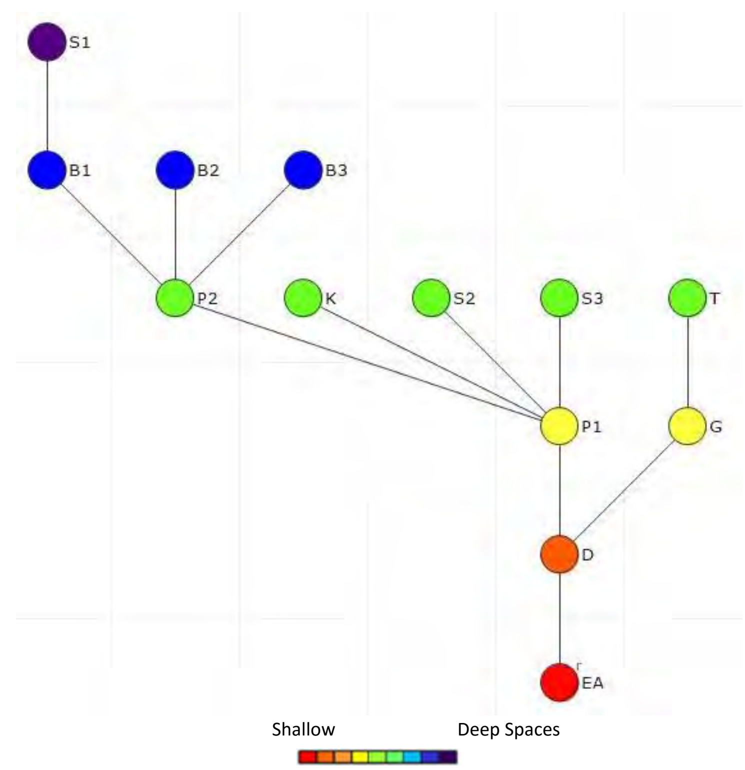
Ground Floor Plan

- 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)
- Clr — Vertical Circulation (Stairs to roof / upper floors)

Space Syntax Analysis

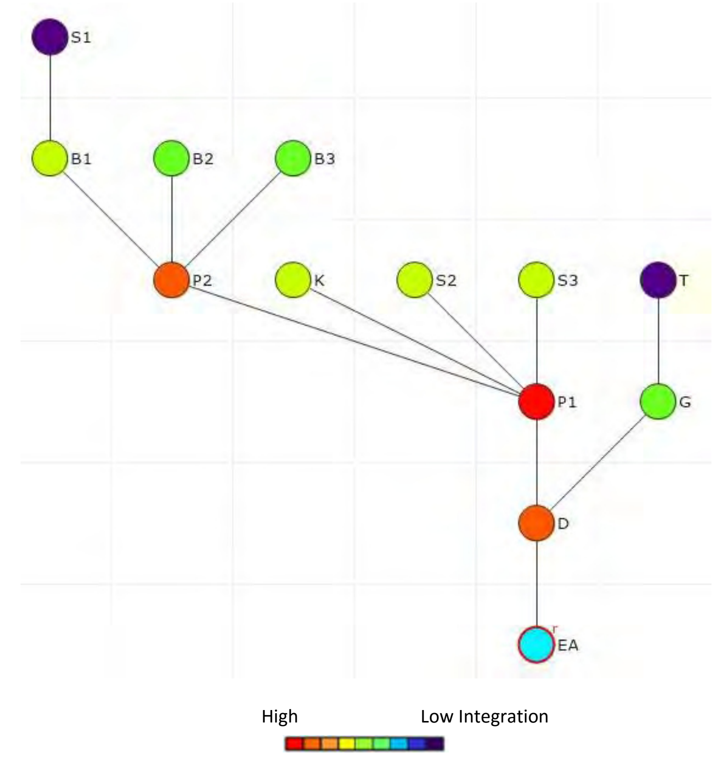
Diagrams produced by Researcher using AGRAPH Online software (https://www.ntnu.no/ab/spacesyntax)

Depth of Spaces



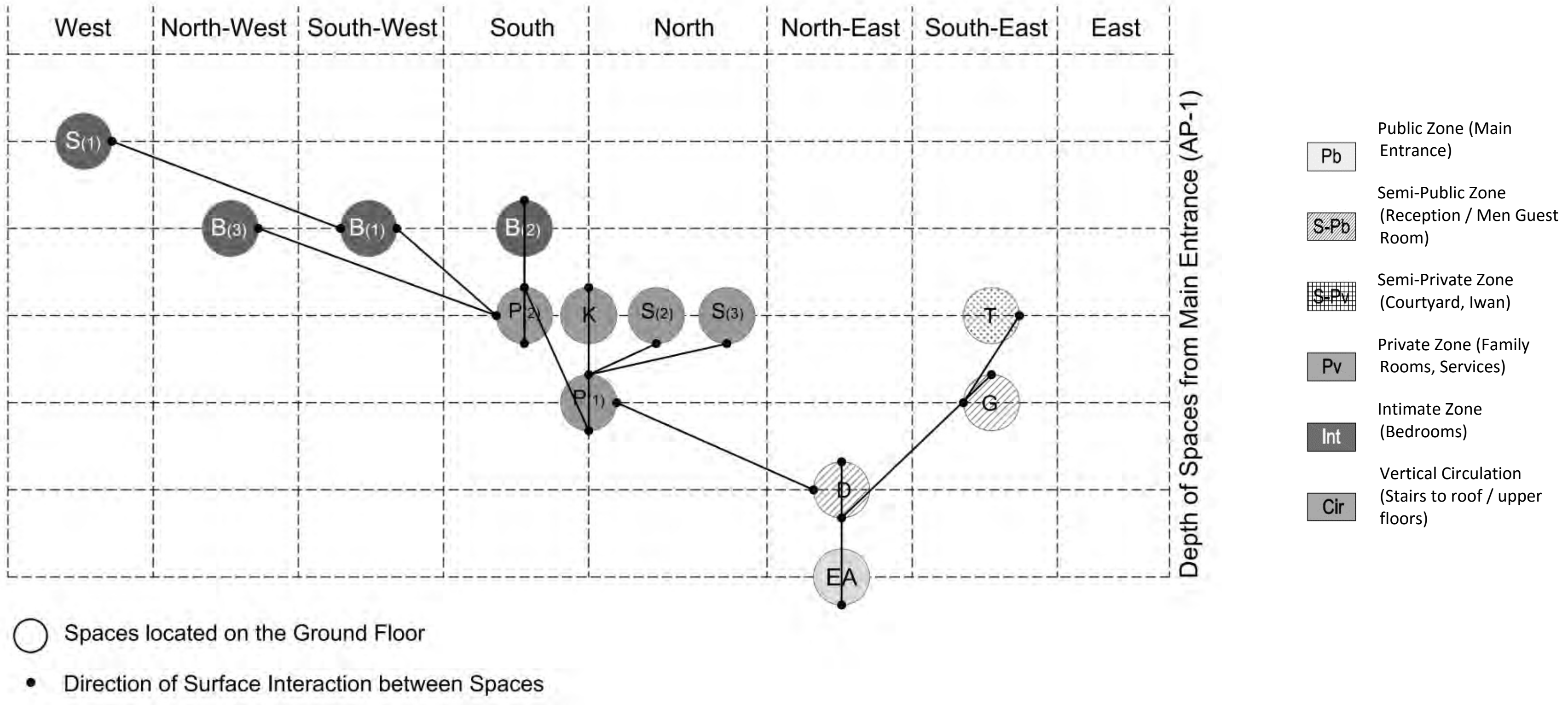
Integration of Spaces with the Living Room and the Entrance

(the courtyard has the greatest control value)

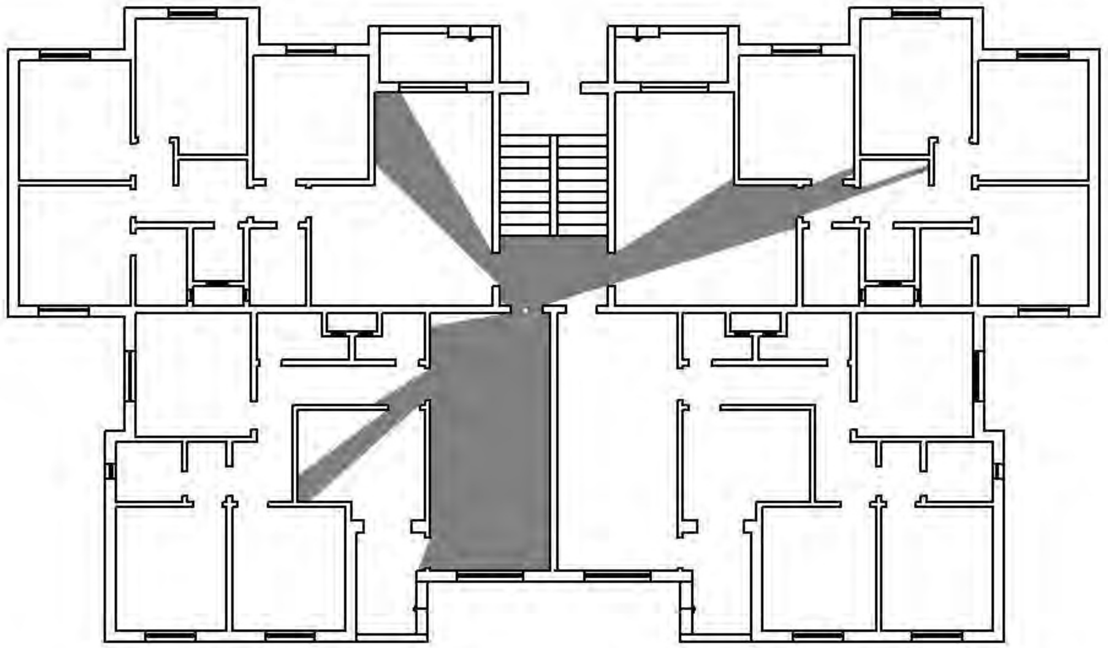


The Social Logic of the Spatial Arrangement of an Apartment Building in Amman, Jordan	Region	Middle East	Country	Jordan	Case No.	AP-3

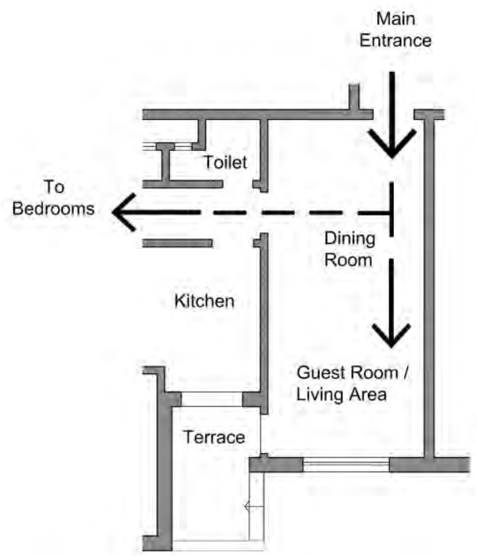
Hierarchy and Depth of Spaces (according to the orientation, and type of spaces)
(Researcher)



Visual analysis from the main entrance towards guest rooms and private/intimate spaces (Produced by Syntax2D) (https://sourceforge.net/projects/syntax2d/?source=typ_redirect)



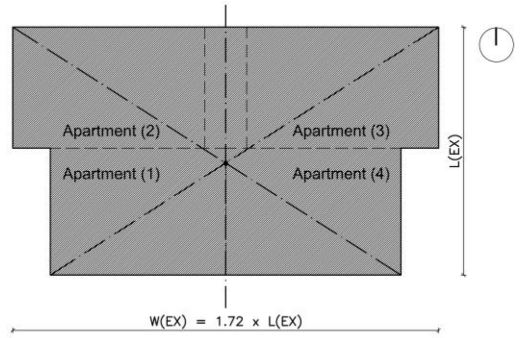
Pattern of movement from the entrance to other spaces
(Researcher)



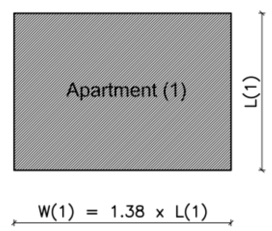
There is no entry hall. The entrance door is connected directly with the reception area that is used as dining room, guest/family space. A corridor that leads to other spaces (toilets, kitchen, and bedrooms) is also connected directly with the dining room.

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
	23 % of the total area of the floor
Thickness of exterior walls	30 cm
Height of Guest/Living spaces	



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	1.94		
Mean	**33.23**	**2.76**	**0.32**	**3.52**		
Max	46.00	3.83	0.51	7.33		

Integration Values:
Corridors > Dining Room > Services, Kitchen > Bedroom (1) > Guest Room, Bedrooms (2, 3) > Entrance > Services (Toilets) > Terrace

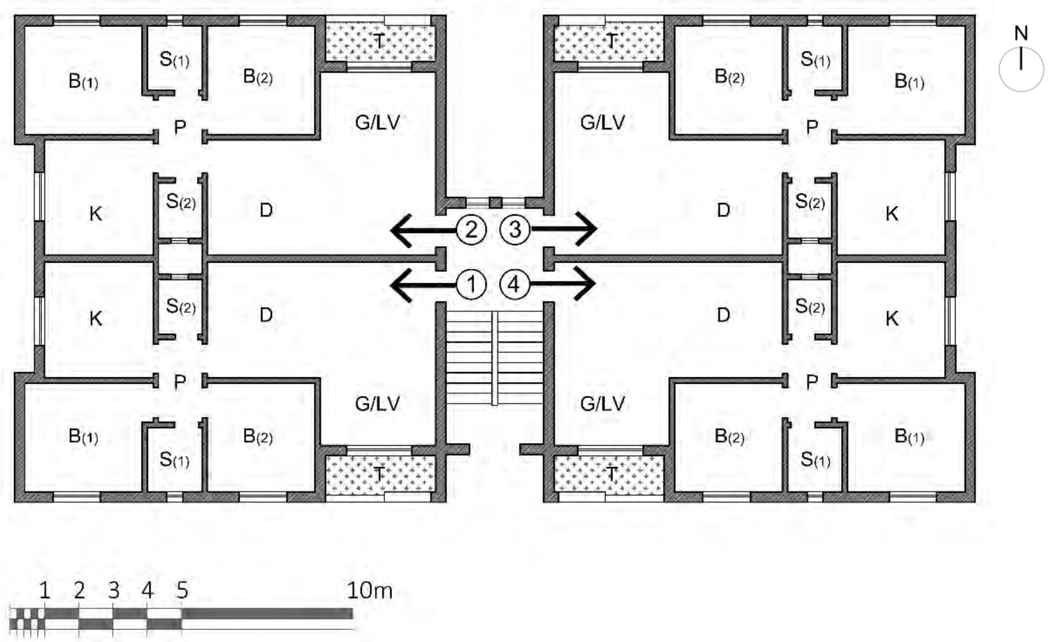
Lowest Integration Values:
- Terraces
- Services (Toilets)
- Entrance

Highest Integration and Control Values:
- Corridors

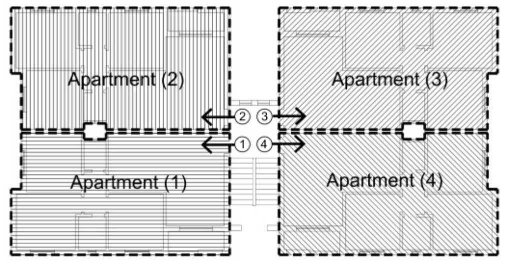
The Social Logic of the Spatial Arrangement of an Apartment Building in Amman, Jordan	Region	Middle East	Country	Jordan	Case No.	AP-4

Architectural Plans for an Apartment Building, Amman, Jordan

(Redrawn by Researcher, http://www.csbe.org (accessed 20/10/2016))



Ground Floor Plan



EA: Main Entrance Hall/Corridor
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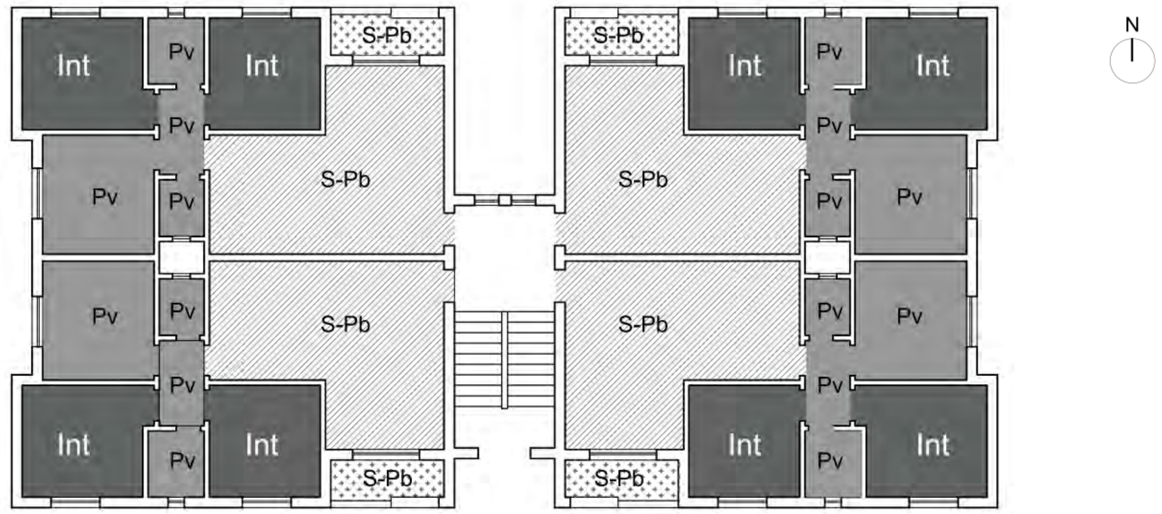
D : Dining Room
LV: Family Living Room
B : Intimate Spaces (Bedrooms)
K : Kitchen
S : Services (Toilets, Storage)
P : Passage / Transitional Space
DV: Double Volume

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)

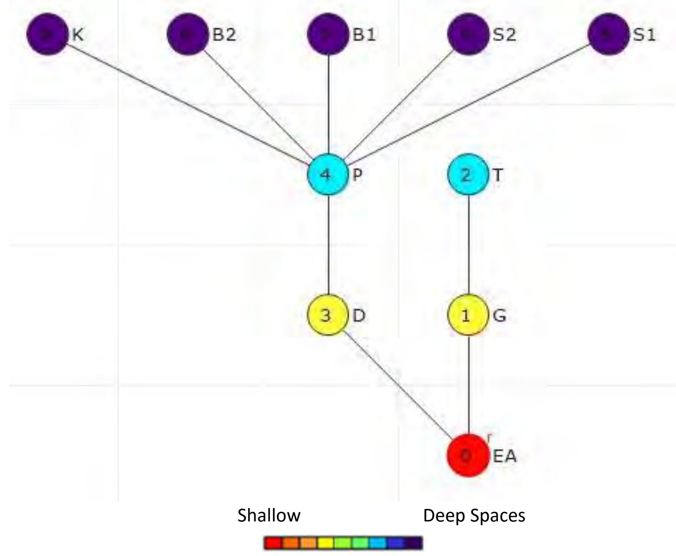
Int — Intimate Zone (Bedrooms)

Cir — Vertical Circulation (Stairs to roof / upper floors)

Space Syntax Analysis

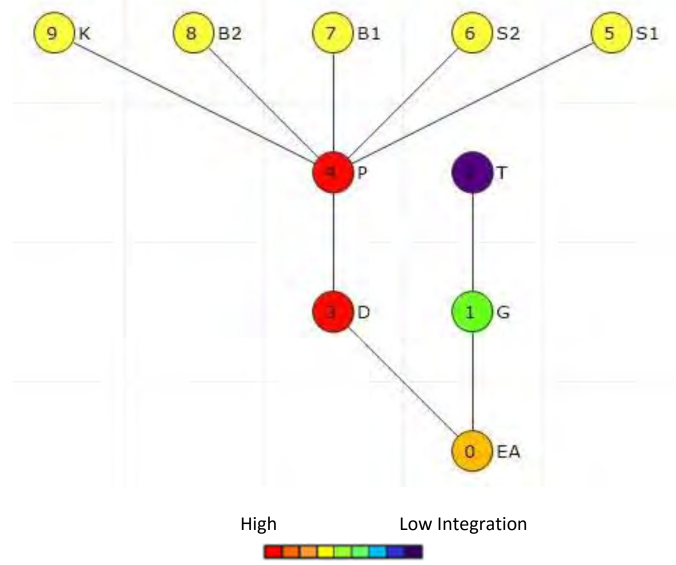
Diagrams produced by Researcher using AGRAPH Online software (https://www.ntnu.no/ab/spacesyntax)

Depth of Spaces



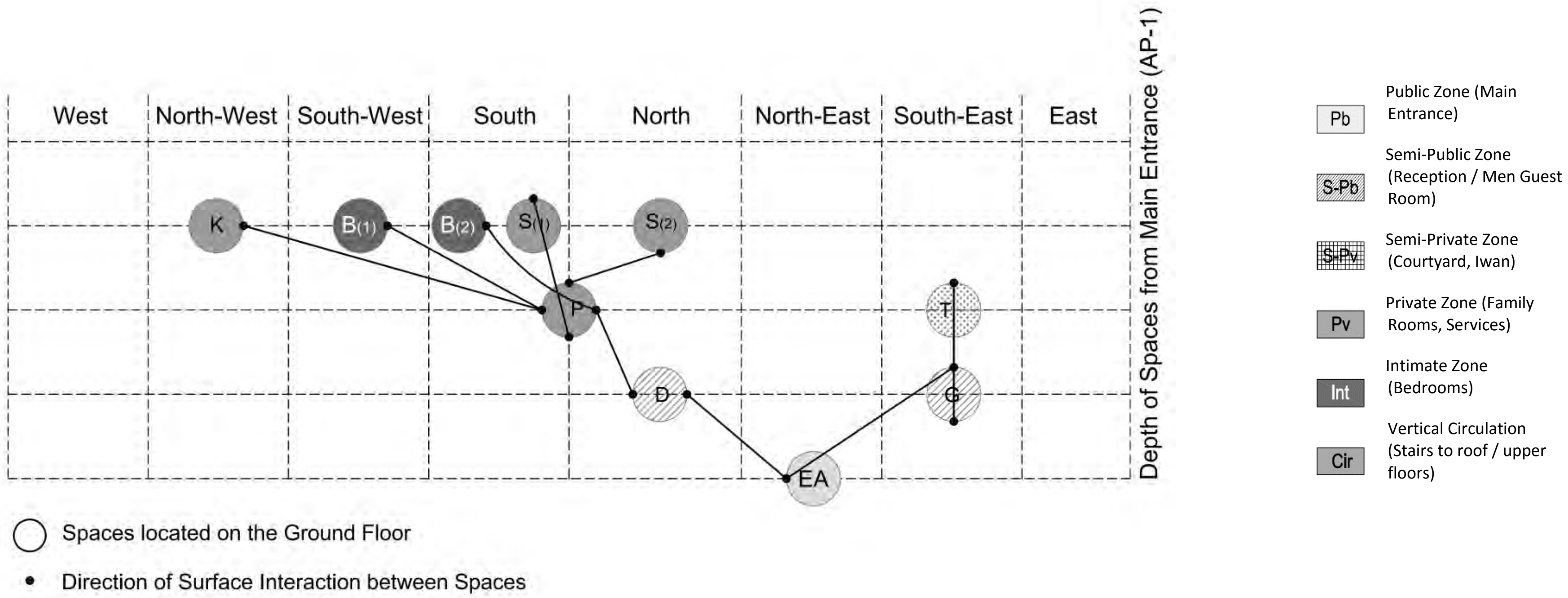
Integration of Spaces with the Living Room and the Entrance

(the courtyard has the greatest control value)

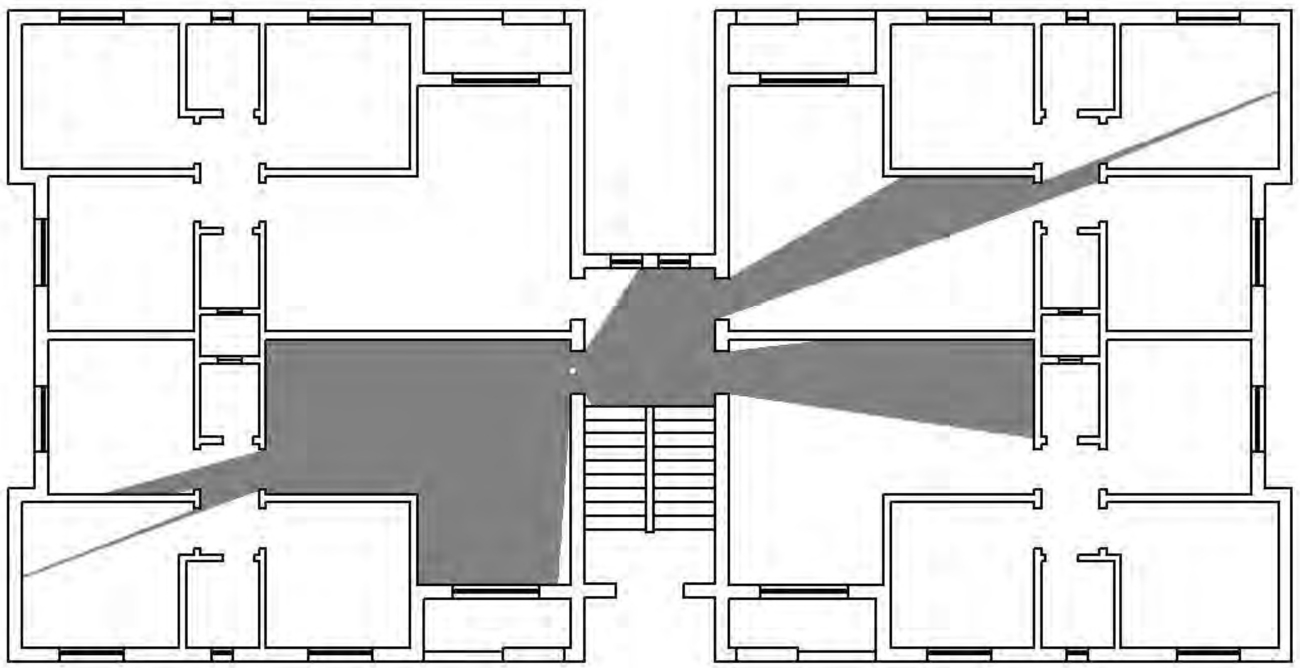


The Social Logic of the Spatial Arrangement of an Apartment Building in Amman, Jordan	Region	Middle East	Country	Jordan	Case No.	AP-4

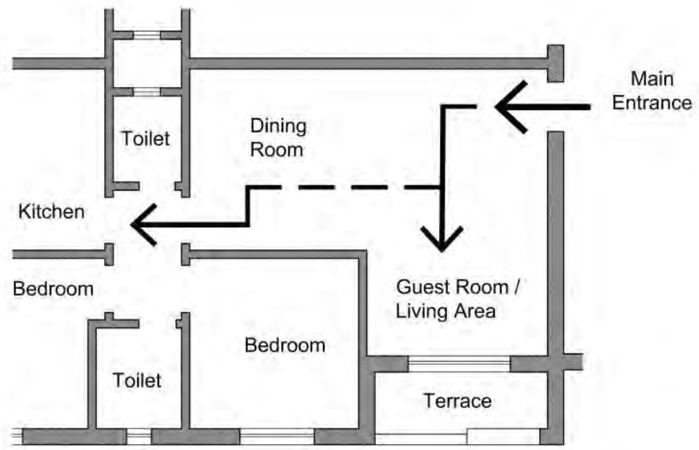
Hierarchy and Depth of Spaces (according to the orientation, and type of spaces)
(Researcher)



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)



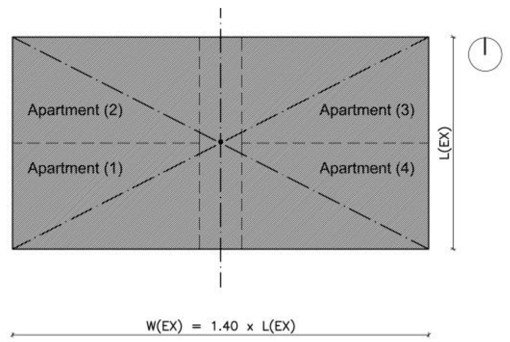
Pattern of movement from the entrance to other spaces
(Researcher)



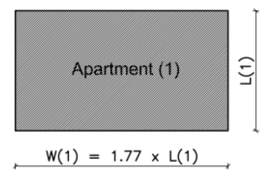
There is no entry hall. The entrance door is connected directly with the reception area that is used as dining room, guest/family space. A corridor that leads to other spaces (toilets, kitchen, and bedrooms) is also connected directly with the dining room.

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)



Typology	Recatngular 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

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

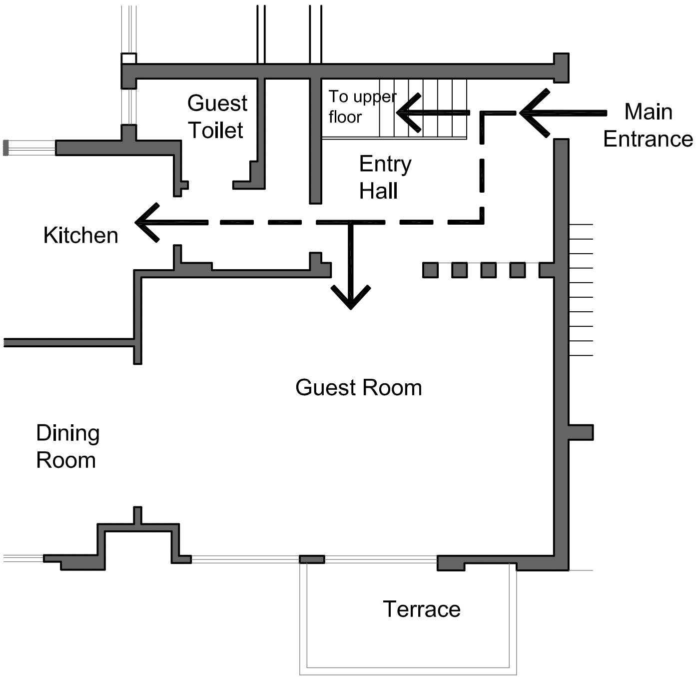
TDn	Total Depth (TD) for actual node	RA	Relative Asymmetry = 2*(MD-1)/(K-2)
MDn	Mean Depth (MD) for actual node = TD/(K-1)	I	Integration Value = 1/RA
K	Number of Nodes	CV	Control Value
NCn	Number of Connections from Node		

Spaces	TDn	MDn	RA	i	CV	NCn
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		

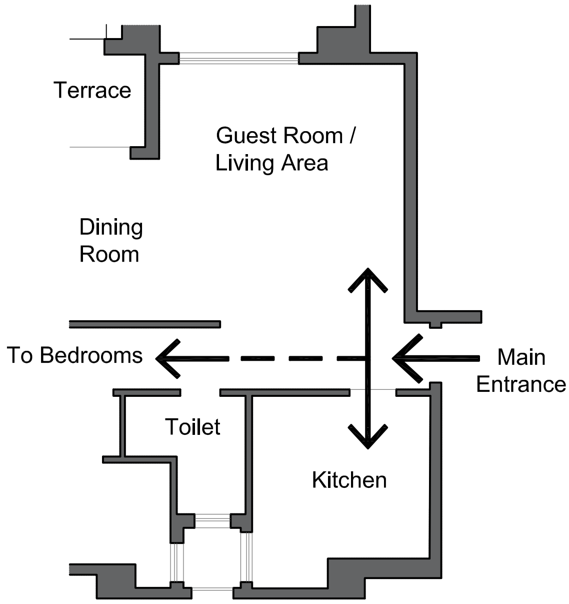
Integration Values:
Corridors > Dining Room > Services, Kitchen > Bedroom (1) > Guest Room, Bedrooms (2, 3) > Entrance > Services (Toilets) > Terrace

Lowest Integration Values:
- Terraces
- Guest Room

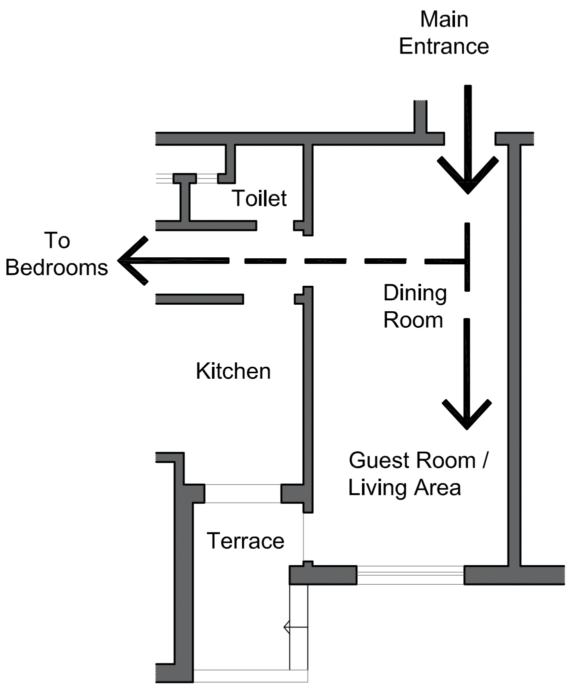
Highest Integration and Control Values:
- Corridors
- Dining Room
- Entrance



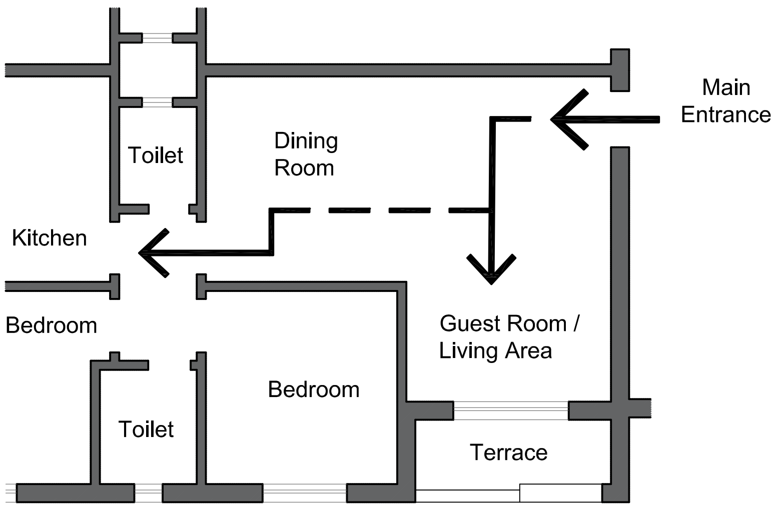
AP-1



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 Area (Pb)		Area (S-Pb)		Area (S-Pv)		Area (Pv)		Area (Int)		Sum of Hierarchy
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%		0%	13	11%		0%	37	30%
APA-2B	22	14%	20	13%		0%		0%		0%		0%		0%		0%		0%	47	30%
APA-3A	12	14%	10	12%		0%		0%		0%		0%		0%	6	7%		0%	32	37%
APA-3B	11	13%	7	8%		0%		0%		0%		0%		0%	5	6%		0%	30	36%
APA-4	20	25%	10	13%		0%		0%		0%		0%		0%	4	5%		0%	22	28%
APA-5A	86	19%	24	5%	68	15%		0%		0%		0%		0%		0%		0%	85	19%
APA-5B					52	33%		0%		0%		0%		0%		0%		0%	50	32%
APA-5C	52	18%	24	8%	37	13%		0%		0%		0%		0%		0%		0%	85	29%
	35	**18%**	**16**	**9%**	**45**	**8%**		**0%**		**0%**		**0%**		**0%**	**10**	**4%**		**0%**	**51**	**30%**

Case	Services with Kitch		Kitchen	Main EN		Service EN		Corridor & Stairs		Total	Main Liv x	y	prop.	direction	Guest x	y	prop.	direction	M/F/M+F	No. of Guest Rooms	WALLS
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

Parametric Relationships between Social Sustainability and Elements of Design at the Scale of Residential Unit (House)

1. Main Courtyard (MC)

1.1. Proportion (W:L)

1:1 — 1:1.66

- Human Comfort +

1.2. Percentage of Area (relative to the Total Area of the House)

6.4% — 29.8%

+ Density and Crowding -
- Social Interaction +
- Acoustical Privacy +
- Spirituality +

1.3. Location / Orientation

West — South — East — Center

+ Human Comfort -
- Olfactory Privacy +
+ Viewing the Outside -

1.4. Width of Adjacent Rooms ($W_{(rooms)}$ / $W_{(MC)}$)

MC: Center	0.30	$W_{(R.E)} / W_{(MC)}$	1.88
	0.16	$W_{(R.S)} / W_{(MC)}$	1.87
	0.16	$W_{(R.N)} / W_{(MC)}$	2.07
	0.26	$W_{(R.W)} / W_{(MC)}$	2.22
MC: South	0.41	$W_{(R.E)} / W_{(MC)}$	0.92
	0.67	$W_{(R.W)} / W_{(MC)}$	1.17
	0.45	$W_{(R.N)} / W_{(MC)}$	1.71
MC: East	0.82	$W_{(R.W)} / W_{(MC)}$	1.52
	0.66	$W_{(R.N)} / W_{(MC)}$	0.85
	0.46	$W_{(R.S)} / W_{(MC)}$	1.02
MC: West	0.75	$W_{(R.E)} / W_{(MC)}$	1.67
	0.67	$W_{(R.N)} / W_{(MC)}$	1.12
	0.78	$W_{(R.S)} / W_{(MC)}$	1.26

- Safety and Security +
- Acoustical Privacy +

2. Iwan (IW)

2.1. Number of Iwans

0 — 1 — 2

- Social Interaction +
- Hierarchy of Spaces +

2.2. Location / Orientation

West — South — North — East

+ Human Comfort -

2.3. Proportion (W:L)

1:1.18	IW: North	1:2.14
1:1	IW: South	1:1.51
1:1.18	IW: East	1:1.6
1:1.33	IW: West	1:1.8

- Human Comfort +

2.4. Width ($W_{(IW)}$ / $W_{(MC)}$)

0.18	IW: North	0.80
0.21	IW: South	0.65
0.42	IW: East	0.66
0.44	IW: West	0.48

- Viewing the Outside +

3. Gallery (GL)

3.1. Number of Galleries

0 — 1 — 2 — 3 — 4

- Accessibility +
- Hierarchy of Spaces +

3.2. Location / Orientation

West — South — North — East

+ Human Comfort -

3.3. Width (W) in meters

1.15	GL: North	3.65
1.50	GL: South	3.60
1.40	GL: East	3.10
1.10	GL: West	4.80

- Accessibility +
- Visual Privacy +
+ Viewing the Outside -

3.4. No. of Openings

3 — 4

- Viewing the Outside +

3.5. Width ($W_{(GL)}$ / $W_{(MC)}$)

0.13	GL: North	0.53
0.17	GL: South	0.47
0.10	GL: East	0.47
0.15	GL: West	0.43

- Viewing the Outside +

4. Main Entrance (EA)

4.1. Relationship with Adjacent Spaces

Courtyard — Gallery — Corridor

- Hierarchy of Spaces +
- Visual Privacy +
- Safety and Security +

4.2. Geometric Properties

Corridor — Room — L-shape — Z-shape

+ Accessibility -
- Visual Privacy +

4.3. Patterns of Openings

Diagonal (45°) — L-shape (90°)

- Visual Privacy +

4.4. Percentage of Area (relative to the Total Area of the House)

2.2%	EA: Room	5.3%
1.4%	EA: Corridor	3.8%
2.2%	EA: L-shape	3.5%
2.2%	EA: Z-shape	5.3%

- Accessibility +

4.5. Width of Space (in meters)

2.25	EA: Room	3.60
1.35	EA: Corridor	1.90
1.35	EA: L-shape	1.90
1.35	EA: Z-shape	1.90

- Accessibility +

4.5. Width of Doors (in meters)

0.90 — 1.30

- Accessibility +

Parametric Relationships between Social Sustainability and Elements of Design at the Scale of Residential Unit (House)

5. Guest Room (G)

5.1. Percentage of Area (relative to the Total Area of the House)

4.5% — 13.1%

- Social Interaction +

5.2. Proportion (W:L)

1:0.8 — 1:3.77

- Human Comfort +

5.3. Movement Pattern between EA & G

Linear (G ↑ EA) — L-shape (90°) (EA → G) — U-shape (180°) (EA G)

- Visual Privacy +

5.4 Location

Ground Floor — First Floor

+ Visual Privacy -
+ Hierarchy of Spaces -
+ Accessibility -

6. Distributing Functions on Floors

6.1. Number of Floors

Single-Floor — Two-Floors

+ Density and Crowding -
- Visual Privacy +
- Hierarchy of Spaces +
+ Accessibility -

6.2. Percentage of First Floor Area (relative to the Area of the Ground Floor)

26% — 93%

- Density and Crowding +
+ Viewing the Outside -
- Hierarchy of Spaces +

7. Living Room (LV)

7.1. Percentage of Area (relative to the Total Area of the House)

7% — Total Area for All Living Rooms — 21%

4% — Area for Each Living Room — 12%

+ Density and Crowding -
- Social Interaction +

7.2. Proportion (W:L)

1:1.17 — 1:3.25

- Human Comfort +

7.3. Number of Living Rooms

1 — Ground Floor — 3

0 — First Floor — 1

+ Density and Crowding -
- Social Interaction +
- Hierarchy of Spaces +

7.4. Orientation of Windows

West — East — North — South

- Human Comfort +

7.5. Location

Adjacent to EA/G — Opposite to B — Adjacent to B

- Visual Privacy +
- Hierarchy of Spaces +

8. Bedrooms (B)

8.1. Percentage of Area (relative to the Total Area of the House)

12% — Total Area for All Bedrooms — 28%

4% — Area for Each Bedroom — 7%

+ Density and Crowding -

8.2. Proportion (W:L)

1:1 — 1:2

- Human Comfort +

8.3. Number of Bedrooms

1 — Ground Floor — 4

0 — First Floor — 7

+ Density and Crowding -

8.4. Orientation of Windows

South — West — East — North

- Human Comfort +

8.5. Location

Attached to LV — Opposite to LV — On First Floor

- Visual Privacy +
- Hierarchy of Spaces +
- Acoustical Privacy +

9. Vertical Circulation (Cir)

9.1. Adjacent Rooms on the Ground Floor

EA — MC — GL — B

- Safety and Security +
- Visual Privacy +
+ Accessibility -
- Hierarchy of Spaces +

9.2. Adjacent Rooms on the First Floor

P — GL — T

+ Visual Privacy -
+ Accessibility -
+ Hierarchy of Spaces -

10. Service Entrance (EB)

10.1. Location

Attached to EA — Opposite to EA — Opposite to EA and Attached to a Gallery

- Visual Privacy +
- Hierarchy of Spaces +
+ Accessibility -

10.2. Width of Space (in meters)

2.25 — EB: Room — 3.60

1.35 — EA: Corridor — 1.90

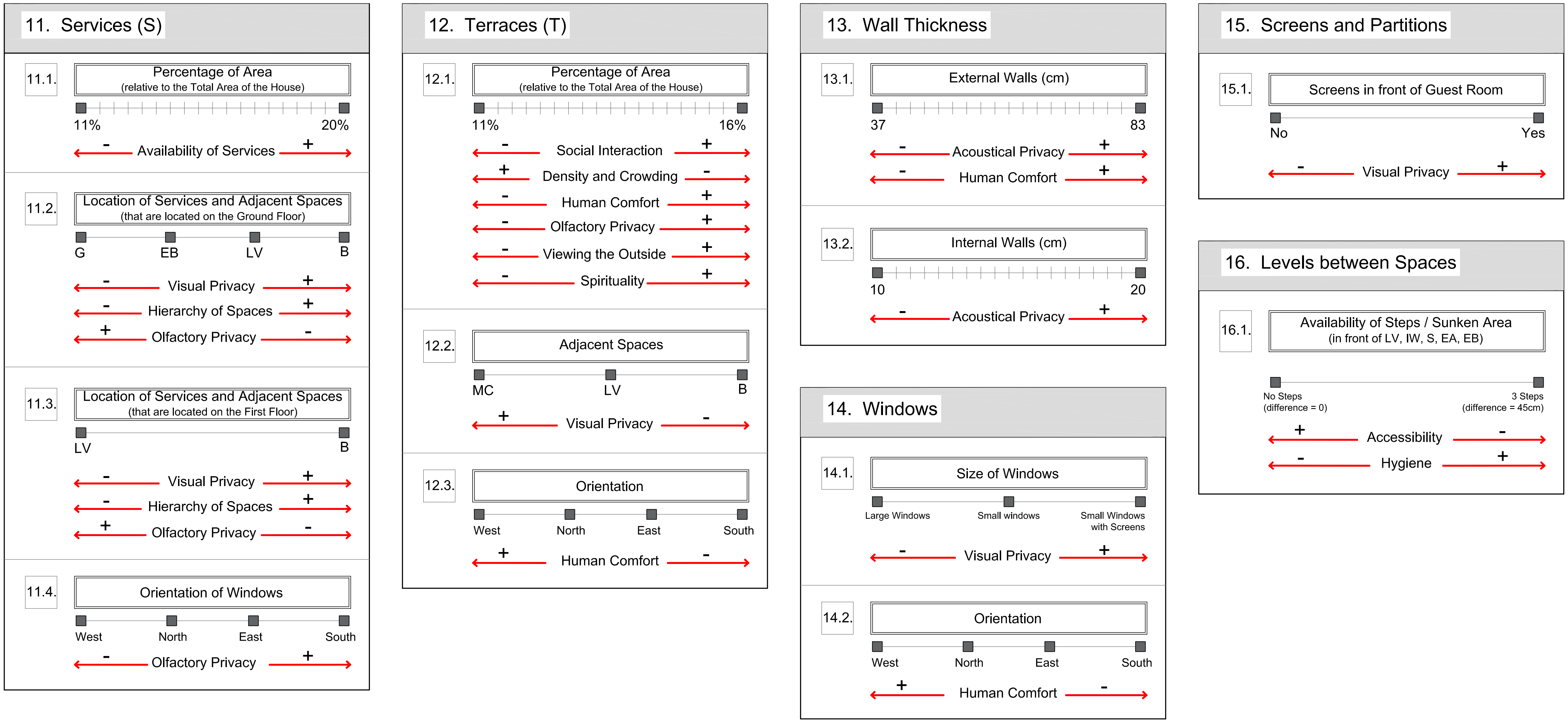
- Accessibility +

10.3. Width of Doors (in meters)

0.90 — 1.30

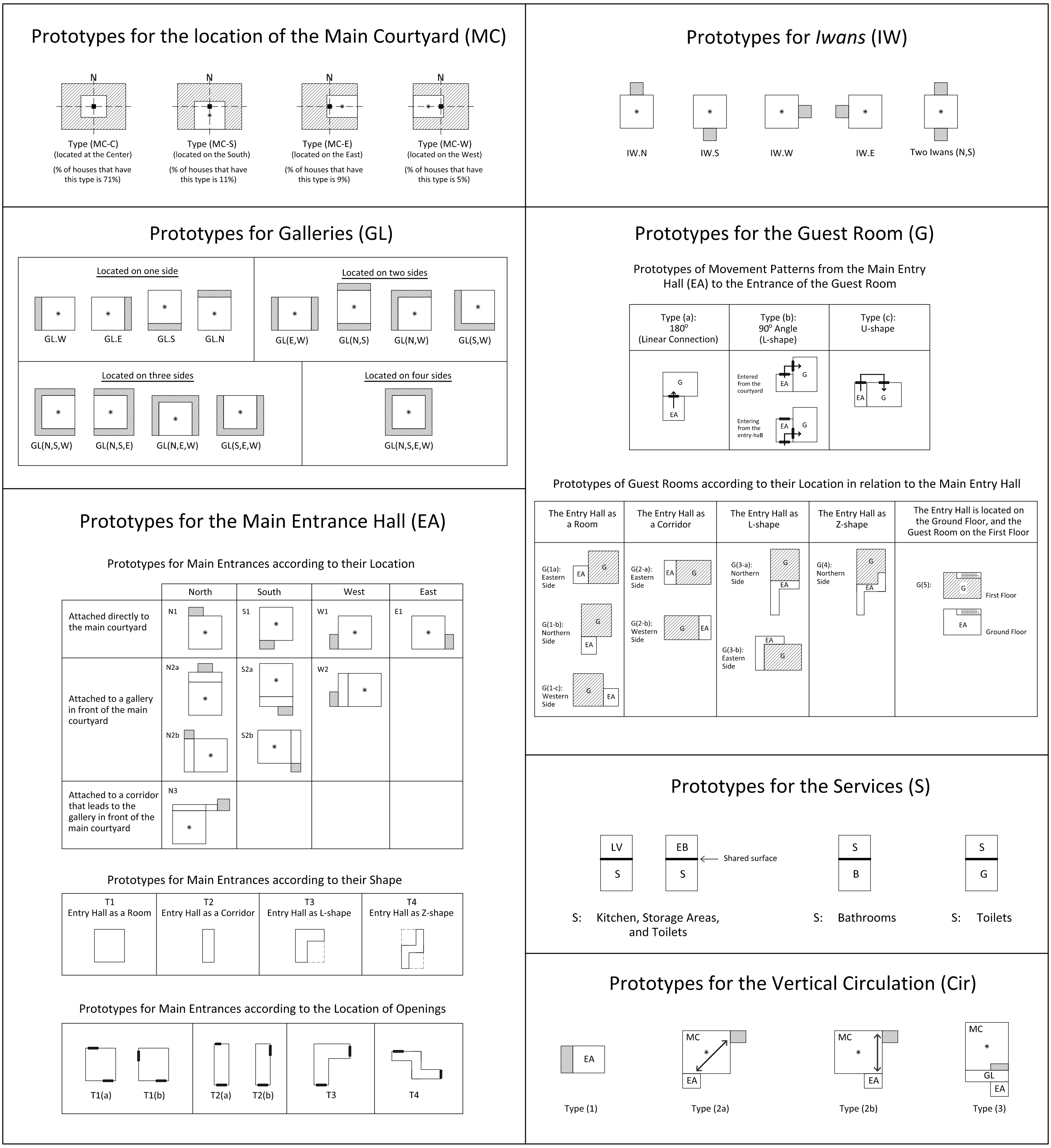
- Accessibility +

Parametric Relationships between Social Sustainability and Elements of Design at the Scale of Residential Unit (House)

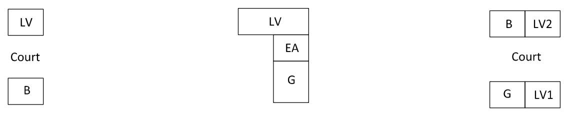


Appendix (5-A-2)

Parametric Rules for the Configuration of Vernacular Houses in MENA Region


Prototypes for the location of the Main Courtyard (MC)
N
Type (MC-C) (located at the Center) (% of houses that have this type is 71%)
Type (MC-S) (located on the South) (% of houses that have this type is 11%)
Type (MC-E) (located on the East) (% of houses that have this type is 9%)
Type (MC-W) (located on the West) (% of houses that have this type is 5%)
Prototypes for Iwans (IW)
IW.N
IW.S
IW.W
IW.E
Two Iwans (N,S)
Prototypes for Galleries (GL)
Located on one side
GL.W
GL.E
GL.S
GL.N
Located on two sides
GL(E,W)
GL(N,S)
GL(N,W)
GL(S,W)
Located on three sides
GL(N,S,W)
GL(N,S,E)
GL(N,E,W)
GL(S,E,W)
Located on four sides
GL(N,S,E,W)
Prototypes for the Guest Room (G)
Prototypes of Movement Patterns from the Main Entry Hall (EA) to the Entrance of the Guest Room
Type (a): 180° (Linear Connection)
Type (b): 90° Angle (L-shape)
Type (c): U-shape
Entered from the courtyard
Entering from the entry-hall
EA
G
Prototypes of Guest Rooms according to their Location in relation to the Main Entry Hall
The Entry Hall as a Room
The Entry Hall as a Corridor
The Entry Hall as L-shape
The Entry Hall as Z-shape
The Entry Hall is located on the Ground Floor, and the Guest Room on the First Floor
G(1a): Eastern Side
G(1-b): Northern Side
G(1-c): Western Side
G(2-a): Eastern Side
G(2-b): Western Side
G(3-a): Northern Side
G(3-b): Eastern Side
G(4): Northern Side
G(5):
First Floor
Ground Floor
Prototypes for the Main Entrance Hall (EA)
Prototypes 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
S2a
W2
N2b
S2b
Attached to a corridor that leads to the gallery in front of the main courtyard
N3
Prototypes for Main Entrances according to their Shape
T1 Entry Hall as a Room
T2 Entry Hall as a Corridor
T3 Entry Hall as L-shape
T4 Entry Hall as Z-shape
Prototypes for Main Entrances according to the Location of Openings
T1(a)
T1(b)
T2(a)
T2(b)
T3
T4
Prototypes for the Services (S)
LV
S
EB
Shared surface
B
G
S: Kitchen, Storage Areas, and Toilets
S: Bathrooms
S: Toilets
Prototypes for the Vertical Circulation (Cir)
MC
GL
Type (1)
Type (2a)
Type (2b)
Type (3)

Prototypes for Living Rooms (LV) and Bedrooms (B) that are located on the Ground Floor



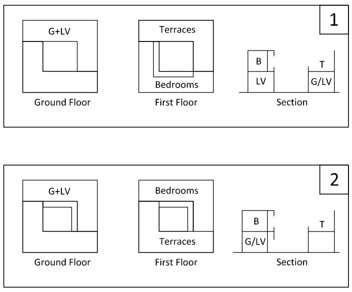
Prototypes for the Service Entrance (EB)

Service Entrance is located opposite to the Main Entrance

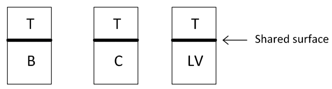
Service Entrance is located adjacent to the Main Entrance

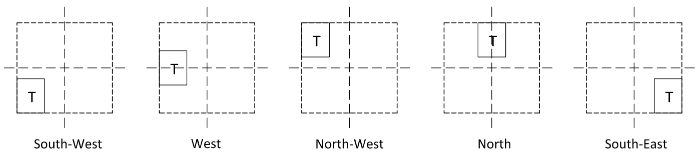
Prototypes for Living Rooms (LV) and Bedrooms (B) that are located on the Upper Floors

The Layout of the Ground Floor	For MC-S		For MC-C						For MC-E
The Layout of the First Floor	Type S1 U-shape (N+E+W sides)	Type S2 I-shape (N side)	Type C1 O-shape (All sides)	Type C2 L-shape (S+E sides)	Type C3 L-shape (S+W sides)	Type C4 U-shape (N+E+S sides)	Type C5 I-shape (N+S sides)	Type C6 L-shape (N+E sides)	Type E L-shape (S+W sides)
% of the 1st Floor Area from the Ground Floor	87%	36%	73% ↔ 93% (AVG = 83%)	34% ↔ 65% (AVG = 47%)	26% ↔ 46% (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

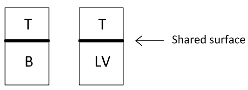


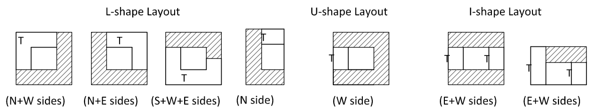
Prototypes for Terraces (T) that are located on the Ground Floor





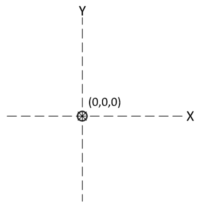
Prototypes for Terraces (T) that are located on Upper Floors





Initial Shape:

⊗ (0,0,0)

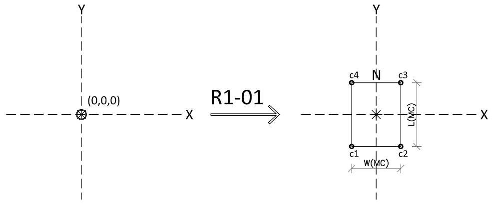


Stage (1): Rules for Generating a Main Courtyard (MC)

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:

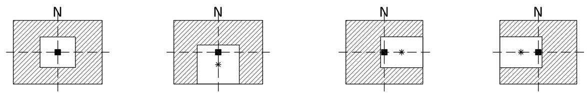
$W_{(MC)}$: width of the main courtyard
$L_{(MC)}$: length of the main courtyard
$Area_{(MC)}$: area of the main courtyard
$Area_{(AP)}$: allowable built-up area for the appartment

Type (AP-1) : 1-floor Apartment (100-110 m^2)
Type (AP-2a) : 1-floor Apartment (110-140 m^2)
Type (AP-2b) : 2-floor Apartment (140-180 m^2)
Type (AP-3a) : 1-floor Apartment (180-220 m^2)
Type (AP-3) : 2-floor Apartment (220-250 m^2)

N : North direction
∘ : corners of main courtyard
✳ : the centroid of the main courtyard = $(x,y,z)_{MC}$

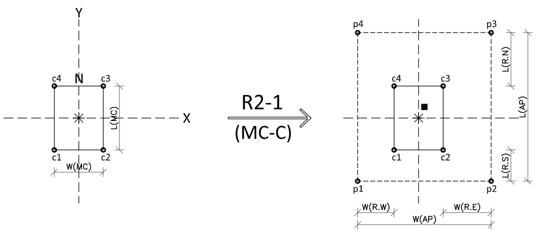
Stage (2): Rules for Generating Schematic Layout for the Ground Floor (based on the location of the main courtyard)

Typologies for the Location of the Main Courtyard



Type (MC-C) (located at the Center) (% of houses that have this type is 71%)
Type (MC-S) (located on the South) (% of houses that have this type is 11%)
Type (MC-E) (located on the East) (% of houses that have this type is 9%)
Type (MC-W) (located on the West) (% of houses that have this type is 5%)

Rule (2-01): Generating Schematic Layout for the Ground Floor that has a Main Courtyard located at the Center (Type MC-C)



■ : the centroid of the initial layout of the apartment $(x,y,z)_{AP}$
$W_{(R.W)}$: 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

Design Parameters:

$0.34 \leq W_{(MC)} / W_{(AP)} \leq 0.53$
$-2.33 \leq x_{(MC)} - x_{(AP)} \leq 4.11$ m (AVG = 0.07 m)
$-4.25 \leq y_{(MC)} - y_{(AP)} \leq 1.95$ m (AVG = -0.25 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:

$0.31 \leq W_{(R.E)} / W_{(MC)} \leq 1.17$ (AVG=0.68)
$0.26 \leq W_{(R.W)} / W_{(MC)} \leq 1.13$ (AVG=0.64)
$0.16 \leq L_{(R.N)} / L_{(MC)} \leq 1.51$ (AVG=0.55)
$0.16 \leq L_{(R.S)} / L_{(MC)} \leq 1.02$ (AVG=0.53)

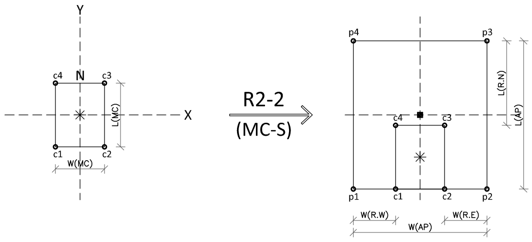
For Apartments located in North-Africa:

$0.30 \leq W_{(R.E)} / W_{(MC)} \leq 1.38$ (AVG=0.60)
$0.27 \leq W_{(R.W)} / W_{(MC)} \leq 1.04$ (AVG=0.53)
$0.36 \leq L_{(R.N)} / L_{(MC)} \leq 1.49$ (AVG=0.74)
$0.35 \leq L_{(R.S)} / L_{(MC)} \leq 0.96$ (AVG=0.66)

For Apartments located in the Gulf Area:

$0.34 \leq W_{(R.E)} / W_{(MC)} \leq 1.88$ (AVG=0.94)
$0.32 \leq W_{(R.W)} / W_{(MC)} \leq 2.22$ (AVG=1.01)
$0.35 \leq L_{(R.N)} / L_{(MC)} \leq 2.07$ (AVG=1.00)
$0.28 \leq L_{(R.S)} / L_{(MC)} \leq 1.87$ (AVG=1.06)

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:

$0.34 \leq W_{(MC)} / W_{(AP)} \leq 0.53$

$L_{(AP)} = L_{(MC)} + L_{(R.N)}$

$W_{(AP)} = W_{(MC)} + W_{(R.E)} + W_{(R.W)}$

$(x)_{(MC)} = (x)_{(AP)}$

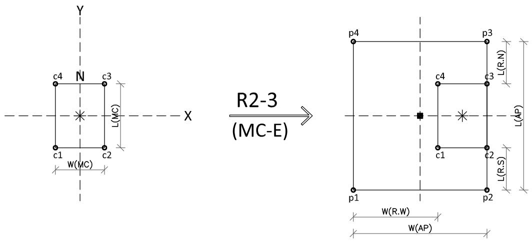
$0.41 \leq W_{(R.E)} / W_{(MC)} \leq 0.92$ (AVG=0.62)

$0.67 \leq W_{(R.W)} / W_{(MC)} \leq 1.17$ (AVG=0.78)

$0.45 \leq L_{(R.N)} / L_{(MC)} \leq 1.71$ (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:

$0.34 \leq W_{(MC)} / W_{(AP)} \leq 0.53$

$L_{(AP)} = L_{(MC)} + L_{(R.N)} + L_{(R.S)}$

$W_{(AP)} = W_{(MC)} + W_{(R.W)}$

$(y)_{(MC)} = (y)_{(AP)}$

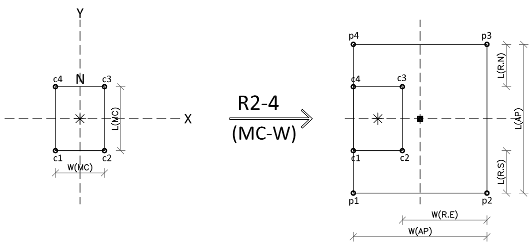
$W_{(R.E)} = 0.00$

$0.82 \leq W_{(R.W)} / W_{(MC)} \leq 1.52$ (AVG=1.07)

$0.66 \leq L_{(R.N)} / L_{(MC)} \leq 0.85$ (AVG=0.73)

$0.46 \leq L_{(R.S)} / L_{(MC)} \leq 1.02$ (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:

$0.34 \leq W_{(MC)} / W_{(AP)} \leq 0.53$

$L_{(AP)} = L_{(MC)} + L_{(R.S)} + L_{(R.N)}$

$W_{(AP)} = W_{(MC)} + W_{(R.E)}$

$(y)_{(MC)} = (y)_{(AP)}$

$0.75 \leq W_{(R.E)} / W_{(MC)} \leq 1.67$ (AVG=1.21)

$W_{(R.W)} = 0.00$

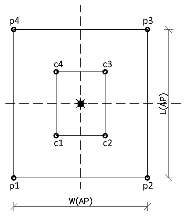
$0.67 \leq L_{(R.N)} / L_{(MC)} \leq 1.12$ (AVG=0.90)

$0.78 \leq L_{(R.S)} / L_{(MC)} \leq 1.26$ (AVG=1.02)

Stage (3): Rules for Generating Schematic Layout for the 1st Floor in 2-Floor Houses

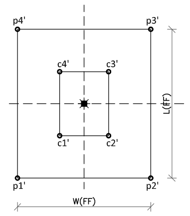
Typologies for the Layout of the First Floor

	For MC-S		For MC-C						For MC-E
The Layout of the Ground Floor									
The Layout of the First Floor	Type S1 U-shape (N+E+W sides)	Type S2 I-shape (N side)	Type C1 O-shape (All sides)	Type C2 L-shape (S+E sides)	Type C3 L-shape (S+W sides)	Type C4 U-shape (N+E+S sides)	Type C5 I-shape (N+S sides)	Type C6 L-shape (N+E sides)	Type E L-shape (S+W sides)
% of the 1st Floor Area from the Ground Floor	87%	36%	73% ↔ 93% (AVG = 83%)	34% ↔ 65% (AVG = 47%)	26% ↔ 46% (AVG = 36%)	47%	70%	40%	73%



Ground Floor

R3-1a
Type C1



First Floor

$73\% * Area_{(GF)} \leq Area_{(FF)} \leq 93\% * Area_{(GF)}$ (AVG = 83%)

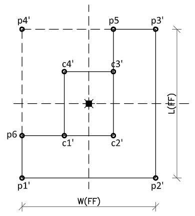
$W_{(FF)} \leq W_{(AP)}$

$L_{(FF)} \leq L_{(AP)}$

$(x_c, y_c) = (x_{c'}, y_{c'}, h)$

where:
h = height of ground floor + thickness of slab between ground floor and first floor

R3-1b
Type C2



First Floor

$34\% * Area_{(GF)} \leq Area_{(FF)} \leq 65\% * Area_{(GF)}$ (AVG = 47%)

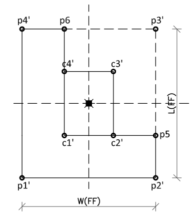
$W_{(FF)} \leq W_{(AP)}$

$L_{(FF)} \leq L_{(AP)}$

$(x_c, y_c) = (x_{c'}, y_{c'}, h)$

where:
h = height of ground floor + thickness of slab between ground floor and first floor

R3-1c
Type C3



First Floor

$26\% * Area_{(GF)} \leq Area_{(FF)} \leq 46\% * Area_{(GF)}$ (AVG = 36%)

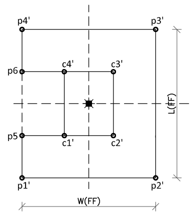
$W_{(FF)} \leq W_{(AP)}$

$L_{(FF)} \leq L_{(AP)}$

$(x_c, y_c) = (x_{c'}, y_{c'}, h)$

where:
h = height of ground floor + thickness of slab between ground floor and first floor

R3-1d
Type C4



First Floor

$Area_{(FF)} \leq 47\% * Area_{(GF)}$

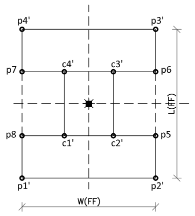
$W_{(FF)} \leq W_{(AP)}$

$L_{(FF)} \leq L_{(AP)}$

$(x_c, y_c) = (x_{c'}, y_{c'}, h)$

where:
h = height of ground floor + thickness of slab between ground floor and first floor

R3-1e
Type C5



First Floor

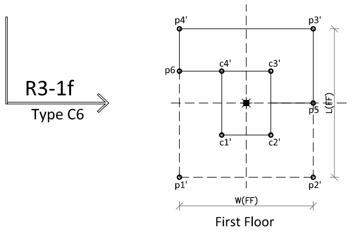
$Area_{(FF)} \leq 70\% * Area_{(GF)}$

$W_{(FF)} \leq W_{(AP)}$

$L_{(FF)} \leq L_{(AP)}$

$(x_c, y_c) = (x_{c'}, y_{c'}, h)$

where:
h = height of ground floor + thickness of slab between ground floor and first floor



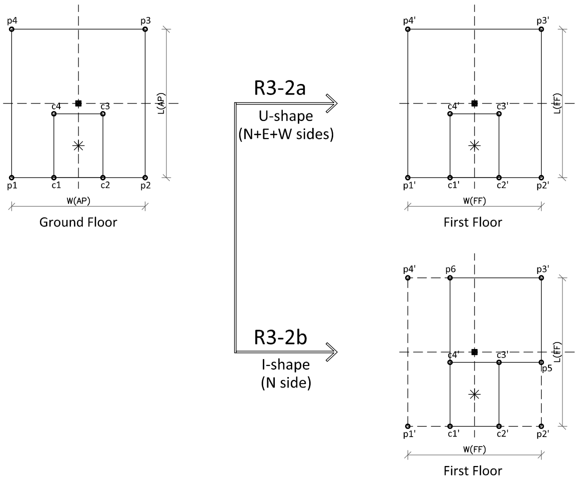
$Area_{(FF)} \leq 40\% * Area_{(GF)}$

$W_{(FF)} \leq W_{(AP)}$

$L_{(FF)} \leq L_{(AP)}$

$(x_c, y_c) = (x_{c'}, y_{c'}, h)$

where:
h = height of ground floor + thickness of slab between ground floor and first floor



$Area_{(FF)} \leq 87\% * Area_{(GF)}$

$W_{(FF)} \leq W_{(AP)}$

$L_{(FF)} \leq L_{(AP)}$

$(x_c, y_c) = (x_{c'}, y_{c'}, h)$

where:
h = height of ground floor + thickness of slab between ground floor and first floor

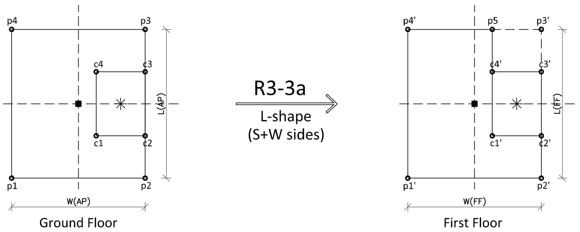
$Area_{(FF)} \leq 36\% * Area_{(GF)}$

$W_{(FF)} \leq W_{(AP)}$

$L_{(FF)} \leq L_{(AP)}$

$(x_c, y_c) = (x_{c'}, y_{c'}, h)$

where:
h = height of ground floor + thickness of slab between ground floor and first floor



$Area_{(FF)} \leq 73\% * Area_{(GF)}$

$W_{(FF)} \leq W_{(AP)}$

$L_{(FF)} \leq L_{(AP)}$

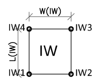
$(x_c, y_c) = (x_{c'}, y_{c'}, h)$

where:
h = height of ground floor + thickness of slab between ground floor and first floor

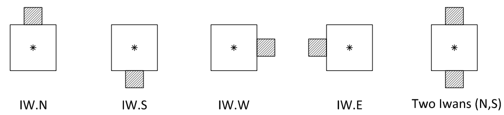
Stage (4): Rules for the Configuration of Semi-Open Spaces (*Iwans* (IW))

Descriptions:

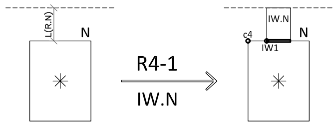
- IW: it is a semi-open space (shared surface with courtyard is an opening)
- IW: it is a semi-private space (S-Pv)
- IW: it is located only in the Middle East and North Africa, and it does not exist in the Gulf Area



Typologies for *Iwans* according to their Location:



Rule (4-01): Generating ONE *Iwan* (IW-N) on the Northern side of the courtyard



Design Parameters:

$1.18 \le W_{(IW.N)} / L_{(IW.N)} \le 1.97$

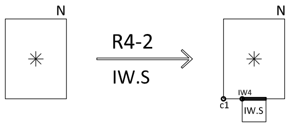
$0.44 \le W_{(IW.N)} / W_{(MC)} \le 0.80$

$L_{(IW.N)} = L_{(R.N)}$

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:

$1.00 \le W_{(IW.S)} / L_{(IW.S)} \le 1.51$

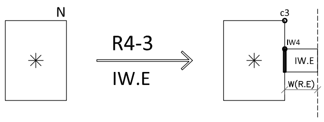
$0.21 \le W_{(IW.S)} / W_{(MC)} \le 0.65$

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. $(x,y)_{IW.S} = (x,y)_{MC} + ((W_{(MC)}/2) + (W_{(IW.S)}/2) + d)$

   $0 \le d \le (L_{(MC)}/2) - (L_{(IW.S)}/2)$

Rule (4-03): Generating ONE *Iwan* (IW-E) on the Eastern side of the courtyard



Design Parameters:

$1.18 \le W_{(IW.E)} / L_{(IW.E)} \le 1.60$

$0.42 \le L_{(IW.E)} / L_{(MC)} \le 0.66$

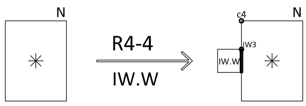
$L_{(IW.E)} = W_{(R.E)}$

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. $(x,y)_{IW.E} = (x,y)_{MC} + ((W_{(MC)}/2) + (W_{(IW.E)}/2) + d)$

   $0 \le d \le (L_{(MC)}/2) - (L_{(IW.E)}/2)$

Rule (4-04): Generating ONE *Iwan* (IW-W) on the Western side of the courtyard



Design Parameters:

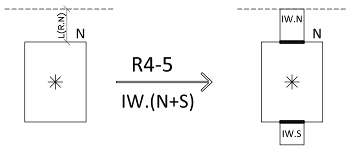
$1.33 \le W_{(IW.W)} / L_{(IW.W)} \le 1.80$

$0.44 \le L_{(IW.W)} / L_{(MC)} \le 0.48$

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:

$1.52 \le W_{(IW.N)} / L_{(IW.N)} \le 2.14$

$1.04 \le W_{(IW.S)} / L_{(IW.S)} \le 1.42$

$0.18 \le W_{(IW.N)} / W_{(MC)} \le 0.63$

$0.30 \le W_{(IW.S)} / W_{(MC)} \le 0.65$

$L_{(IW.N)} = L_{(R.N)}$

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. $(x,y)_{IW.N} = (x,y)_{MC} + ((W_{(MC)}/2) + (W_{(IW.N)}/2) + d)$

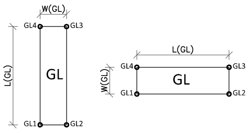
   $0 \le d \le (L_{(MC)}/2) - (L_{(IW.N)}/2)$

Stage (5): Rules for the Configuration of Semi-Open Spaces (*Galleries* (GL))

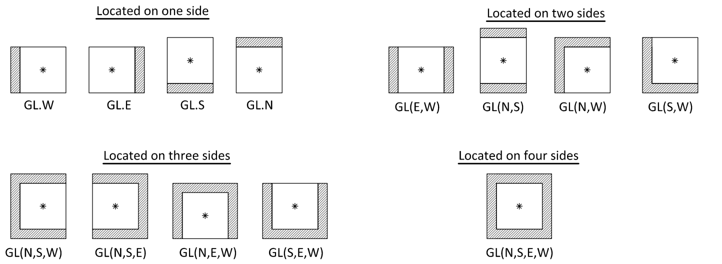
Descriptions:

GL: it is a semi-open space (3 to 4 openings are located on the shared surface with the courtyard)

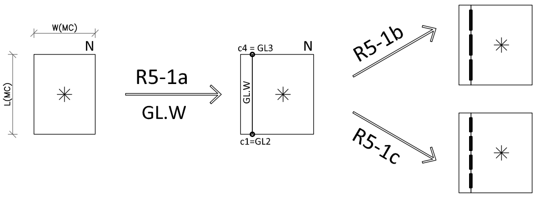
GL: it is a semi-private space (S-Pv)



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:

$L_{(GL.W)} = L_{(MC)}$

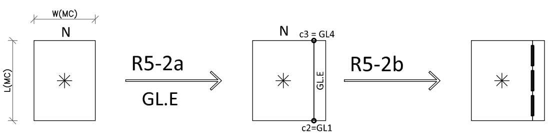
$1.10 \leq W_{(GL.W)} \leq 4.80$ m

$(0.15 * W_{(MC)}) \leq W_{(GL.W)} \leq (0.43 * W_{(MC)})$

$(x,y)_{(GL3)} = (x,y)_{(c4)}$

$(x,y)_{(GL2)} = (x,y)_{(c1)}$

Rule (5-02): Generating Gallery (GL.E) on the Eastern side of the courtyard



Design Parameters:

$L_{(GL.E)} = L_{(MC)}$

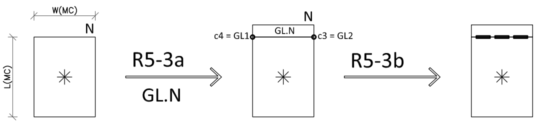
$1.40 \leq W_{(GL.E)} \leq 3.10$ m

$(0.10 * W_{(MC)}) \leq W_{(GL.W)} \leq (0.47 * W_{(MC)})$

$(x,y)_{(GL1)} = (x,y)_{(c2)}$

$(x,y)_{(GL4)} = (x,y)_{(c3)}$

Rule (5-03): Generating Gallery (GL.N) on the Northern side of the courtyard



Design Parameters:

$L_{(GL.N)} = W_{(MC)}$

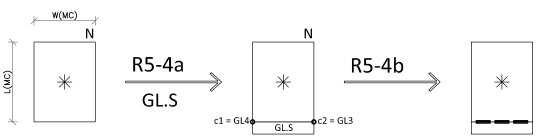
$1.15 \leq W_{(GL.N)} \leq 3.65$ m

$(0.13 * L_{(MC)}) \leq W_{(GL.N)} \leq (0.53 * L_{(MC)})$

$(x,y)_{(GL1)} = (x,y)_{(c4)}$

$(x,y)_{(GL2)} = (x,y)_{(c3)}$

Rule (5-04): Generating Gallery (GL.S) on the Southern side of the courtyard



Design Parameters:

$L_{(GL.S)} = W_{(MC)}$

$1.50 \leq W_{(GL.S)} \leq 3.60$ m

$(0.17 * L_{(MC)}) \leq W_{(GL.S)} \leq (0.47 * L_{(MC)})$

$(x,y)_{(GL4)} = (x,y)_{(c1)}$

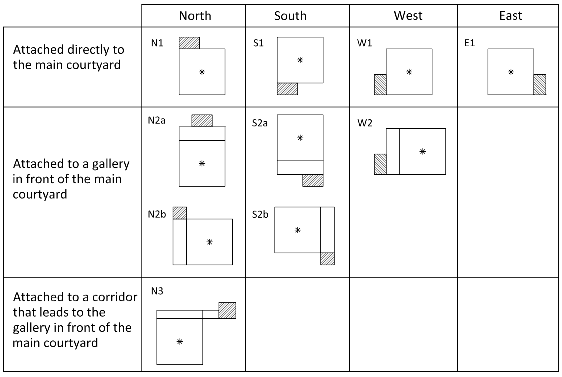
$(x,y)_{(GL3)} = (x,y)_{(c2)}$

Stage (6): Rules for the Spatial Configuration of the Main Entry Hall (EA)

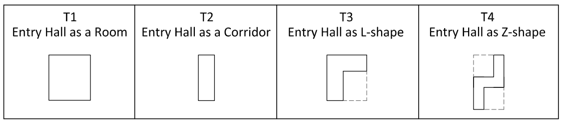
Descriptions:

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

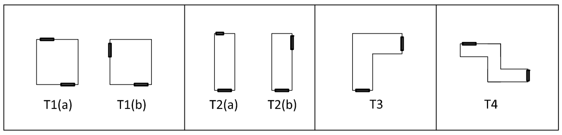
Typologies for Main Entrances according to their Location



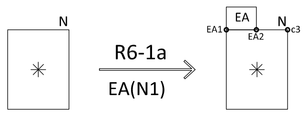
Typologies for Main Entrances according to their Shape



Typologies for Main Entrances according to the Location of Openings

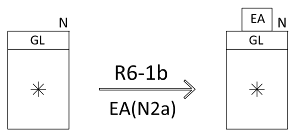


Rules for Generating Main Entry Hall (EA.N) on the Northern side of the Courtyard



Options for the location of EA:

1. $(x,y)_{(EA1)} = (x,y)_{(c4)}$
2. $(x,y)_{(EA2)} = (x,y)_{(c3)}$

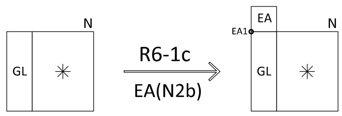


Design Parameters:

$(x,y)_{(EA)} = (x,y)_{(MC)} + W_{(GL)} + (L_{(EA)}/2)$

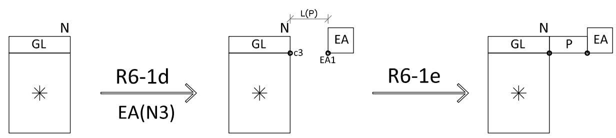
where:

$(x,y)_{(EA)}$: center of the Entry Hall
$(x,y)_{(MC)}$: center of the Courtyard



Design Parameters:

$(x,y)_{(EA1)} = (x,y)_{(GL4)}$
$W_{(EA)} = W_{(GL)}$



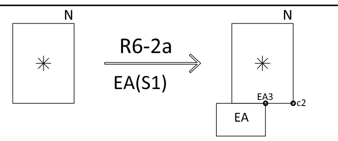
L(P): length of corridor between the gallery and the entry hall

W(P): width of corridor between the gallery and the entry hall

Design Parameters:

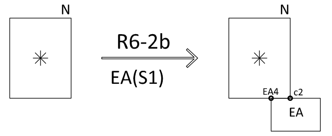
$(x, y)_{(EA1)} = ((x_{(c3)}+L_{(P)}), (y_{(c3)}))$
$W_{(P)} = W_{(GL)}$

Rules for Generating Main Entry Hall (EA.S) on the Southern side of the Courtyard



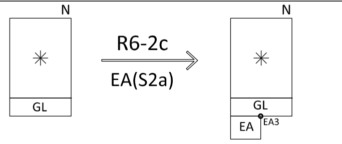
Design Parameters:

$(x)_{(c1)} \le (x)_{(EA3)} \le (x)_{(c2)}$
$(y)_{(EA3)} = (y)_{(c2)} = (y)_{(c1)}$



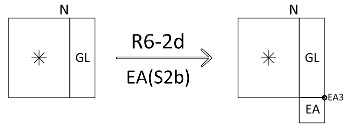
Design Parameters:

$(x)_{(c1)} \le (x)_{(EA4)} \le (x)_{(c2)}$
$(y)_{(EA4)} = (y)_{(c2)} = (y)_{(c1)}$



Design Parameters:

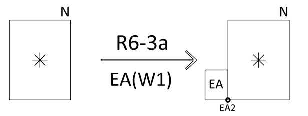
$(x)_{(GL1)} \le (x)_{(EA3)} \le (x)_{(GL2)}$
$(y)_{(EA3)} = (y)_{(GL2)} = (y)_{(GL1)}$



Design Parameters:

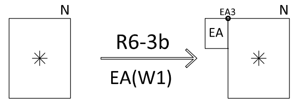
$(x,y)_{(EA3)} = (x,y)_{(GL2)}$
$W_{(EA)} = W_{(GL)}$

Rules for Generating Main Entry Hall (EA.W) on the Western side of the Courtyard



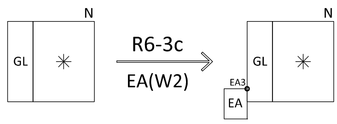
Design Parameters:

$(x,y)_{(EA2)} = (x,y)_{(c1)}$



Design Parameters:

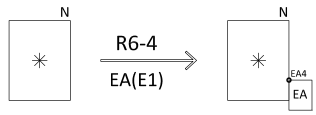
$(x,y)_{(EA3)} = (x,y)_{(c4)}$



Design Parameters:

$(x)_{(EA3)} = (x)_{(GL1)}$
$(y)_{(GL1)} \le (y)_{(EA3)} \le ((y)_{(GL4)}/2)$

Rules for Generating Main Entry Hall (EA.E) on the Eastern side of the Courtyard

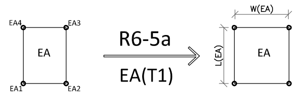


Design Parameters:

$(x)_{(EA4)} = (x)_{(MC2)} = (x)_{(MC3)}$
$(y)_{(MC2)} \le (y)_{(EA4)} \le (y)_{(MC3)}$

Rules for Determining the Shape of the Main Entry Hall

EA(T1): Entry Hall as a Room



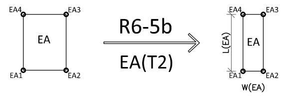
Design Parameters:

$(2.2\%*Area_{(L)}) \leq (W_{(EA)}*L_{(EA)}) \leq (5.3\%*Area_{(L)})$

$2.25 \leq W_{(EA)} \leq 3.60$ m

$L_{(EA)}$ = length of adjacent room

EA(T2): Entry Hall as a Corridor



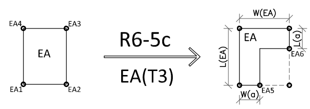
Design Parameters:

$(1.4\%*Area_{(L)}) \leq (W_{(EA)}*L_{(EA)}) \leq (3.8\%*Area_{(L)})$

$1.35 \leq W \leq 1.90$ m

$L_{(EA)}$ = length of adjacent room

EA(T3): Entry Hall as L-shape



Design Parameters:

$(W_{(EA)}*L_{(EA)}) \leq (3.5\%*Area_{(L)})$

$1.35 \leq W_{(a)} \leq 1.90$ m

$L_{(EA)}$, $W_{(EA)}$= width & length of adjacent rooms

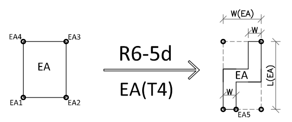
$(x)_{EA5} = (x)_{EA1} + W_{(a)}$

$(y)_{EA5} = (y)_{EA1}$

$(y)_{EA6} = (y)_{EA3} - L_{(a)}$

$(x)_{EA6} = (x)_{EA3}$

EA(T4): Entry Hall as Z-shape



Design Parameters:

$(W_{(EA)}*L_{(EA)}) \leq (5.3\%*Area_{(L)})$

$1.35 \leq W \leq 1.90$ m

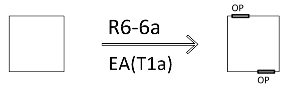
$L_{(EA)}$, $W_{(EA)}$= width and length of adjacent rooms

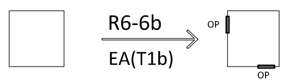
$(x)_{EA5} = (x)_{EA1} + W$

$(y)_{EA5} = (y)_{EA1}$

Rules for Determining Openings for the Main Entry Hall

Openings for EA(T1): Entry Hall as a Room

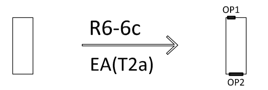


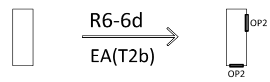


Design Parameters:

$0.90 \leq W_{(OP)} \leq 1.30$ m

Openings for EA(T2): Entry Hall as a Corridor



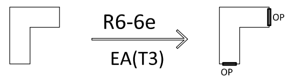


Design Parameters:

$0.90 \leq W_{(OP1)} \leq 1.00$ m

$0.90 \leq W_{(OP2)} \leq 1.30$ m

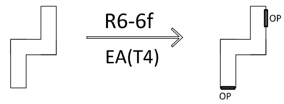
Openings for EA(T3): Entry Hall as a L-shape



Design Parameters:

$0.90 \leq W_{(OP)} \leq 1.30$ m

Openings for EA(T4): Entry Hall as a Z-shape



Design Parameters:

$0.90 \leq W_{(OP)} \leq 1.30$ 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

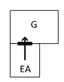
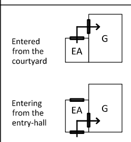
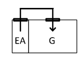
Design Parameters:

Movement Pattern from the Main Entry Hall to the Entrance og the Guest Room
Location of the Guest Room in relation to the Main Entry Hall

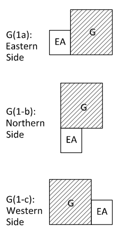
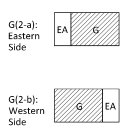
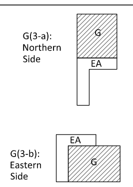
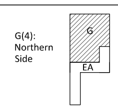
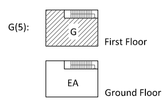
$(4.5\%*Area_{(L)}) \leq (W_{(G)}*L_{(G)}) \leq (13.1\%*Area_{(L)})$

$0.80 \leq W_{(G)}/L_{(G)} \leq 3.77$

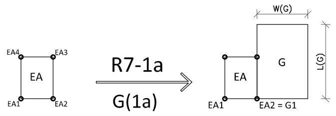
Typologies of Movement Patterns from the Main Entry Hall (EA) to the Entrance of the Guest Room

Type (a): 180° (Linear Connection)	Type (b): 90° Angle (L-shape)	Type (c): U-shape
		

Typologies of Guest Rooms according to their Location in relation to the Main Entry Hall

The Entry Hall as a Room	The Entry Hall as a Corridor	The Entry Hall as L-shape	The Entry Hall as Z-shape	The Entry Hall is located on the Ground Floor, and the Guest Room on the First Floor
				

Rules for Generating a Guest Room (G - Type1), which is attached to a Room Entry-Hall



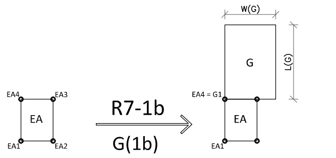
Design Parameters:

$4.10 \leq W_{(G)} \leq 10.95$ m

$3.20 \leq L_{(G)} \leq 5.00$ m

$1.15 \leq W_{(G)}/L_{(G)} \leq 3.00$

$(x,y)_{(EA2)} = (x,y)_{(G1)}$



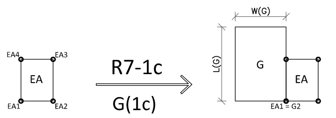
Design Parameters:

$5.75 \leq W_{(G)} \leq 10.75$ 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:

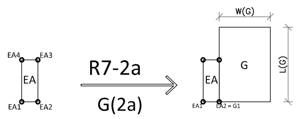
$4.45 \leq W_{(G)} \leq 10.30$ m

$2.50 \leq L_{(G)} \leq 6.75$ 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



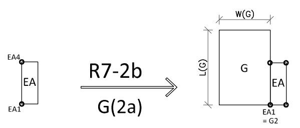
Design Parameters:

$4.70 \leq W_{(G)} \leq 11.45$ 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:

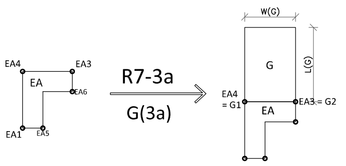
$5.30 \leq W_{(G)} \leq 9.65$ m

$2.75 \leq L_{(G)} \leq 6.75$ 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:

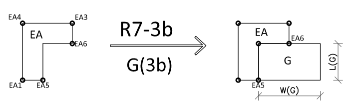
$5.20 \leq W_{(G)} \leq 7.25$ m

$4.10 \leq L_{(G)} \leq 6.45$ 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

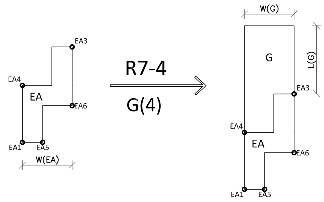
$0.80 \leq W_{(G)}/L_{(G)} \leq 1.77$

$(x,y)_{(EA5)} = (x,y)_{(G1)}$

$(x)_{(G4)} = (x)_{(EA5)}$

$(y)_{(G4)} = (y)_{(EA6)}$

Rules for Generating a Guest Room (G - Type 4), which is attached to Z-shape Entry-Hall



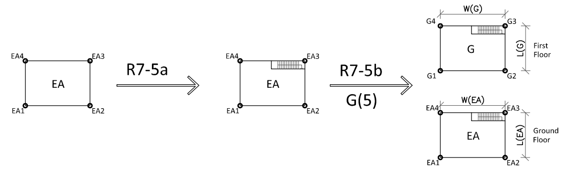
Design Parameters:

$W_{(G)} = W_{(EA)}$

$W_{(G)}/L_{(G)} = 0.40$

$(x,y)_{(EA4)} = (x,y)_{(G1)}$

Rules for Generating a Guest Room (G - Type 5), which is located on the First Floor



Design Parameters:

$W_{(G)} = W_{(EA)}$

$L_{(G)} = L_{(EA)}$

$(x,y)_{(EA1)} = (x,y)_{(G1)}$

$(x,y)_{(EA3)} = (x,y)_{(G3)}$

$6.10 \leq W_{(G)} \leq 9.00$

$2.70 \leq L_{(G)} \leq 3.20$

$2.25 \leq W_{(G)}/L_{(G)} \leq 2.80$

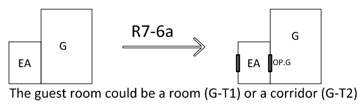
Rules for Generating Doors for the Guest Room (in relation to the Main Entrance)

Type (a): a Linear Pattern of Movement (180°), and entered directly from the entry-hall →

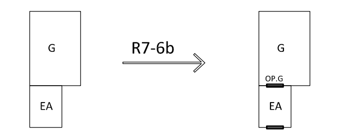
Design Parameters:

$0.90 \leq W_{(OP.G)} \leq 1.30$ m

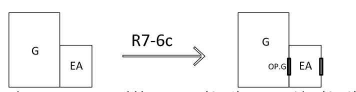
where
OP.G: the main entry point for the guest room



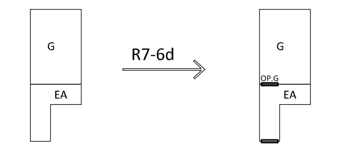
The guest room could be a room (G-T1) or a corridor (G-T2)



The guest room could be a room (G-T1) or a corridor (G-T2)



The guest room could be a room (G-T1) or a corridor (G-T2)



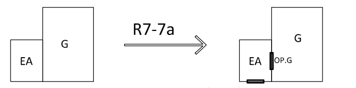
The type of the guest room is (G-T3a)

Type (b1): 90° Pattern of Movement, and entered directly from the entry-hall

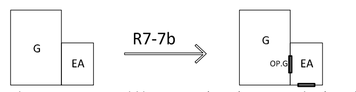
Design Parameters:

$0.90 \leq W_{(OP.G)} \leq 1.30$ m

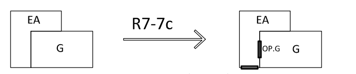
where
OP.G: the main entry point for the guest room



The guest room could be a room (G-T1) or a corridor (G-T2)



The guest room could be a room (G-T1) or a corridor (G-T2)



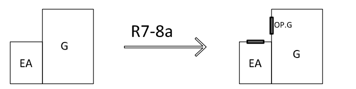
The type of the guest room is (G-T3b)

Type (b2): 90° Pattern of Movement, and entered from the courtyard

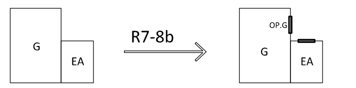
Design Parameters:

$0.90 \leq W_{(OP.G)} \leq 1.30$ m

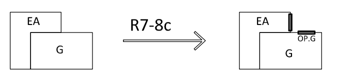
where
OP.G: the main entry point for the guest room



The guest room could be a room (G-T1) or a corridor (G-T2)



The guest room could be a room (G-T1) or a corridor (G-T2)



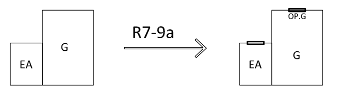
The type of the guest room is (G-T3b)

Type (c): U-shape Pattern of Movement, and entered from the courtyard

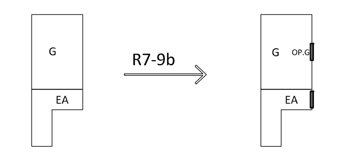
Design Parameters:

$0.90 \leq W_{(OP.G)} \leq 1.30$ m

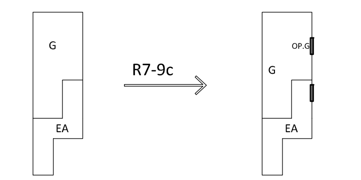
where
OP.G: the main entry point for the guest room



The guest room could be a room (G-T1) or a corridor (G-T2)



The type of the guest room is (G-T3a)



The type of the guest room is (G-T4)

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 %)

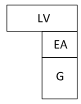
$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (AVG = 1.88)

$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$

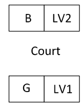
Design Parameters:

- 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).

Living Room is located opposite to Bedrooms (for achieving acoustical privacy)



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

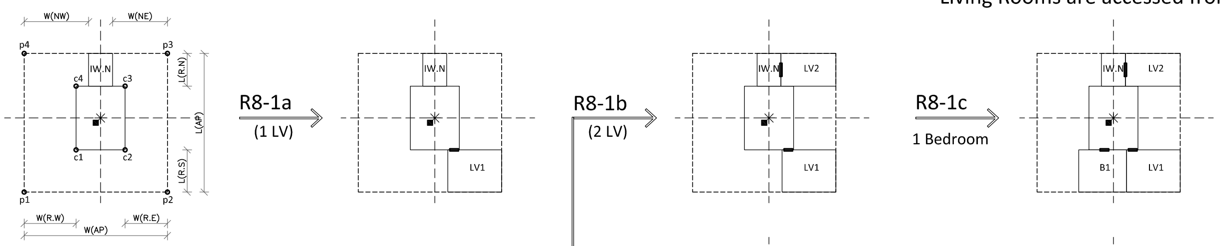


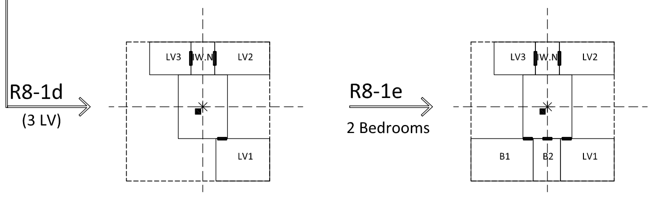
In some cases, there are two living rooms: one is for female visitors (adjacent to the Guest Room), and the other is for the family (adjacent to Bedrooms)

Rules for Houses that have one *Iwan* located on the Northern Side of the Courtyard:

Conditions: MC: Center, IW: North

Living Rooms are accessed from Iwan





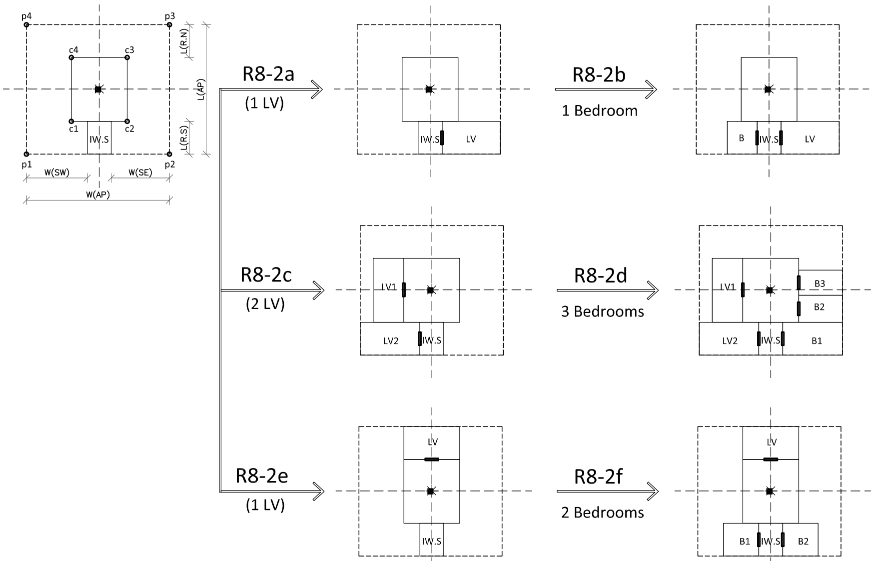
Area of Each Living Room = 4 % - 12 % (AVG = 8.5 %)
Area of Each Bedroom = 4 % - 7 % (AVG = 5.5 %)

$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (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



Living Room and Bedrooms are accessed from Iwan, and Bedrooms are opposite to Living Room

Living Room and Bedrooms are accessed from Iwan/Courtyard, and Bedrooms are opposite to Living Room

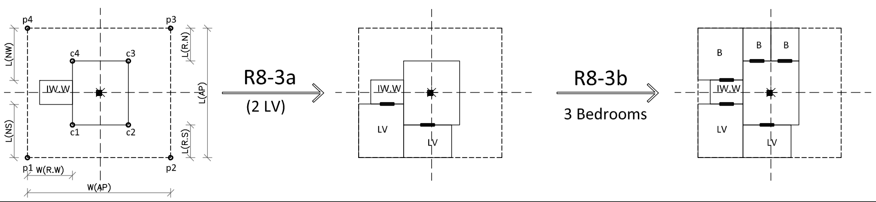
Bedrooms are accessed from Iwan, and Bedrooms are opposite to Living Room

Area of Each Living Room = 4 % - 12 % (AVG = 8.5 %)
Area of Each Bedroom = 4 % - 7 % (AVG = 5.5 %)

$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (AVG = 1.88)

$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$

Conditions: MC: Center, IW: West, L(R.W) < 8 m



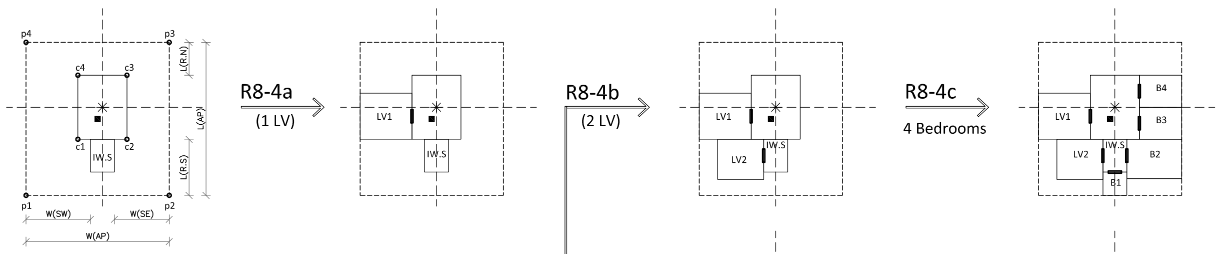
Bedrooms are accessed from Iwan/Courtyard, and Bedrooms are opposite to Living Room

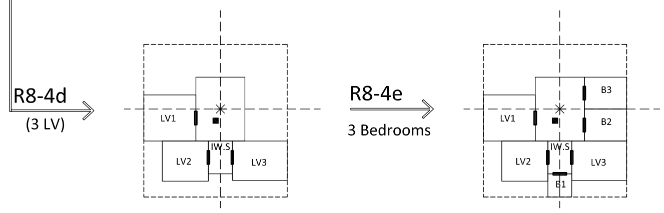
Area of Each Living Room = 4 % - 12 % (AVG = 8.5 %)
Area of Each Bedroom = 4 % - 7 % (AVG = 5.5 %)

$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (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

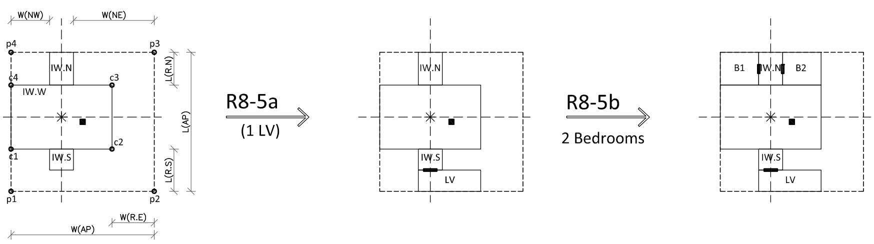
Area of Each Living Room = 4 % - 12 % (AVG = 8.5 %)
Area of Each Bedroom = 4 % - 7 % (AVG = 5.5 %)

$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (AVG = 1.88)

$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$

Rules for Houses that have two *Iwans* located on the Southern/Norhetrn Sides of the Courtyard:

Conditions: MC: West, IW: North and South, L(R.S) > 8 m



Living Rooms and Bedrooms are accessed from Iwans

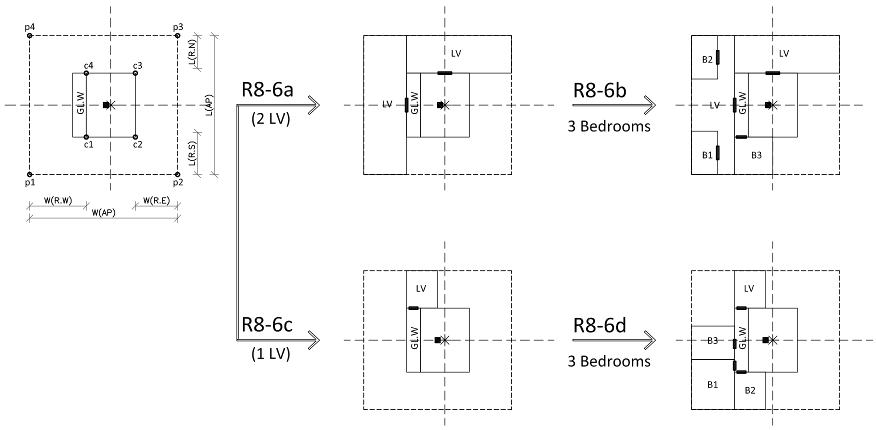
Area of Each Living Room = 4 % - 12 % (AVG = 8.5 %)
Area of Each Bedroom = 4 % - 7 % (AVG = 5.5 %)

$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (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

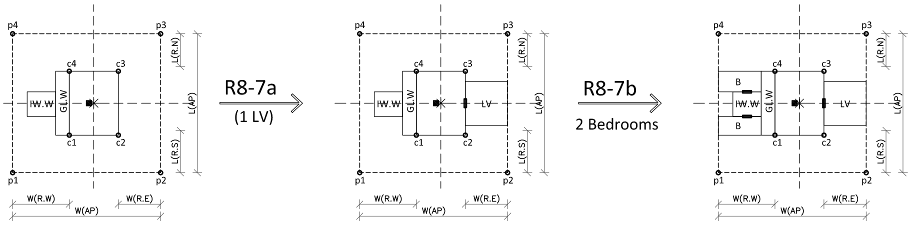
Living Room and Bedrooms are accessed from Gallery

Area of Each Living Room = 4 % - 12 % (AVG = 8.5 %)
Area of Each Bedroom = 4 % - 7 % (AVG = 5.5 %)

$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (AVG = 1.88)

$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$

Conditions: MC: Center, IW: West, GL: West



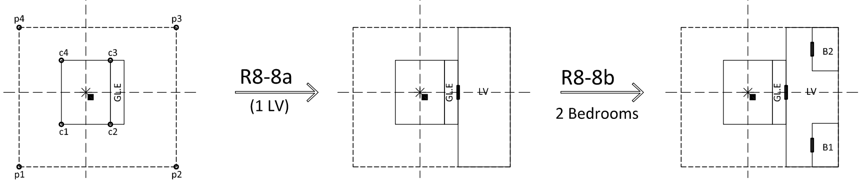
Living Room is accessed from courtyard, and Bedrooms are accessed from Iwan

Area of Each Living Room = 4 % - 12 % (AVG = 8.5 %)
Area of Each Bedroom = 4 % - 7 % (AVG = 5.5 %)

$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (AVG = 1.88)

$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$

Conditions: MC: Center, GL: West



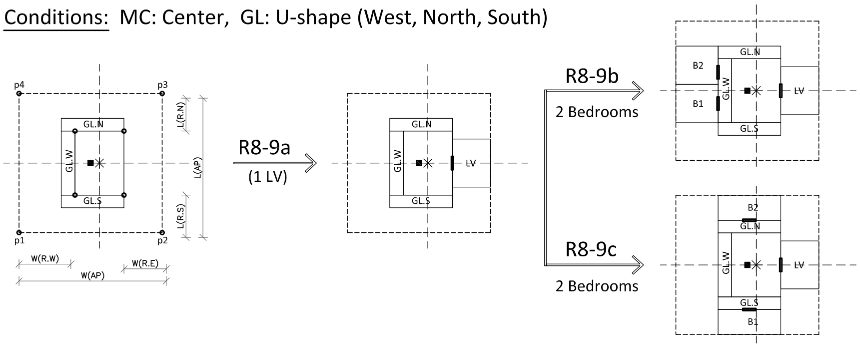
Living Room is accessed from Gallery, and Bedrooms are accessed from Living Room

Area of Each Living Room = 4 % - 12 % (AVG = 8.5 %)
Area of Each Bedroom = 4 % - 7 % (AVG = 5.5 %)

$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (AVG = 1.88)

$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$

Conditions: MC: Center, GL: U-shape (West, North, South)



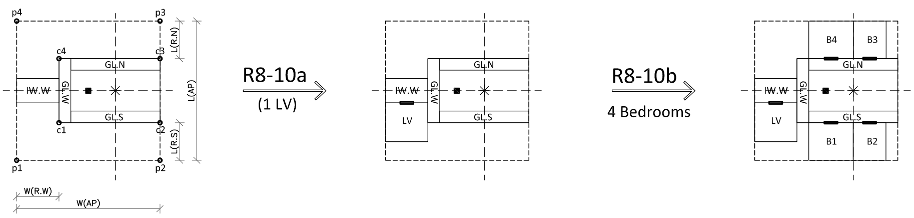
Bedrooms are accessed from Gallery, and opposite to Living Room

Area of Each Living Room = 4 % - 12 % (AVG = 8.5 %)
Area of Each Bedroom = 4 % - 7 % (AVG = 5.5 %)

$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (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

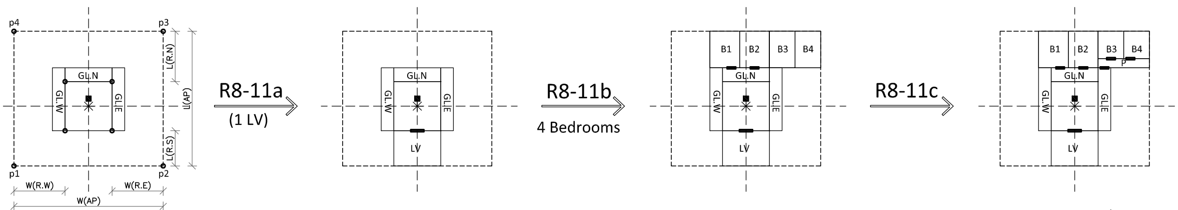
Area of Each Living Room = 4 % - 12 % (AVG = 8.5 %)
Area of Each Bedroom = 4 % - 7 % (AVG = 5.5 %)

$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (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



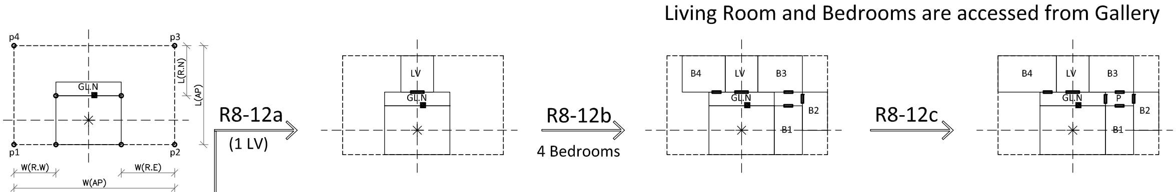
Area of Each Living Room = 4 % - 12 % (AVG = 8.5 %)
Area of Each Bedroom = 4 % - 7 % (AVG = 5.5 %)

$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (AVG = 1.88)

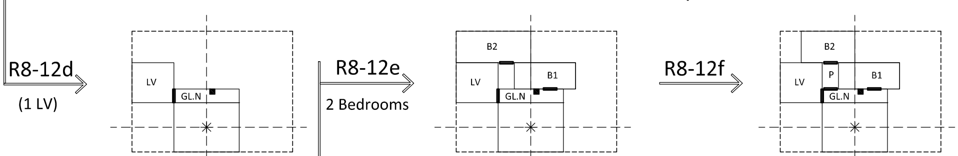
$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$

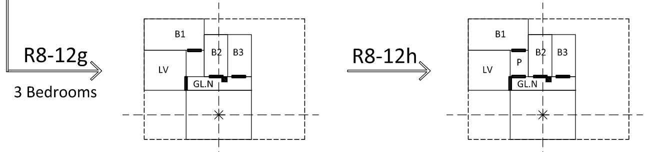
Conditions: MC: South, GL: North

L(R.N) < 8 m, L(R.N) < 8 m,
Living Room and Bedrooms are accessed from Gallery



L(R.N) > 8 m, Living Room and Bedrooms are accessed from Gallery





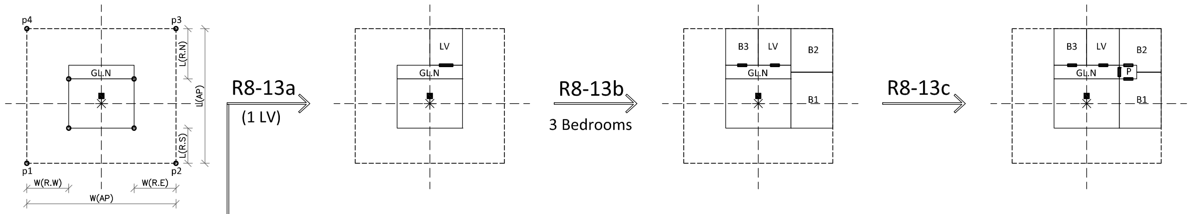
Area of Each Living Room = 4 % - 12 % (AVG = 8.5 %)
Area of Each Bedroom = 4 % - 7 % (AVG = 5.5 %)

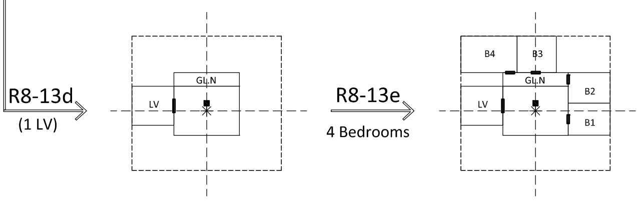
$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (AVG = 1.88)

$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$

Conditions: MC: Center, GL: North

Living Room and Bedrooms are accessed from Gallery





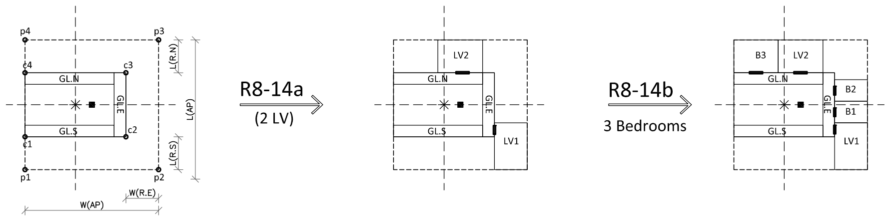
Bedrooms are accessed from Gallery and Courtyard , and Bedrooms are opposite to Living Room

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

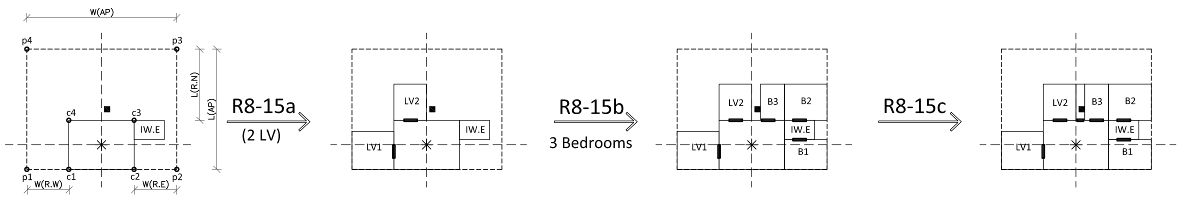
Area of Each Living Room = 4 % - 12 % (AVG = 8.5 %)
Area of Each Bedroom = 4 % - 7 % (AVG = 5.5 %)

$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (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



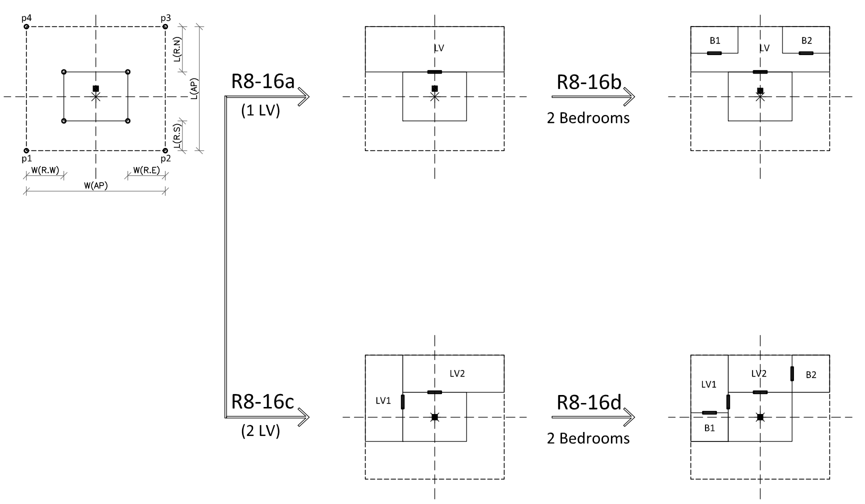
Area of Each Living Room = 4 % - 12 % (AVG = 8.5 %)
Area of Each Bedroom = 4 % - 7 % (AVG = 5.5 %)

$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (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)

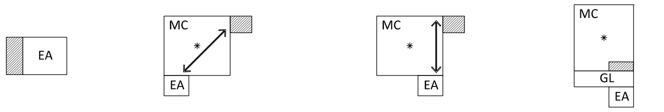
$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$

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



Type (1): (accessed directly from the Entry Hall)

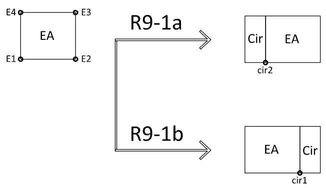
Type (2a): adjacent to the Courtyard, and located at the opposite corner of the Entry Hall (diagonal relationships)

Type (2b): adjacent to the Courtyard, and located at the opposite corner of the Entry Hall (linear relationships)

Type (3): adjacent to the Courtyard/Gallery, and accessed from the Gallery

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:

$x_{(cir2)} = x_{(E1)}$

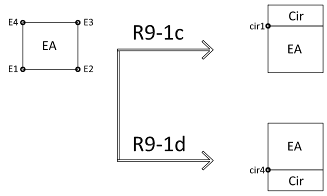
$y_{(E1)} \leq y_{(cir2)} \leq y_{(E4)}$

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:

$x_{(E4)} \leq x_{(cir1)} \leq x_{(E3)}$

$y_{(cir1)} = y_{(E3)}$

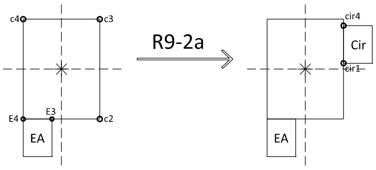
Design Parameters:

$x_{(E1)} \leq x_{(cir4)} \leq x_{(E2)}$

$y_{(cir4)} = y_{(E2)}$

Rules for Allocating Stairs (Cir) Type 2-a (Diagonal Relationship with EA)

Conditions: EA is located on the Southern side of the courtyard



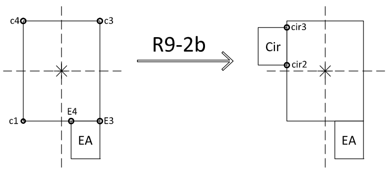
Design Parameters:

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:

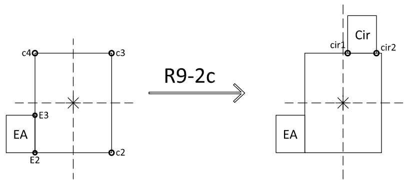
If $y_{(E3)} = y_{(E4)} = y_{(c1)}$, then

$x_{(cir2)} = x_{(cir3)} = x_{(c1)}$

$(y_{(c1)}+y_{(c4)})/2 \leq y_{(cir2)}$

$y_{(cir3)} \leq y_{(c4)}$

Conditions: EA is located on the Eastern or Western sides of the courtyard



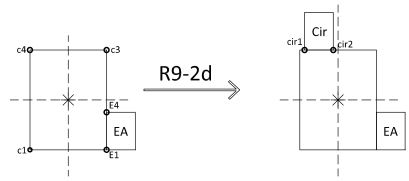
Design Parameters:

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:

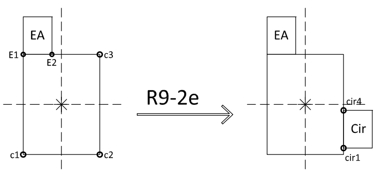
If $x_{(E1)} = x_{(E4)} = y_{(c3)}$, then

$y_{(cir2)} = y_{(cir1)} = y_{(c3)}$

$x_{(cir2)} \leq (x_{(c3)}+x_{(c4)})/2$

$x_{(c4)} \leq x_{(cir1)}$

Conditions: EA is located on the Northern side of the courtyard



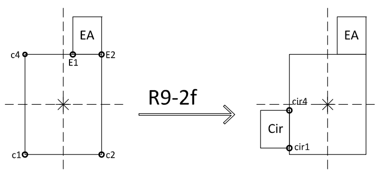
Design Parameters:

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

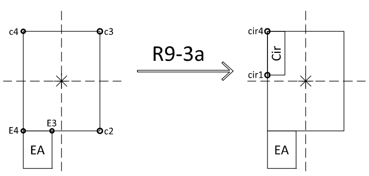
$x_{(cir1)} = x_{(cir4)} = x_{(c1)}$

$y_{(cir4)} \leq (y_{(c1)}+y_{(c4)})/2$

$y_{(cir1)} \leq y_{(c1)}$

Rules for Allocating Stairs (Cir) Type 2-b (Linear Relationship with EA)

Conditions: EA is located on the Southern side of the courtyard



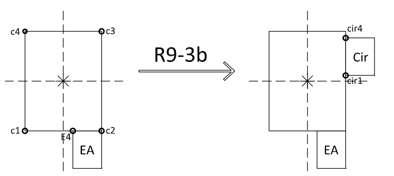
Design Parameters:

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:

$(x,y)_{(cir2)} = (x,y)_{(c2)}$

$x_{(cir3)} = x_{(cir2)}$

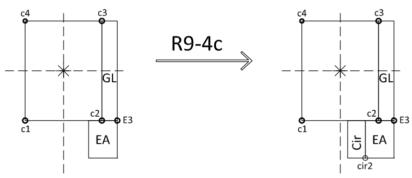
$(y_{(c2)}+y_{(c3)})/2 \leq y_{(cir3)}$

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

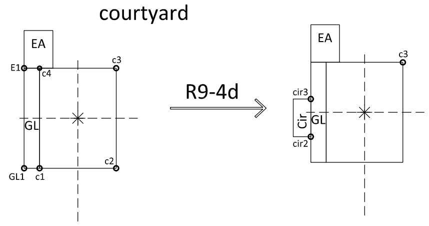


Design Parameters:

$(x,y)_{(cir2)} = (x,y)_{(E1)}$

$(x,y)_{(cir3)} = (x,y)_{(E4)}$

Conditions: EA is located on the Northern side of the courtyard/gallery, and the Gallery is located on the Western side of the courtyard



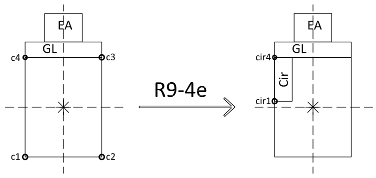
Design Parameters:

$x_{(cir2)} \leq x_{(cir2)} \leq x_{(GL1)}$

$y_{(GL1)} \leq y_{(cir2)} \leq y_{(GL4)}$

$y_{(cir3)} = y_{(cir2)}$

Conditions: EA and GL are located on the Northern side of the courtyard



Design Parameters:

$(x,y)_{(cir4)} = (x,y)_{(c4)}$

$x_{(cir1)} = x_{(cir4)}$

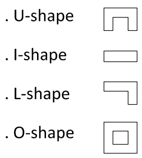
$(y_{(c1)}+y_{(c4)})/2 \leq y_{(cir1)}$

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.

Typologies for the First Floor Layout:



Design Parameters:

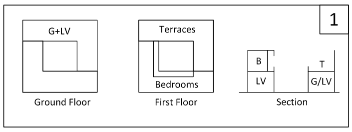
- Number of Bedrooms and Living Rooms.
- The Layout of Ground/First Floors.
- Location of Bedrooms in relation to Guest Rooms and Living Rooms.
- Location of Private/Intimate Spaces in relation to Semi-private Spaces (IW, GL, MC)

Typologies for the Layout of the First Floor

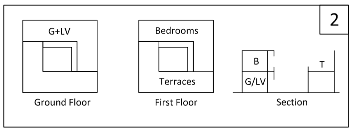
The Layout of the Ground Floor	For MC-S		For MC-C						For MC-E
The Layout of the First Floor	Type S1 U-shape (N+E+W sides)	Type S2 I-shape (N side)	Type C1 O-shape (All sides)	Type C2 L-shape (S+E sides)	Type C3 L-shape (S+W sides)	Type C4 U-shape (N+E+S sides)	Type C5 I-shape (N+S sides)	Type C6 L-shape (N+E sides)	Type E L-shape (S+W sides)
% of the 1st Floor Area from the Ground Floor	87%	36%	73% ↔ 93% (AVG = 83%)	34% ↔ 65% (AVG = 47%)	26% ↔ 46% (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

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

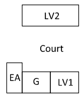


Strategy (2):
- Bedrooms are located above guest/living rooms (with a gallery in front of it)
- Terraces are located opposite to guest rooms (with a gallery in front of it)



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)

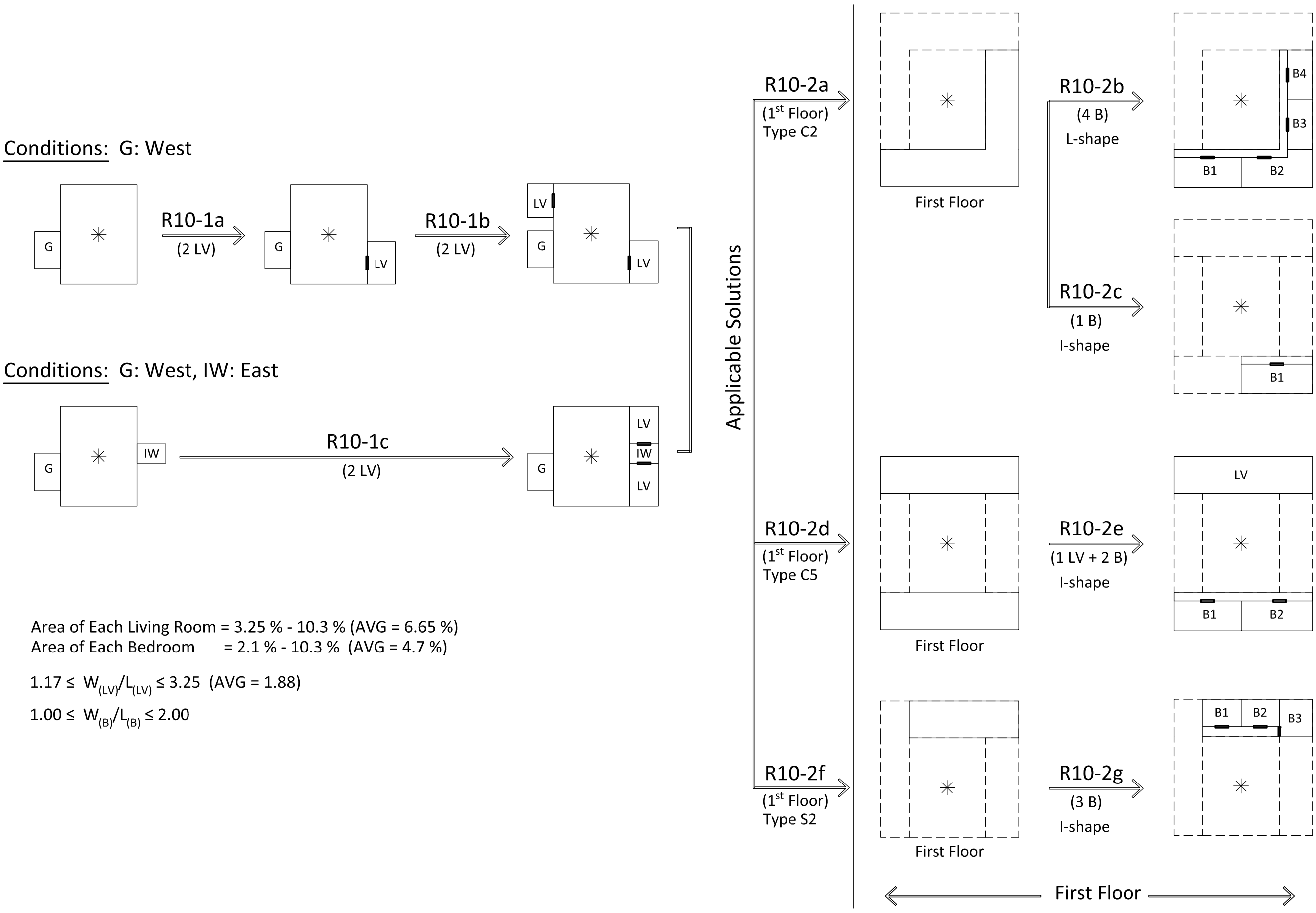


Area of Each Living Room = 3.25 % - 10.3 % (AVG = 6.65 %)
Area of Each Bedroom = 2.1 % - 10.3 % (AVG = 4.7 %)

$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (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:



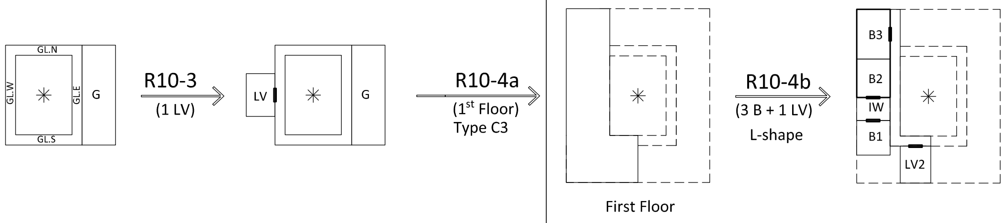
Area of Each Living Room = 3.25 % - 10.3 % (AVG = 6.65 %)
Area of Each Bedroom = 2.1 % - 10.3 % (AVG = 4.7 %)

$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (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 Eastern Side of the Courtyard:

Conditions: G: East, and
GL: East, West, North, South



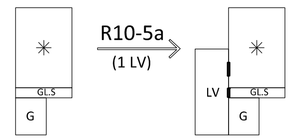
Area of Each Living Room = 3.25 % - 10.3 % (AVG = 6.65 %)
Area of Each Bedroom = 2.1 % - 10.3 % (AVG = 4.7 %)

$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (AVG = 1.88)

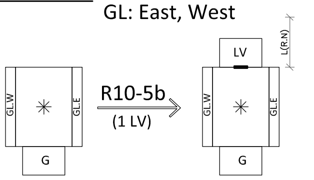
$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$

Rules for Houses that have a Guest Room, which is located on the Southern Side of the Courtyard:

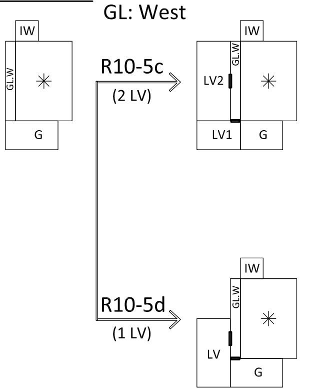
Conditions: G: South,
GL: South



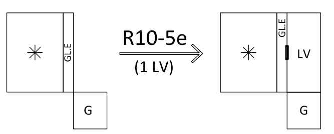
Conditions: G: South, L(R.N) > 8 m
GL: East, West

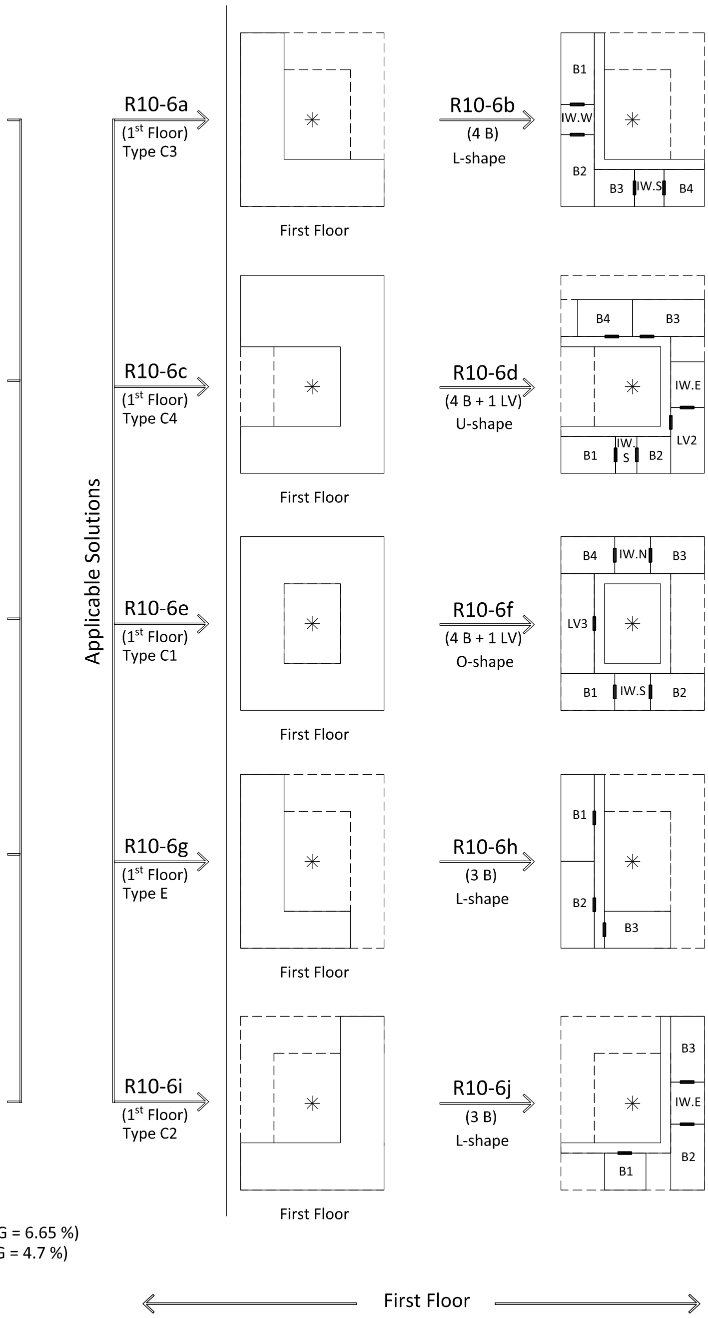


Conditions: G: South,
GL: West



Conditions: G: South,
GL: East





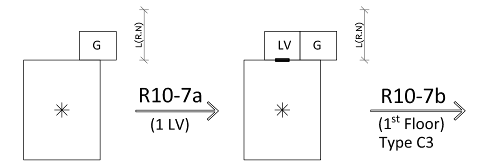
Area of Each Living Room = 3.25 % - 10.3 % (AVG = 6.65 %)
Area of Each Bedroom = 2.1 % - 10.3 % (AVG = 4.7 %)

$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (AVG = 1.88)

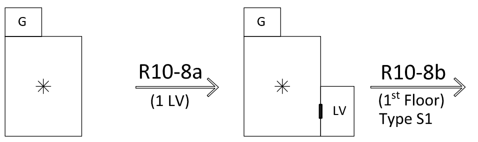
$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$

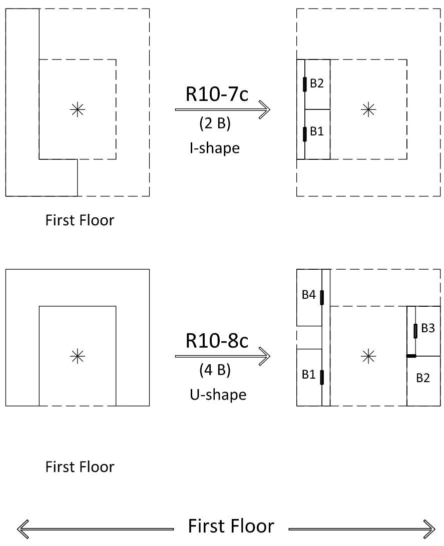
Rules for Houses that have a Guest Room, which is located on the Northern Side of the Courtyard:

Conditions: G: North, L(R.N) > 8 m



Conditions: G: North





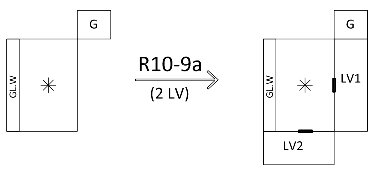
Area of Each Living Room = 3.25 % - 10.3 % (AVG = 6.65 %)
Area of Each Bedroom = 2.1 % - 10.3 % (AVG = 4.7 %)

$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (AVG = 1.88)

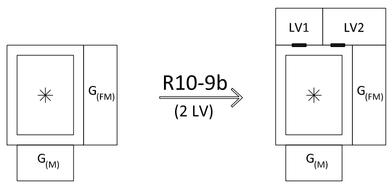
$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$

Rules for Houses that have 5+ Bedrooms:

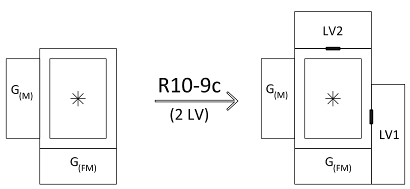
Conditions: MC: Center
G: North, GL: West

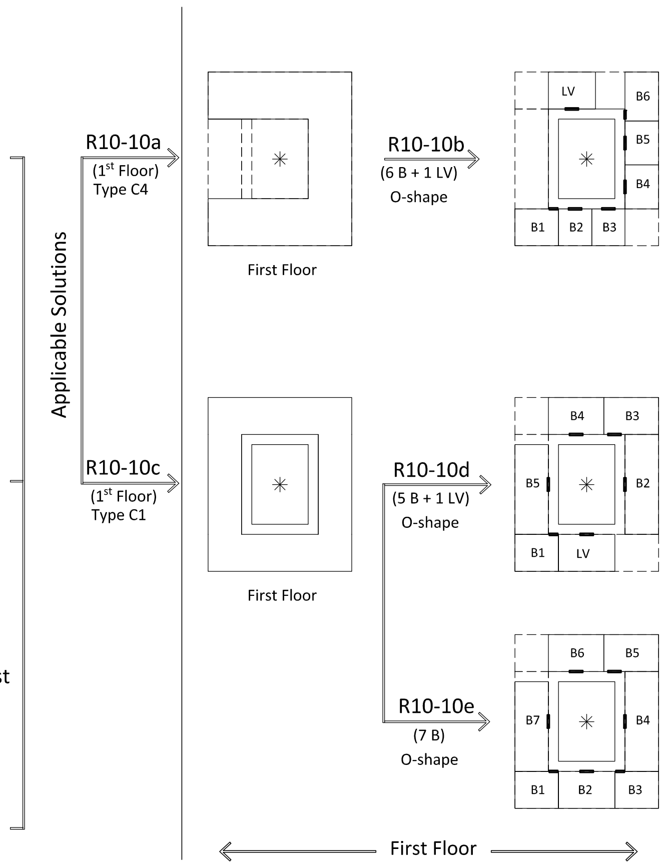


Conditions: MC: Center, G(M): South, G(FM): East
GL: West, East, North, South



Conditions: MC: Center, G(FM): South, G(M): West
GL: West, East, North, South





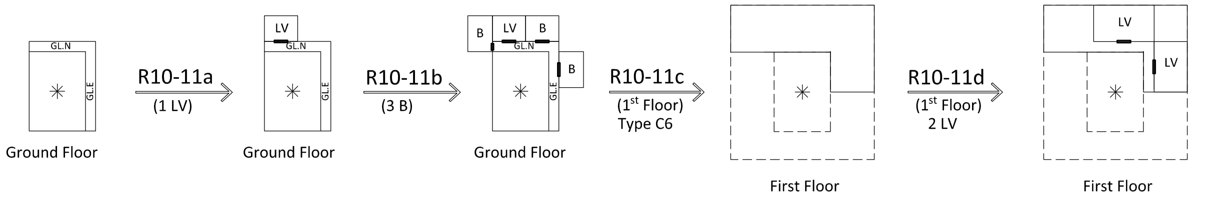
Area of Each Living Room = 3.25 % - 10.3 % (AVG = 6.65 %)
Area of Each Bedroom = 2.1 % - 10.3 % (AVG = 4.7 %)

$1.17 \leq W_{(LV)}/L_{(LV)} \leq 3.25$ (AVG = 1.88)

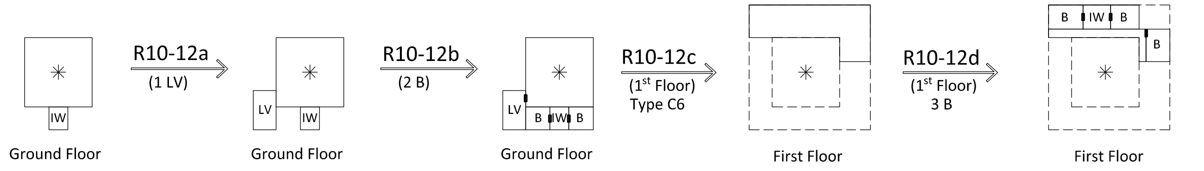
$1.00 \leq W_{(B)}/L_{(B)} \leq 2.00$

Rules for Houses with Bedrooms located on Ground & First Floors:

Conditions: GL: North + East



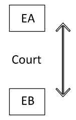
Conditions: IW: South



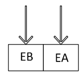
Stage (11): Rules for the Configuration of Service Entrance (EB)

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

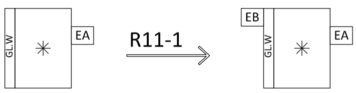


Service Entrance is located opposite to the Main Entrance

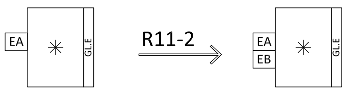


Service Entrance is located adjacent to the Main Entrance

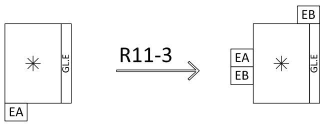
Conditions: GL: West, EA: East



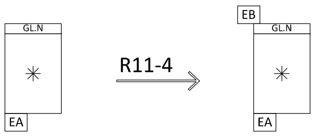
Conditions: GL: East, EA: West



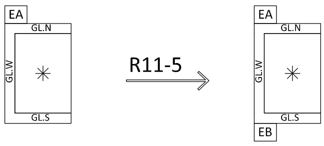
Conditions: GL: East, EA: South



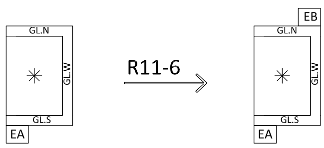
Conditions: GL: North, EA: South



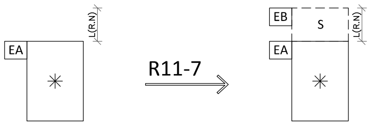
Conditions: GL: West+North+South, EA: North



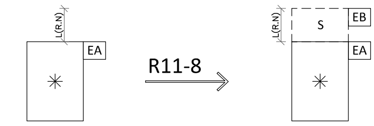
Conditions: GL: East+North+South, EA: South



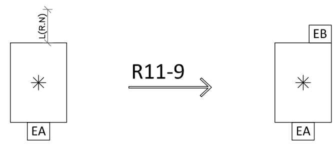
Conditions: GL: East+North+South, EA: West, L(R.N) ≥ 10m



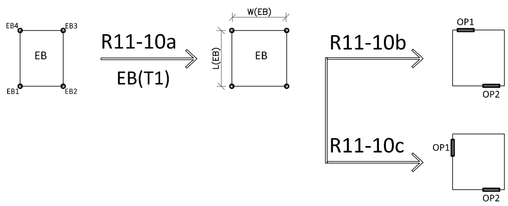
Conditions: GL: East+North+South, EA: East, L(R.N) ≥ 10m



Conditions: GL: East+North+South, EA: East, L(R.N) < 10m



EB(T1): Service Entrance as a Hall



Design Parameters:

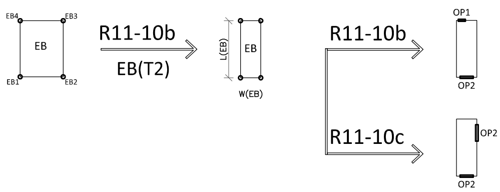
$2.25 \leq W_{(EB)} \leq 3.60$ m

$L_{(EB)}$ = 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)

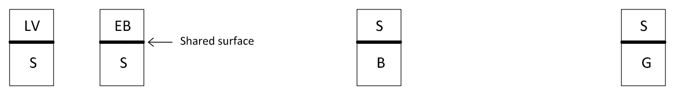
In this grammar, rules indicate the overall layout of services. Subdivisions are not included as they depend on the needs of each design.

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



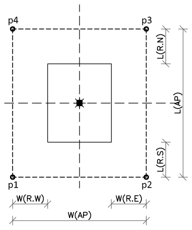
S: Kitchen, Storage Areas, and Toilets (adjacent to living room and/or service entrance)

S: Bathrooms (adjacent to bedrooms)

S: Toilets (adjacent to guestroom)

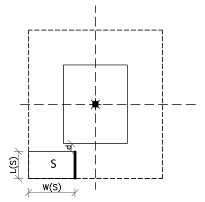
Rules for Houses that have O-shape Layout:

Conditions: Main Courtyard is located at the center of the Layout



R12-1a

S: South



$W_{(S)} \le W_{(AP)}$

$L_{(S)} \le L_{(R.S)}$

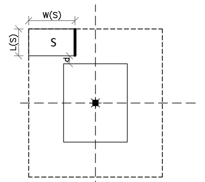
$0 \le d \le W_{(GL)}$

$(x_{(p1)}-(W_{(s)}/2)) \le x_{(s)} \le (x_{(p2)}-(W_{(s)}/2))$

$y_{(S)} = -(y_{(MC)} + (L_{(MC)}/2) + d + (L_{(s)}/2))$

R12-1b

S: North



$W_{(S)} \le W_{(AP)}$

$L_{(S)} \le W_{(R.N)}$

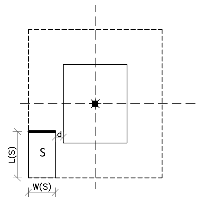
$0 \le d \le W_{(GL)}$

$(x_{(p3)}-(W_{(s)}/2)) \le x_{(s)} \le (x_{(p4)}-(W_{(s)}/2))$

$y_{(S)} = (y_{(MC)} + (L_{(MC)}/2) + d + (L_{(s)}/2))$

R12-1c

S: East



$L_{(S)} \le L_{(AP)}$

$W_{(S)} \le W_{(R.W)}$

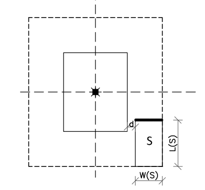
$0 \le d \le W_{(GL)}$

$(y_{(p1)}-(L_{(s)}/2)) \le y_{(s)} \le (y_{(p4)}-(L_{(s)}/2))$

$x_{(S)} = -(x_{(MC)} + (W_{(MC)}/2) + d + (W_{(s)}/2))$

R12-1d

S: West



$L_{(S)} \le L_{(AP)}$

$W_{(S)} \le W_{(R.E)}$

$0 \le d \le W_{(GL)}$

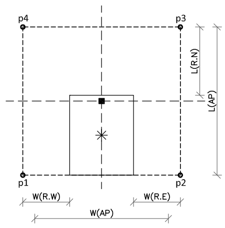
$(y_{(p2)}-(L_{(s)}/2)) \le y_{(s)} \le (y_{(p3)}-(L_{(s)}/2))$

$x_{(S)} = (x_{(MC)} + (W_{(MC)}/2) + d + (W_{(s)}/2))$

shared surface with adjacent room

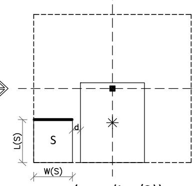
Rules for Houses that have U-shape Layout:

Conditions: Main Courtyard is located on the Southern Side of the Layout



R12-2a

S: West



$L_{(S)} \le L_{(AP)}$

$W_{(S)} \le W_{(R.W)}$

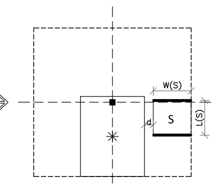
$0 \le d \le W_{(GL)}$

$(y_{(p1)}-(L_{(s)}/2)) \le y_{(s)} \le (y_{(p4)}-(L_{(s)}/2))$

$x_{(S)} = -(x_{(MC)} + (W_{(MC)}/2) + d + (W_{(s)}/2))$

R12-2b

S: East



$L_{(S)} \le L_{(AP)}$

$W_{(S)} \le W_{(R.E)}$

$0 \le d \le W_{(GL)}$

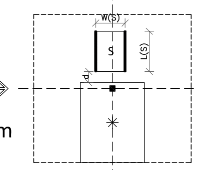
$(y_{(p2)}-(L_{(s)}/2)) \le y_{(s)} \le (y_{(p3)}-(L_{(s)}/2))$

$x_{(S)} = (x_{(MC)} + (W_{(MC)}/2) + d + (W_{(s)}/2))$

R12-2c

S: North

$L_{(R.N)} < 8m$



$W_{(S)} \le W_{(AP)}$

$L_{(S)} \le W_{(R.N)}$

$0 \le d \le W_{(GL)}$

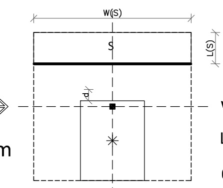
$(x_{(p3)}-(W_{(s)}/2)) \le x_{(s)} \le (x_{(p4)}-(W_{(s)}/2))$

$y_{(S)} = (y_{(MC)} + (L_{(MC)}/2) + d + (L_{(s)}/2))$

R12-2d

S: North

$L_{(R.N)} \ge 8m$



$W_{(S)} \le W_{(AP)}$

$L_{(S)} \le (L_{(R.N)}/2)$

$0 \le d \le W_{(GL)}$

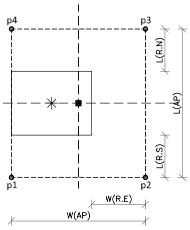
$(x_{(p3)}-(W_{(s)}/2)) \le x_{(s)} \le (x_{(p4)}-(W_{(s)}/2))$

$y_{(S)} = (y_{(MC)} + (L_{(MC)}/2) + d + (L_{(s)}/2))$

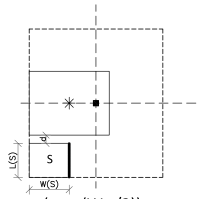
shared surface with adjacent room

Rules for Houses that have U-shape Layout:

Conditions: Main Courtyard is located on the Western Side of the Layout



R12-3a
S: South



$W_{(S)} \leq W_{(AP)}$

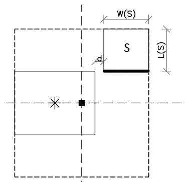
$L_{(S)} \leq L_{(R.S)}$

$0 \leq d \leq W_{(GL)}$

$(x_{(p1)}-(W_{(s)}/2)) \leq x_{(s)} \leq (x_{(p2)}-(W_{(s)}/2))$

$y_{(S)} = -(y_{(MC)} + (L_{(MC)}/2) + d + (L_{(s)}/2))$

R12-3b
S: East



$L_{(S)} \leq L_{(AP)}$

$W_{(S)} \leq W_{(R.E)}$

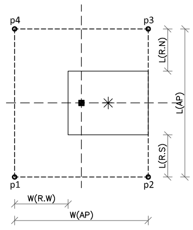
$0 \leq d \leq W_{(GL)}$

$(y_{(p2)}-(L_{(s)}/2)) \leq y_{(s)} \leq (y_{(p3)}-(L_{(s)}/2))$

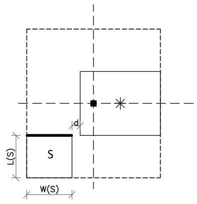
$x_{(S)} = (x_{(MC)} + (W_{(MC)}/2) + d + (W_{(s)}/2))$

——— shared surface with adjacent room

Conditions: Main Courtyard is located on the Eastern Side of the Layout



R12-4a
S: West



$L_{(S)} \leq L_{(AP)}$

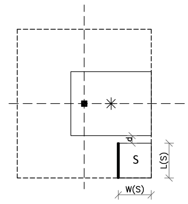
$W_{(S)} \leq W_{(R.W)}$

$0 \leq d \leq W_{(GL)}$

$(y_{(p1)}-(L_{(s)}/2)) \leq y_{(s)} \leq (y_{(p4)}-(L_{(s)}/2))$

$x_{(S)} = -(x_{(MC)} + (W_{(MC)}/2) + d + (W_{(s)}/2))$

R12-4b
S: South



$W_{(S)} \leq W_{(AP)}$

$L_{(S)} \leq L_{(R.S)}$

$0 \leq d \leq W_{(GL)}$

$(x_{(p1)}-(W_{(s)}/2)) \leq x_{(s)} \leq (x_{(p2)}-(W_{(s)}/2))$

$y_{(S)} = -(y_{(MC)} + (L_{(MC)}/2) + d + (L_{(s)}/2))$

——— shared surface with adjacent room

Stage (13): Rules for the Configuration of Services (S) that are located on the First Floor

Descriptions:

S: Services include Bathrooms (Intimate Spaces)

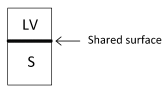
In this grammar, rules indicate the overall layout of services. Subdivisions are not included as they depend on the needs of each design.

Location of services depends on the overall layout of the house, and the location of the courtyard and other rooms specified in previous steps.

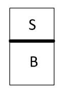
Area of Services = 11 % - 20 % (AVG = 15.5 %)

Width of services depends on the width of rooms surrounding the main courtyard.

Type of Services in relation to Other Spaces

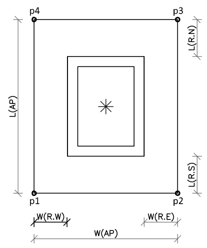


S: Kitchen, Storage Areas, and Toilets
(adjacent to living room and/or service entrance)



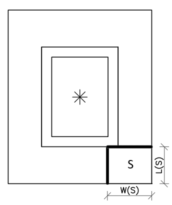
S: Bathrooms
(adjacent to bedrooms)

Rules for a First Floor that has an O-shape Layout:



First Floor

R13-1a
S: South-East



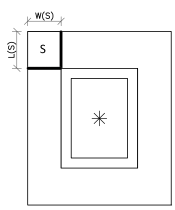
$W_{(S)} \leq W_{(AP)}$

$L_{(S)} \leq L_{(R.S)}$

$(x_{(p1)}-(W_{(s)}/2)) \leq x_{(s)} \leq (x_{(p2)}-(W_{(s)}/2))$

$y_{(S)} = -(y_{(MC)} + (L_{(MC)}/2) + W_{(GL)} + (L_{(s)}/2))$

R13-1b
S: North-West



$W_{(R.W)} \leq W_{(S)} \leq W_{(AP)}$

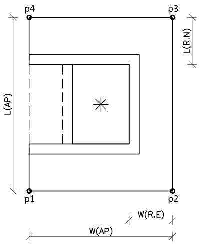
$L_{(R.N)} \leq L_{(S)} \leq L_{(AP)}$

$(x_{(p3)}-(W_{(s)}/2)) \leq x_{(s)} \leq (x_{(p4)}-(W_{(s)}/2))$

$(y_{(p1)}-(L_{(s)}/2)) \leq y_{(s)} \leq (y_{(p4)}-(L_{(s)}/2))$

——— shared surface with adjacent room

Rules for a First Floor that has a U-shape Layout:

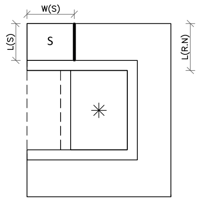


First Floor

R13-2a

S: North

$L_{(R.N)} < 8m$



$W_{(S)} \leq W_{(AP)}$

$L_{(S)} \leq W_{(R.N)}$

$(x_{(p3)}-(W_{(s)}/2)) \leq x_{(s)} \leq (x_{(p4)}-(W_{(s)}/2))$

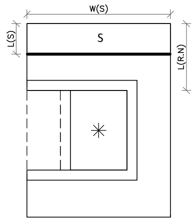
$y_{(S)} = (y_{(MC)} + (L_{(MC)}/2) + W_{(GL)} + (L_{(S)}/2))$

shared surface with adjacent room

R13-2b

S: North

$L_{(R.N)} \geq 8m$



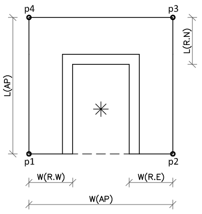
$W_{(S)} \leq W_{(AP)}$

$L_{(S)} \leq (L_{(R.N)}/2)$

$(x_{(p3)}-(W_{(s)}/2)) \leq x_{(s)} \leq (x_{(p4)}-(W_{(s)}/2))$

$y_{(S)} = (y_{(MC)} + (L_{(MC)}/2) + W_{(GL)} + (L_{(S)}/2))$

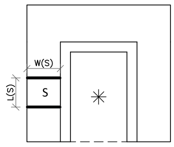
shared surface with adjacent room



First Floor

R13-3a

S: West



$L_{(S)} \leq L_{(AP)}$

$W_{(S)} \leq W_{(R.W)}$

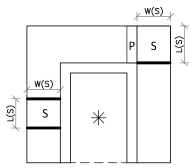
$(y_{(p1)}-(L_{(s)}/2)) \leq y_{(s)} \leq (y_{(p4)}-(L_{(s)}/2))$

$x_{(S)} = -(x_{(MC)} + (W_{(MC)}/2) + d + (W_{(S)}/2))$

shared surface with adjacent room

R13-3b

S: North-East



$L_{(S)} \leq L_{(AP)}$

$W_{(S)} \leq W_{(R.E)}$

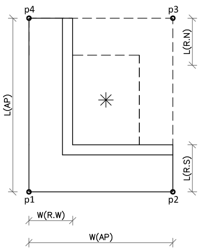
$(y_{(p2)}-(L_{(s)}/2)) \leq y_{(s)} \leq (y_{(p3)}-(L_{(s)}/2))$

$x_{(S)} = (x_{(MC)} + (W_{(MC)}/2) + W_{(GL)} + (W_{(S)}/2))$

$W_{(P)} = W_{(GL)}$

$L_{(P)} \leq W_{(R.N)}$

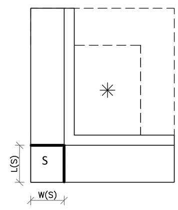
Rules for a First Floor that has L-shape Layout:



First Floor

R13-4a

S: South-West



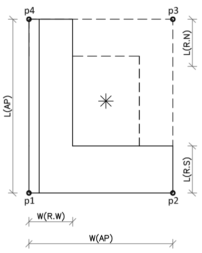
$L_{(S)} \leq L_{(AP)}$

$W_{(S)} \leq W_{(AP)}$

$(y_{(p2)}-(L_{(s)}/2)) \leq y_{(s)} \leq (y_{(p3)}-(L_{(s)}/2))$

$(x_{(p1)}-(W_{(s)}/2)) \leq x_{(s)} \leq (x_{(p4)}-(W_{(s)}/2))$

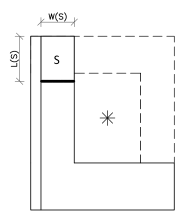
shared surface with adjacent room



First Floor

R13-4b

S: North-West



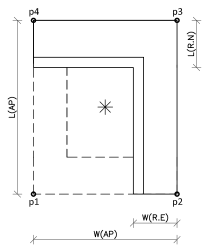
$W_{(S)} = W_{(R.W)} - W_{(GL)}$

$L_{(S)} \leq L_{(AP)}$

$x_{(S)} = -(x_{(MC)} + (W_{(MC)}/2) + (W_{(S)}/2))$

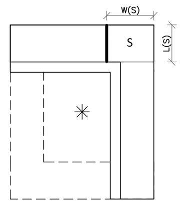
$(y_{(p1)}-(L_{(s)}/2)) \leq y_{(s)} \leq (y_{(p4)}-(L_{(s)}/2))$

shared surface with adjacent room



First Floor

R13-4c
S: North



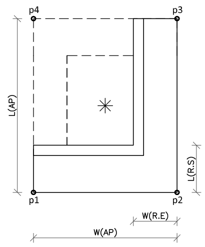
$W_{(S)} \leq W_{(AP)}$

$L_{(S)} \leq W_{(R.N)}$

$(x_{(p3)} - (W_{(s)}/2)) \leq x_{(s)} \leq (x_{(p4)} - (W_{(s)}/2))$

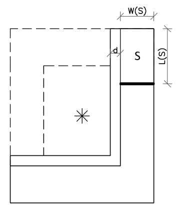
$y_{(S)} = (y_{(MC)} + (L_{(MC)}/2) + W_{(GL)} + (L_{(S)}/2))$

—— shared surface with adjacent room



First Floor

R13-4d
S: North



$L_{(S)} \leq L_{(AP)}$

$W_{(S)} \leq W_{(R.E)}$

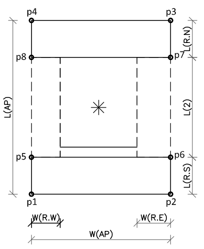
$0 \leq d \leq W_{(GL)}$

$(y_{(p2)} - (L_{(s)}/2)) \leq y_{(s)} \leq (y_{(p3)} - (L_{(s)}/2))$

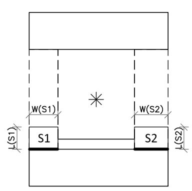
$x_{(S)} = (x_{(MC)} + (W_{(MC)}/2) + d + (W_{(S)}/2))$

—— 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

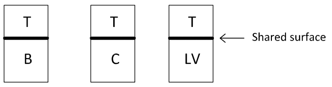
S1 and S2: Bathrooms, connected from North with Terraces, and from South with Bedrooms

Stage (14): Rules for the Configuration of Terraces that are located on the Ground Floor

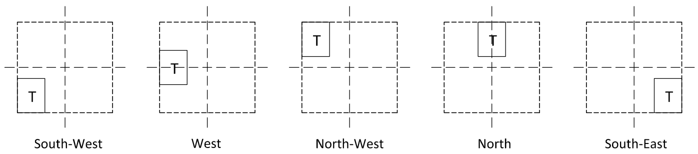
Descriptions:

T: Terraces/Balconies (Semi-Private Spaces)
T: Terraces could be connected with Bedrooms, Living Spaces, or Courtyards

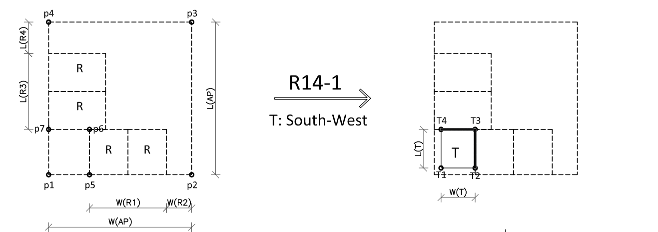
Area of All Terraces = 11 % - 16 % (AVG = 14.3 %) from the total area of the house



Location of Terraces in relation to the Layout of the Ground Floor



Terrace is located on the South-West Direction:



R: Bedroom / Living Room / Courtyard
shared surface with adjacent room

$L_{(T)} \leq (L_{(AP)} - (L_{(R3)}+L_{(R4)}))$

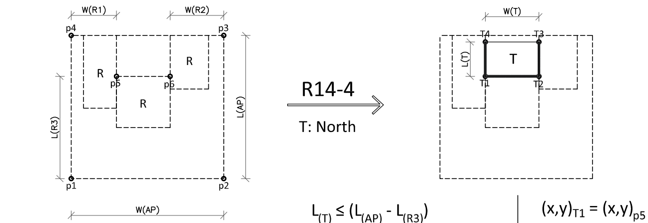
$W_{(T)} \leq (W_{(AP)} - (W_{(R1)}+W_{(R2)}))$

$(x,y)_{T3} = (x,y)_{p6}$

$(x)_{T2} = (x)_{T3} = (x)_{p5}$

$(y)_{T3} = (y)_{T4} = (y)_{p7}$

Terrace is located on the North Direction:



R: Bedroom / Living Room / Courtyard
shared surface with adjacent room

$L_{(T)} \leq (L_{(AP)} - L_{(R3)})$

$W_{(T)} \leq (W_{(AP)} - (W_{(R1)}+W_{(R2)}))$

$(x,y)_{T1} = (x,y)_{p5}$

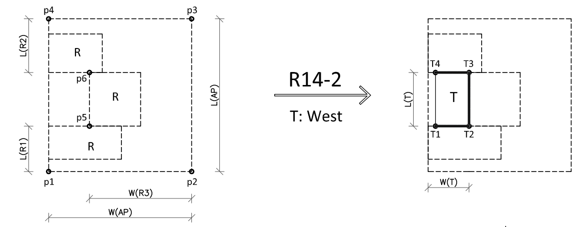
$(x,y)_{T2} = (x,y)_{p6}$

$(y)_{T3} = (y)_{T4}$

$(y)_{T1} = (y)_{T2}$

$(x)_{T1} = (x)_{T4}$

Terrace is located on the West Direction:



R: Bedroom / Living Room / Courtyard
shared surface with adjacent room

$L_{(T)} \leq (L_{(AP)} - (L_{(R1)}+L_{(R2)}))$

$W_{(T)} \leq (W_{(AP)} - W_{(R3)})$

$(x,y)_{T2} = (x,y)_{p5}$

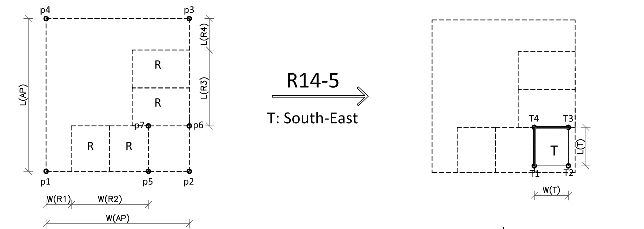
$(x,y)_{T3} = (x,y)_{p6}$

$(y)_{T3} = (y)_{T4}$

$(y)_{T1} = (y)_{T2}$

$(x)_{T1} = (x)_{T4}$

Terrace is located on the South-East Direction:



R: Bedroom / Living Room / Courtyard
shared surface with adjacent room

$L_{(T)} \leq (L_{(AP)} - (L_{(R3)}+L_{(R4)}))$

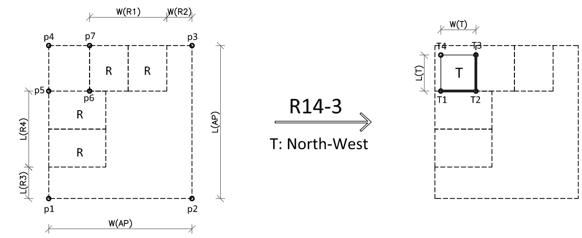
$W_{(T)} \leq (W_{(AP)} - (W_{(R1)}+W_{(R2)}))$

$(x,y)_{T4} = (x,y)_{p7}$

$(x)_{T1} = (x)_{T4} = (x)_{p5}$

$(y)_{T3} = (y)_{T4} = (y)_{p6}$

Terrace is located on the North-West Direction:



R: Bedroom / Living Room / Courtyard
shared surface with adjacent room

$L_{(T)} \leq (L_{(AP)} - (L_{(R3)}+L_{(R4)}))$

$W_{(T)} \leq (W_{(AP)} - (W_{(R1)}+W_{(R2)}))$

$(x,y)_{T2} = (x,y)_{p6}$

$(x)_{T2} = (x)_{T3} = (x)_{p7}$

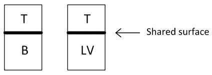
$(y)_{T1} = (y)_{T2} = (y)_{p5}$

Stage (15): Rules for the Configuration of Terraces that are located on the First Floor

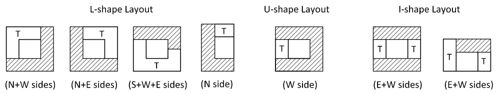
Descriptions:

T: Terraces/Balconies (Semi-Private Spaces)
T: Terraces could be connected with Bedrooms, or Living Spaces

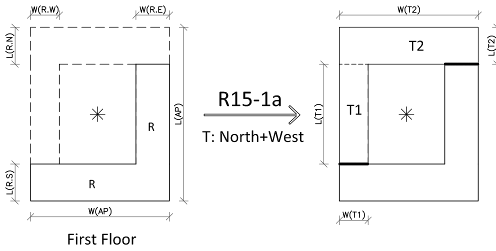
Area of Terraces = 11 % - 16 % (AVG = 14.3 %) from the total area of the house



Location of Terraces in relation to the Layout of the First Floor



Terraces for the First Floor that has L-shape Layout:



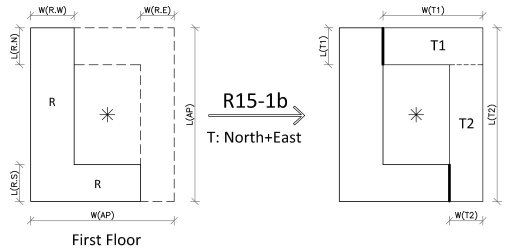
$W_{(T1)} = W_{(R.W)}$

$L_{(T1)} = L_{(AP)} - L_{(R.S)} - L_{(R.N)}$

$W_{(T2)} = W_{(AP)}$

$L_{(T2)} = L_{(R.N)}$

shared surface with adjacent room (bedroom / living space)



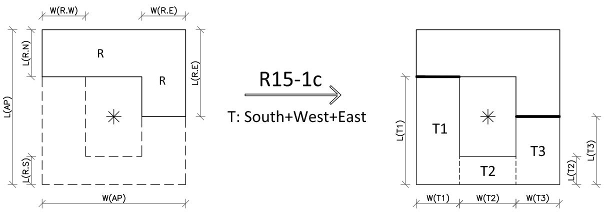
$W_{(T1)} = W_{(AP)} - W_{(R.W)}$

$L_{(T1)} = L_{(R.N)}$

$W_{(T2)} = W_{(R.E)}$

$L_{(T2)} = L_{(AP)} - L_{(R.N)}$

shared surface with adjacent room (bedroom / living space)



$L_{(T1)} = L_{(AP)} - L_{(R.N)}$

$W_{(T1)} = W_{(R.W)}$

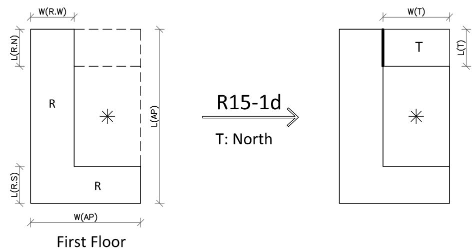
$L_{(T2)} = W_{(R.S)}$

$W_{(T2)} = W_{(AP)} - W_{(R.E)} - W_{(R.W)}$

$L_{(T3)} = L_{(AP)} - L_{(R.E)}$

$W_{(T2)} = W_{(R.E)}$

shared surface with adjacent room (bedroom / living space)

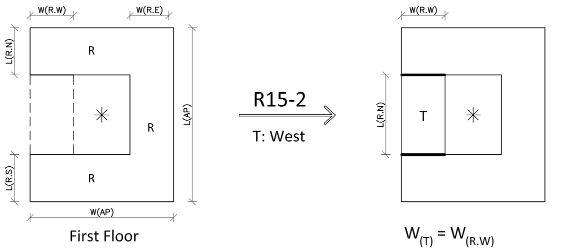


$W_{(T)} = W_{(AP)} - W_{(R.W)}$

$L_{(T1)} = L_{(R.N)}$

shared surface with adjacent room (bedroom / living space)

Terraces for the First Floor that has U-shape Layout:

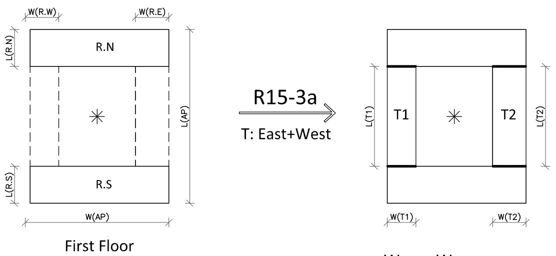


$W_{(T)} = W_{(R.W)}$

$L_{(T)} = L_{(AP)} - L_{(R.S)} - L_{(R.N)}$

shared surface with adjacent room (bedroom / living space)

Terraces for the First Floor that has I-shape Layout:



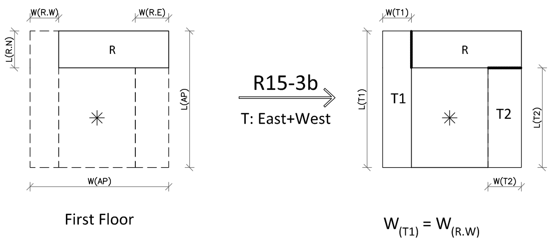
$W_{(T1)} = W_{(R.W)}$

$L_{(T1)} = L_{(AP)} - L_{(R.N)} - L_{(R.S)}$

$W_{(T2)} = W_{(R.E)}$

$L_{(T2)} = L_{(AP)} - L_{(R.N)} - L_{(R.S)}$

shared surface with adjacent room (bedroom / living space)



$W_{(T1)} = W_{(R.W)}$

$L_{(T1)} = L_{(AP)}$

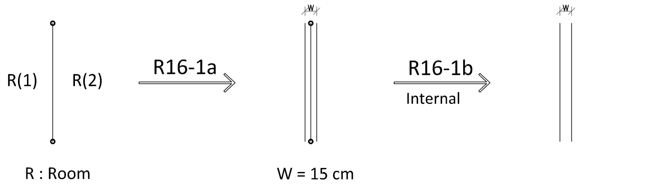
$W_{(T2)} = W_{(R.E)}$

$L_{(T2)} = L_{(AP)} - L_{(R.N)}$

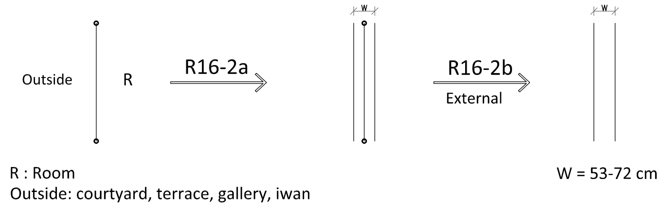
shared surface with adjacent room (bedroom / living space)

Stage (16): Rules for Walls Thickness

Internal Walls

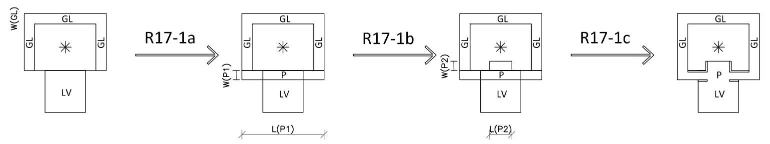


External Walls



Stage (17): Rules for Special Treatments

Rules for Viewing the Outside (Windows)



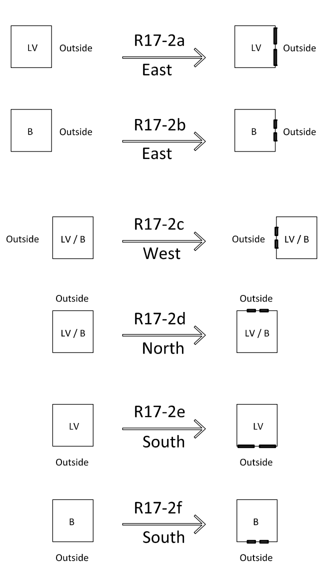
$L_{(P1)} = L_{(GL.N)}$

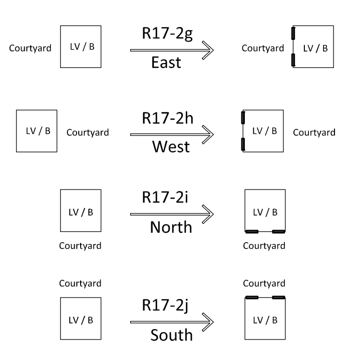
$L_{(P2)} = 0.5 * L_{(LV)}$

$W_{(P1)} = W_{(P2)} = W_{(GL)}$

Internal Wall Thickness = 15 cm

LV is located on South or East



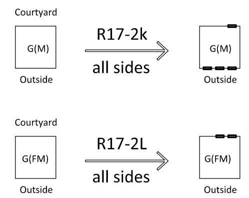


Relationship with Courtyard:

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:

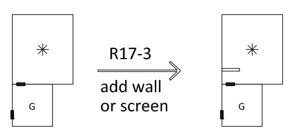
For Living Rooms:
Windows located on South/East: large windows with screens
Windows located on North/West: small windows

For Bedrooms:
Windows located on all sides: small windows with screens

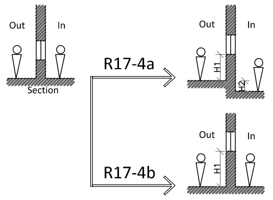
For Guest Rooms (males visitors):
Windows located on outside edges: small windows

For Guest Rooms (female visitors):
Windows located on outside edges: no windows

Rules for Achieving Visual Privacy between Guest Room and Courtyard:



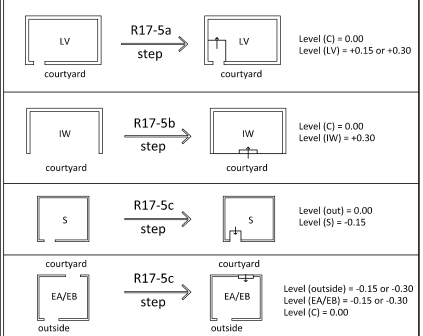
Rules for Achieving Visual Privacy for the Ground Floor



H1 ≤ 175 cm
H2 ≥ 50 cm

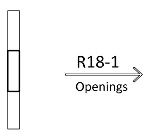
H1 ≥ 175 cm

Rules for Achieving Hygiene:

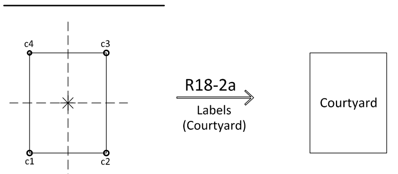


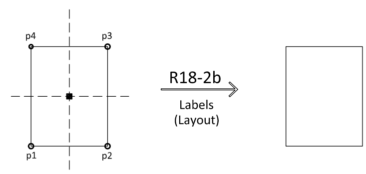
Stage (18): Termination Rules

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

1.1. The Percent of Public Spaces relative to the Total Area of the Cluster

20% — 38%

- \- Social Interaction +
- \+ Density and Crowding -
- \- Human Comfort +

1.2. The Percent of Private Courtyards relative to the Total Area of Houses

18% — 28%

- \- Social Interaction +
- \+ Density and Crowding -
- \- Human Comfort +
- \- Acoustical Privacy +

1.3. Hierarchy of Open Spaces (from Public to Semi-private to Cul-de-sac)

Only a Main Public Space — Hierarchy of Open Spaces

- \- Safety and Security for the Family and Children +
- \- Visual Privacy +

1.4. Availability of Steps between Public Spaces or Alleys, and Semi-private Open Spaces)

No Steps — 5 Steps

- \- Hygiene +
- \+ Accessibility -

1.5. Width of Main Public Spaces

3.15 m — 11.25 m

- \- Social Interaction +
- \+ Density and Crowding -
- \- Human Comfort +
- \+ Safety and Security for the Family and Children -

1.6. Width of Semi-Private Open Spaces

1.15 m — 5.85 m

- \- Social Interaction +
- \+ Density and Crowding -
- \+ Human Comfort -
- \+ Safety and Security for the Family and Children -
- \- Visual Privacy +

2. Arrangement of Main Entrances

2.1. Location of Main Entrances

connected with Main Public Spaces — connected with Alleys, Semi-private Open Spaces

- \- Safety and Security for the Family and Children +
- \- Visual Privacy +

2.2. Angle between opposite Entrances

0° — 90°

- \- Visual Privacy +

2.3. Spatial Elements opposite to Main Entrances

Door — Solid Wall / High Window Sill

- \- Visual Privacy +

3. Circulation Pattern

3.1. Width of Alleys between Houses

2.25 m — 5.45 m

- \- Social Interaction +
- \+ Density and Crowding -
- \+ Human Comfort -
- \+ Safety and Security for the Family and Children -
- \- Visual Privacy +
- \- Acoustical Privacy +
- \- Accessibility +
- \- Hygiene +

3.2. Changes in Directions between Public Spaces, Alleys, and Entrances of Houses

0° — 90°

- \- Visual Privacy +
- \+ Accessibility -
- \+ Human Comfort -

3.3. Orientation of Alleys between Houses

East, South — West, North

- \- Human Comfort +

3.4. Availability of Steps in front of the Main Entrance of the House

No Steps — 5 Steps

- \- Hygiene +
- \+ Accessibility -

3.5. Outside Corner of Buildings

45° — 90°

- \+ Accessibility and Ease of Movement -

4. Configuration of Residential Units

4.1. Thickness of Shared Walls between Adjacent Houses

40 cm — 90 cm

- \- Acoustical Privacy +

4.2. Number of Floors surrounding Open Spaces

1 Floors — +4 Floors

- \+ Visual Privacy -
- \- Safety and Security +
- \- Thermal Comfort +

4.3. Relationships between Adjacent Houses (based on number of shared surfaces)

One shared surface — Four shared surface

- \+ Viewing the Outside -
- \+ Thermal Comfort -

Appendix (5-A-4)

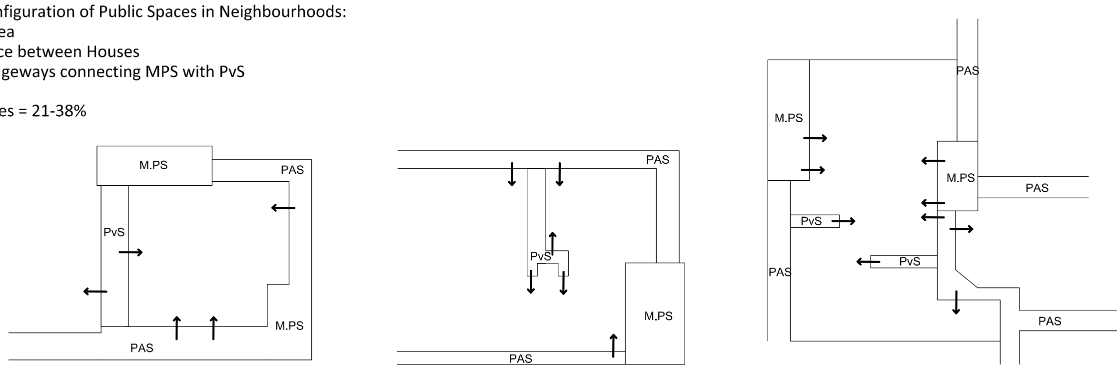
Parametric Rules for the Configuration of Traditional Neighbourhoods (Clusters of Houses) in MENA Region

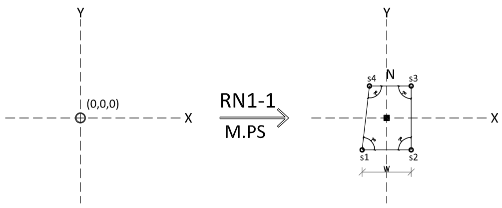
Stage (N1): Rules for the Configuration of Main Public Space (MPS)

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%





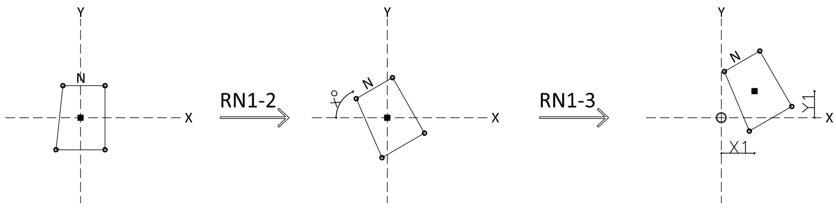
Design Parameters:

$3.15 \le W_{(MPS)} \le 11.25$

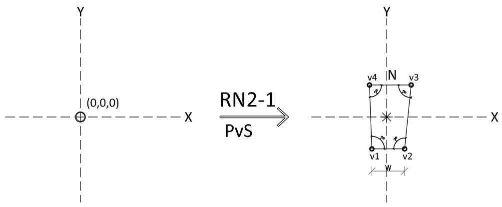
$45^{o} \le X^{o}$

Number of Public Spaces depends on the Area of the Cluster

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 = $(x,y,z)_{Clus}$



Stage (N2): Rules for the Configuration of Semi-Private Open Space (PvS)



Design Parameters:

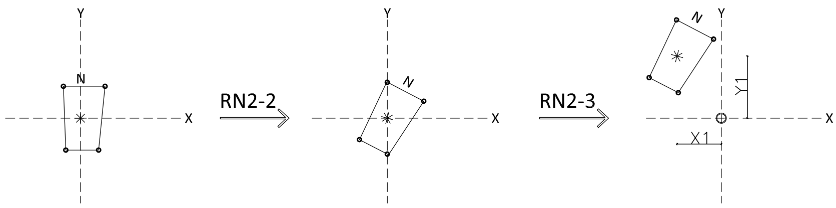
$1.15 \le W_{(PvS)} \le 5.85$

$(21\% * Area_{(Cluster)}) \le Area_{(MPS)} + Area_{(PvS)} \le (28\% * Area_{(Cluster)})$

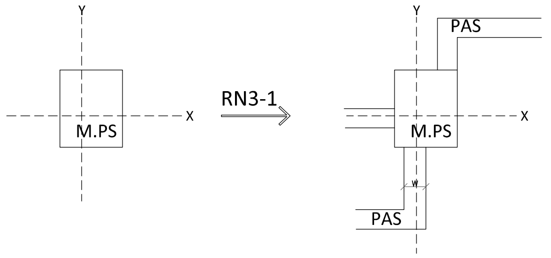
$45^{o} \le X^{o}$

Number of Semi-Private Spaces depends on the Area of the Cluster

N : North direction
∘ : corners of the semi-private space
✳ : the centroid of the semi-private space = $(x,y,z)_{PvS}$



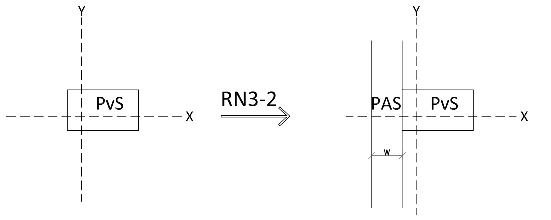
Stage (N3): Rules for the Configuration of Passageways (PAS)



Design Parameters:

$2.25 \leq W_{(PAS)} \leq 5.45$

Passageway could be located on any direction

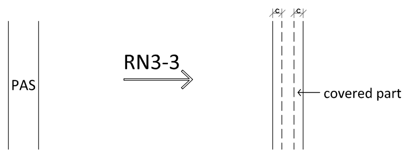


Design Parameters:

$2.25 \leq W_{(PAS)} \leq 5.45$

Passageway is perpendicular on Semi-private Spaces

Passageway could be located on any direction



Design Parameters:

$c \leq 75$ cm

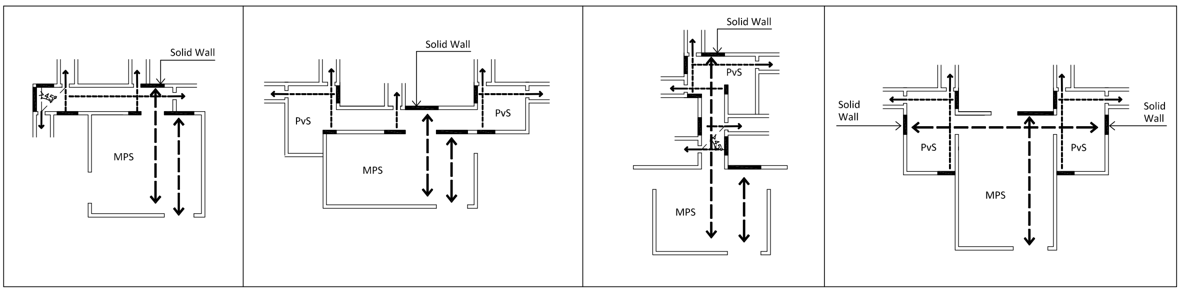
c: is the width of covered part from the passageway. This could be from one side or both sides.

Stage (N4): Rules for Achieving Visual Privacy between Houses

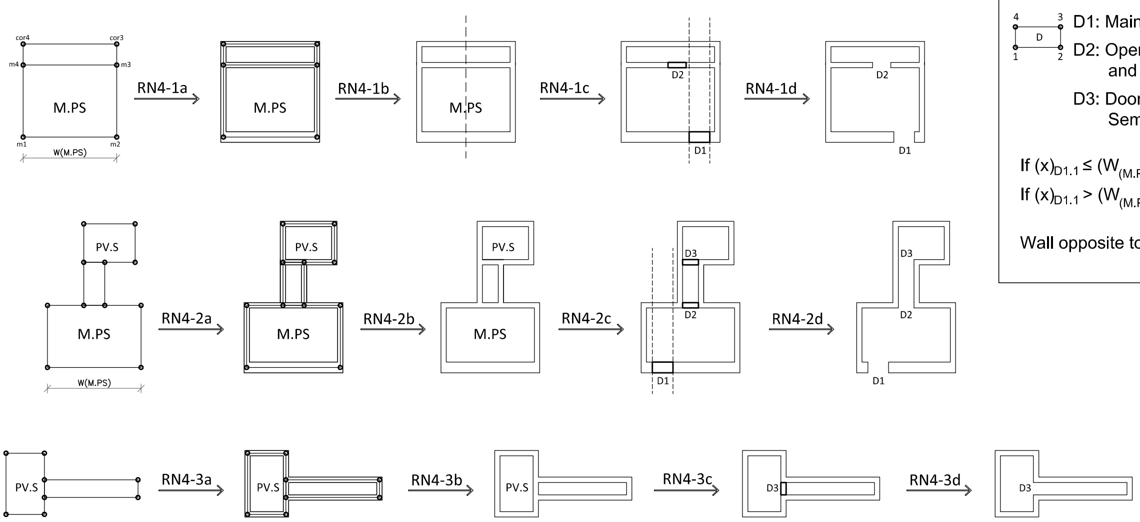
Descriptions:

- 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



D1: Main Entrance for the Cluster

D2: Opening between Passageway and Main Public Space

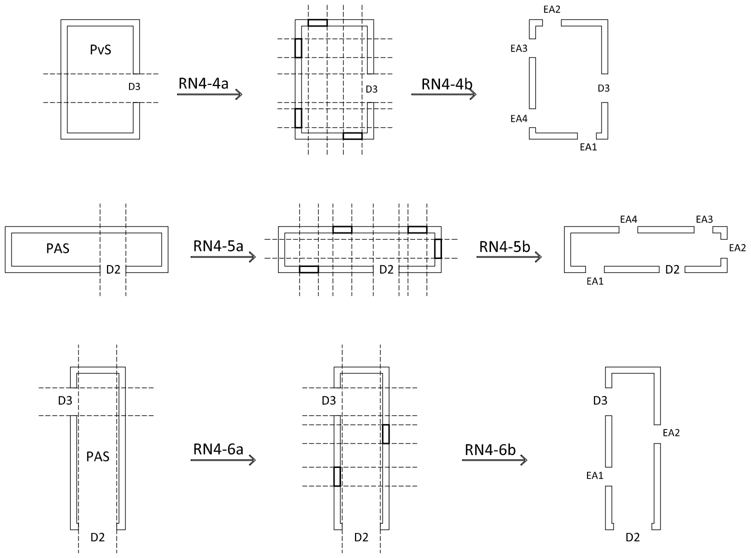
D3: Door between Corridor and Semi-private Space

If $(x)_{D1.1} \leq (W_{(M.PS)}/2)$, $(x)_{D2.1} > (x)_{D1.2}$

If $(x)_{D1.1} > (W_{(M.PS)}/2)$, $(x)_{D2.2} < (x)_{D1.1}$

Wall opposite to any door is a solid wall

Rules for allocating Main Entrances (EA) for Houses

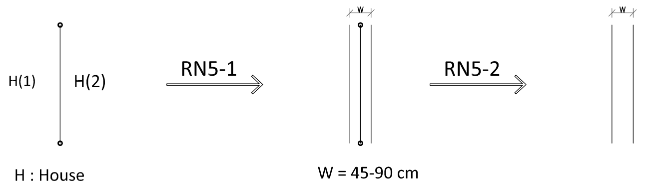


- Wall opposite to any door is a solid wall
- Number of doors depends on the number of houses

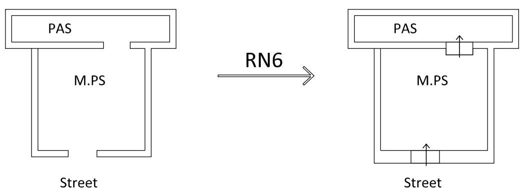
D1: Main Entrance for the Cluster
D2: Door between Corridor and Main Public Space
D3: Door between Corridor and Semi-private Space
EA: Main Entrance for the House

Stage (N5): Rules for Achieving Acoustical Privacy between Houses

Shared Wall between Houses



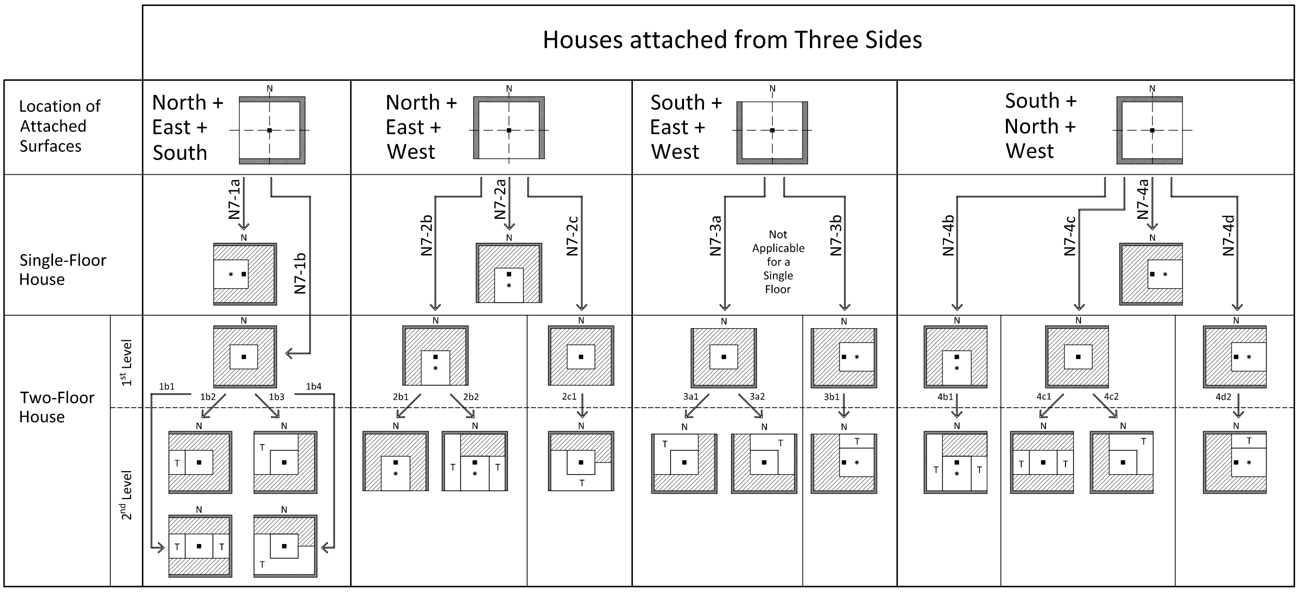
Stage (N6): Rules for Achieving Hygiene between Public Spaces and Houses

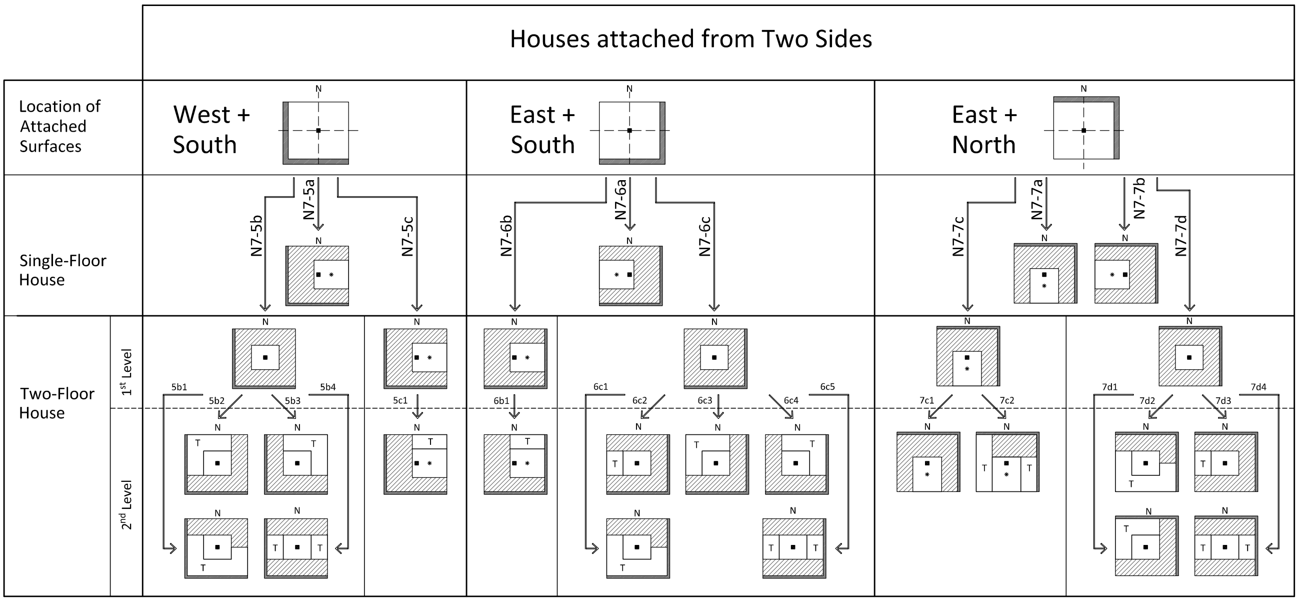


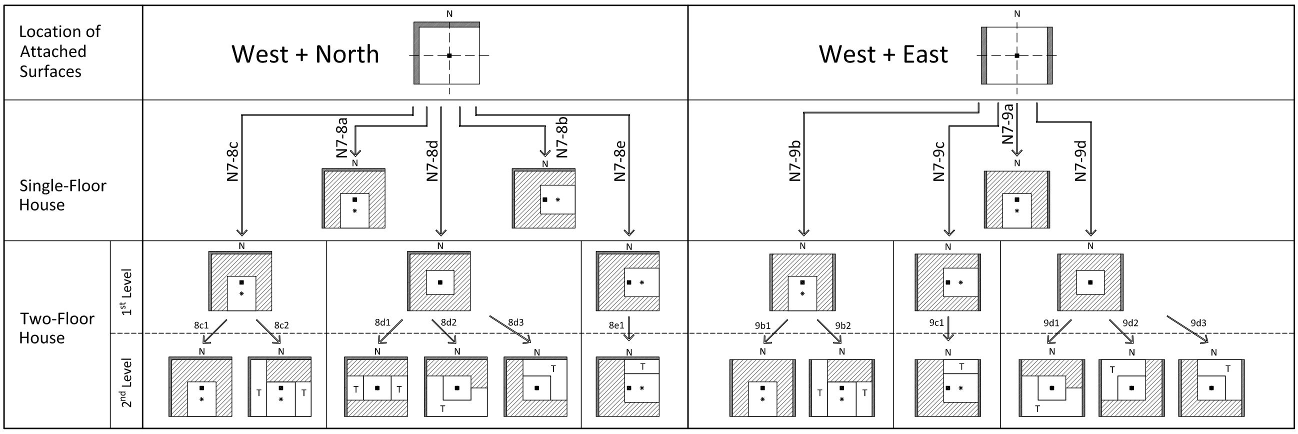
Level (outside) > -0.30
Level (M.PS) = 0.00
Level (PAS) ≤ +0.30

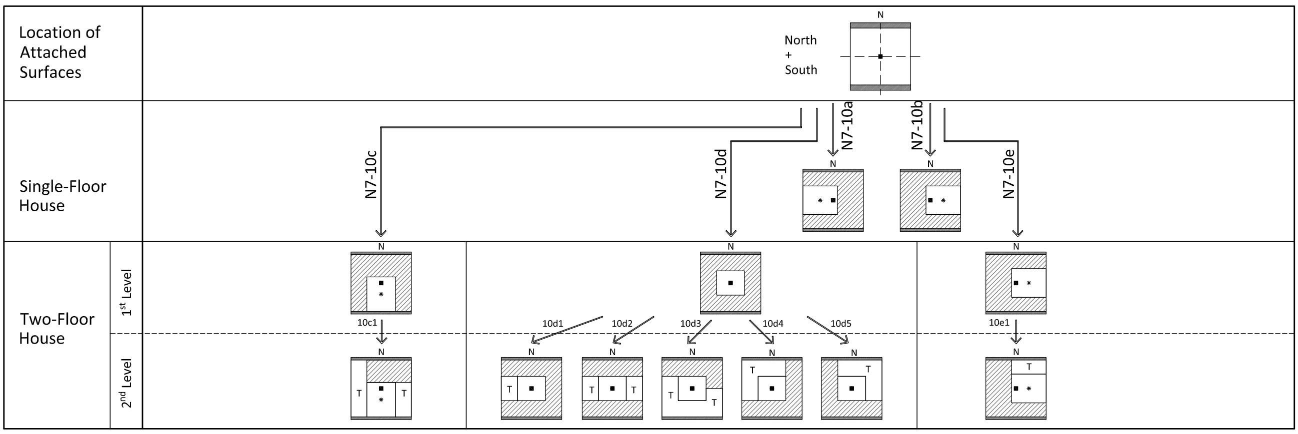
Stage (N7): Rules showing Types of adjacent Houses

Typologies for Houses (based on number and location of shared surfaces)

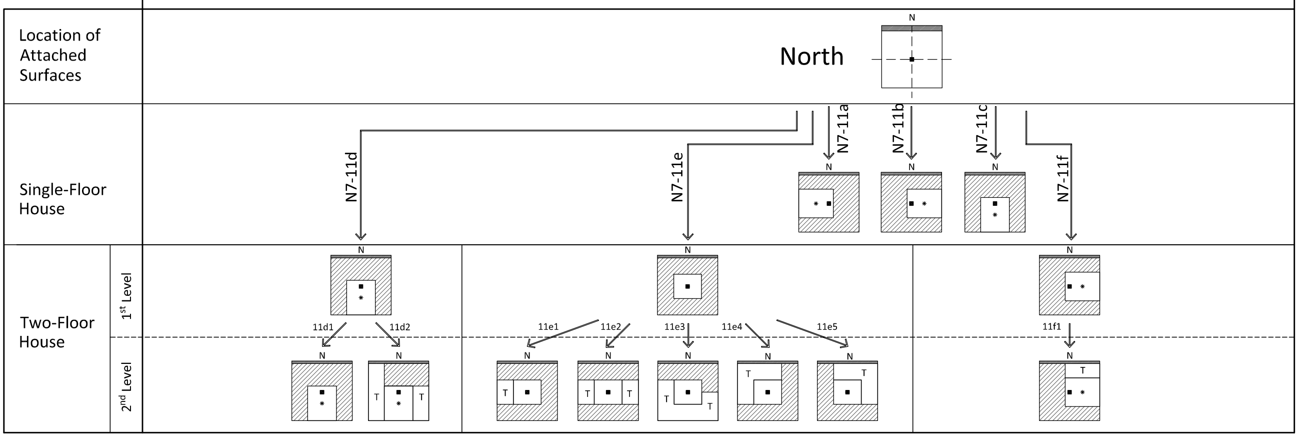


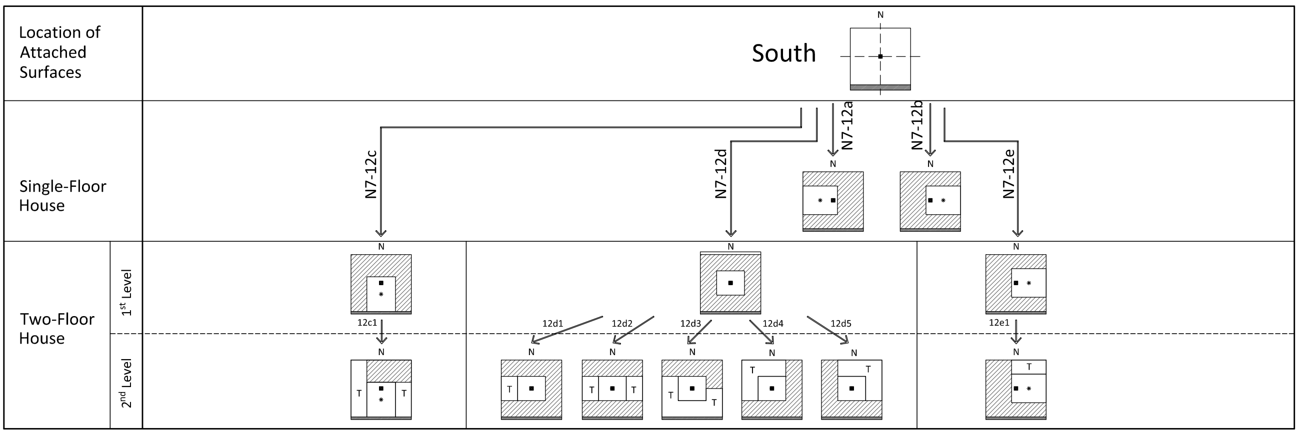


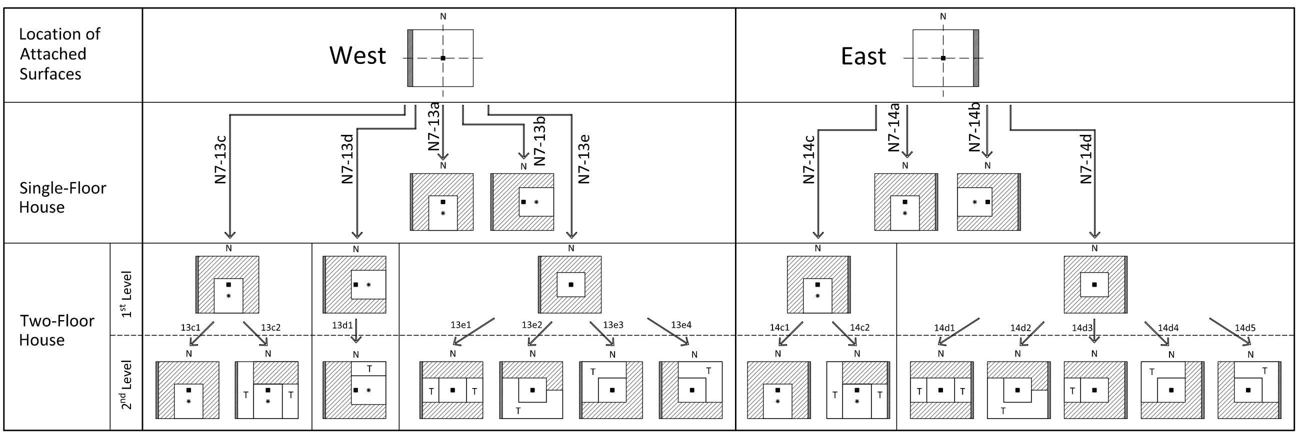




House attached from One Side



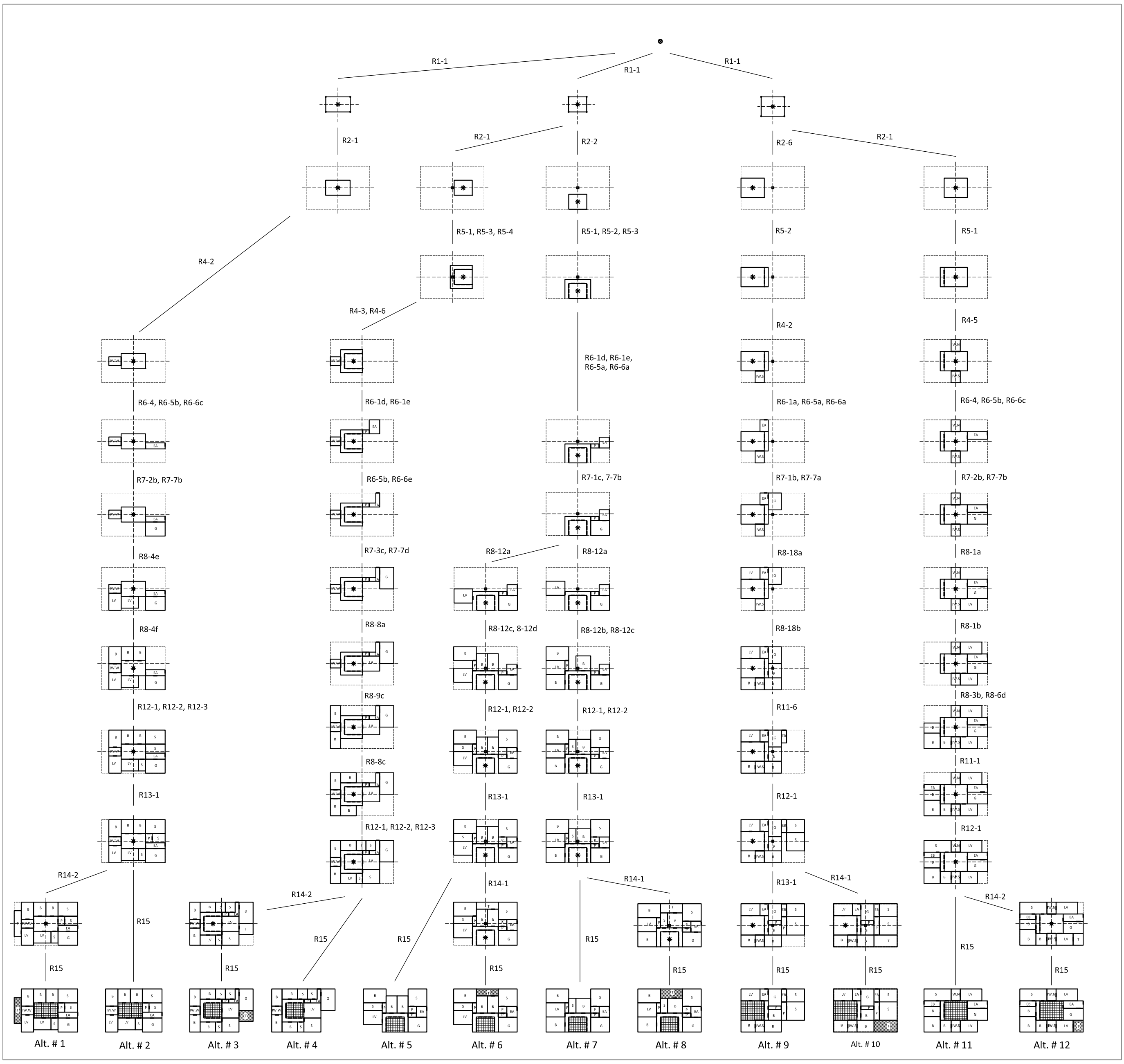




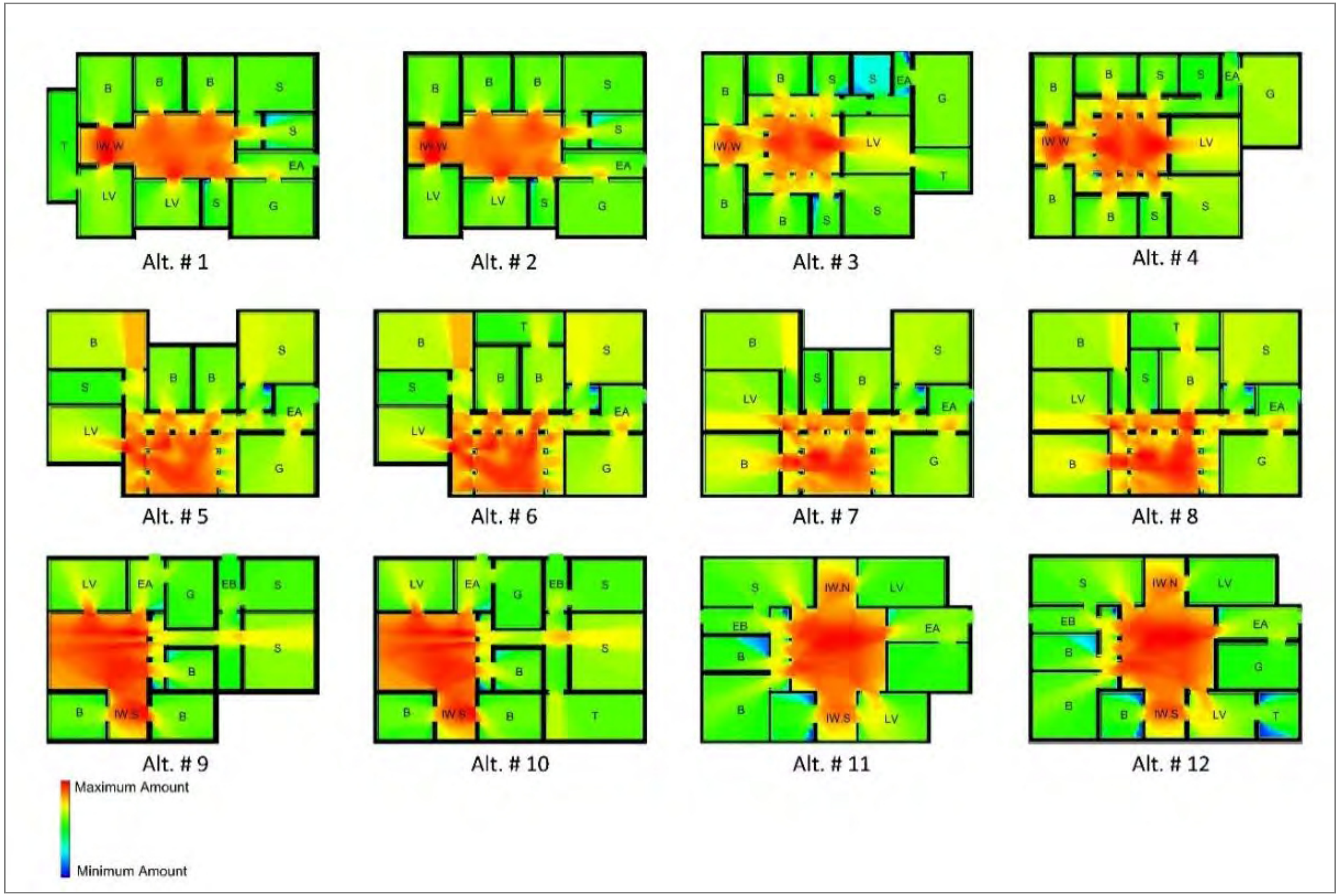
Appendix (5-A-5)

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)

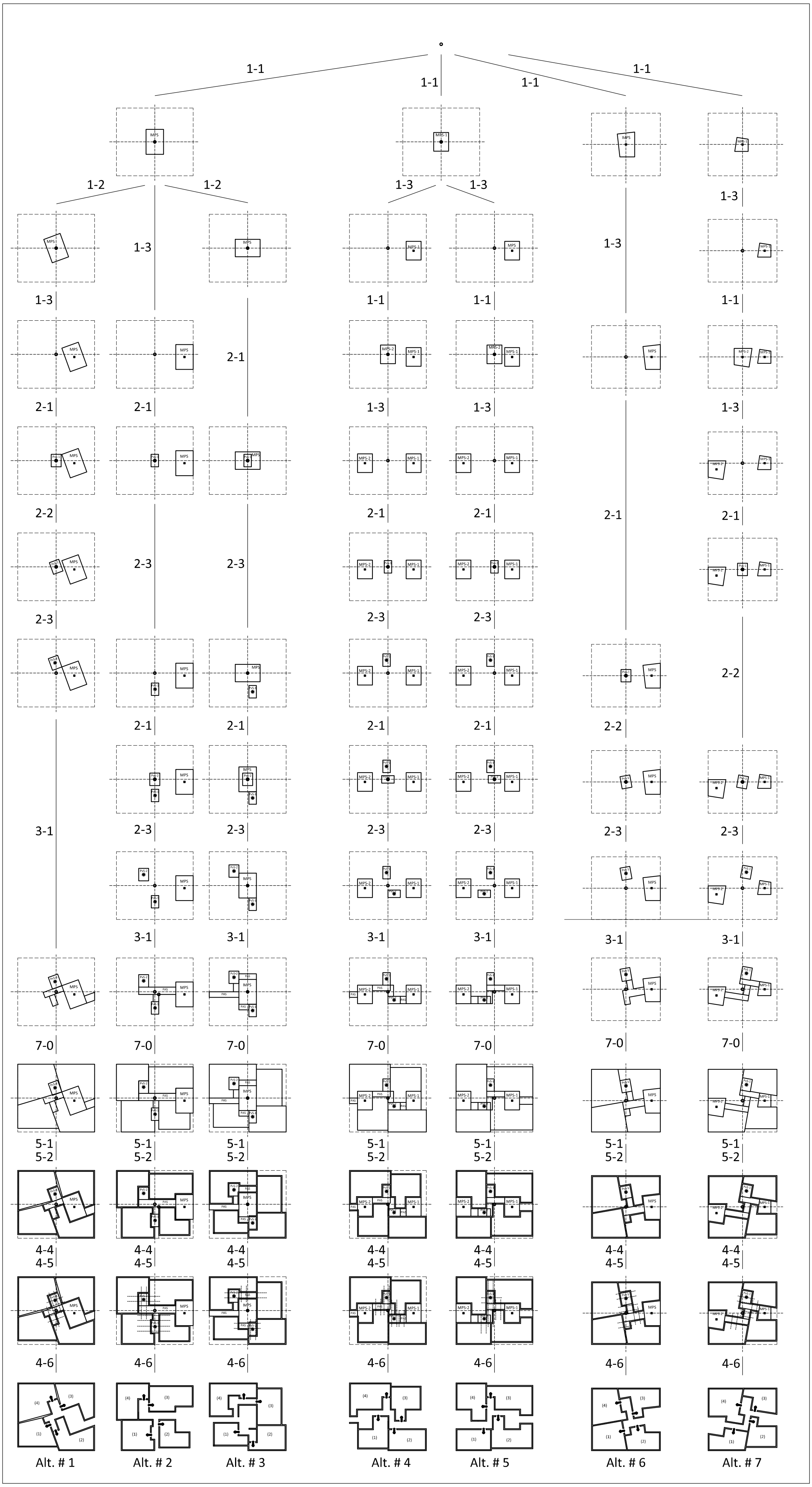


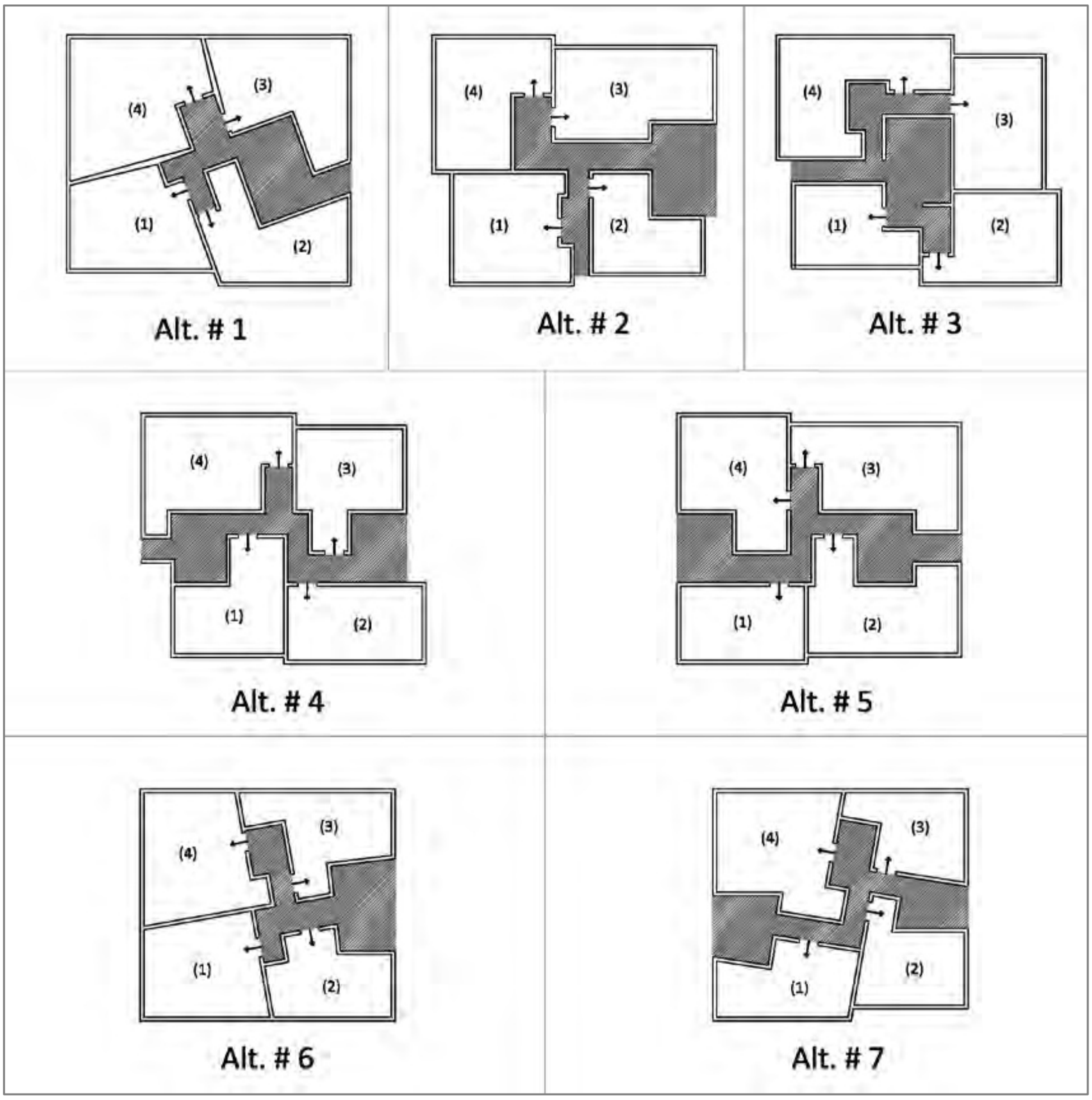
Visibility graph analysis for the new solutions showing the connectivity value for each space
(Produced by the Researcher, using DepthmapX software)

Appendix (5-A-6)

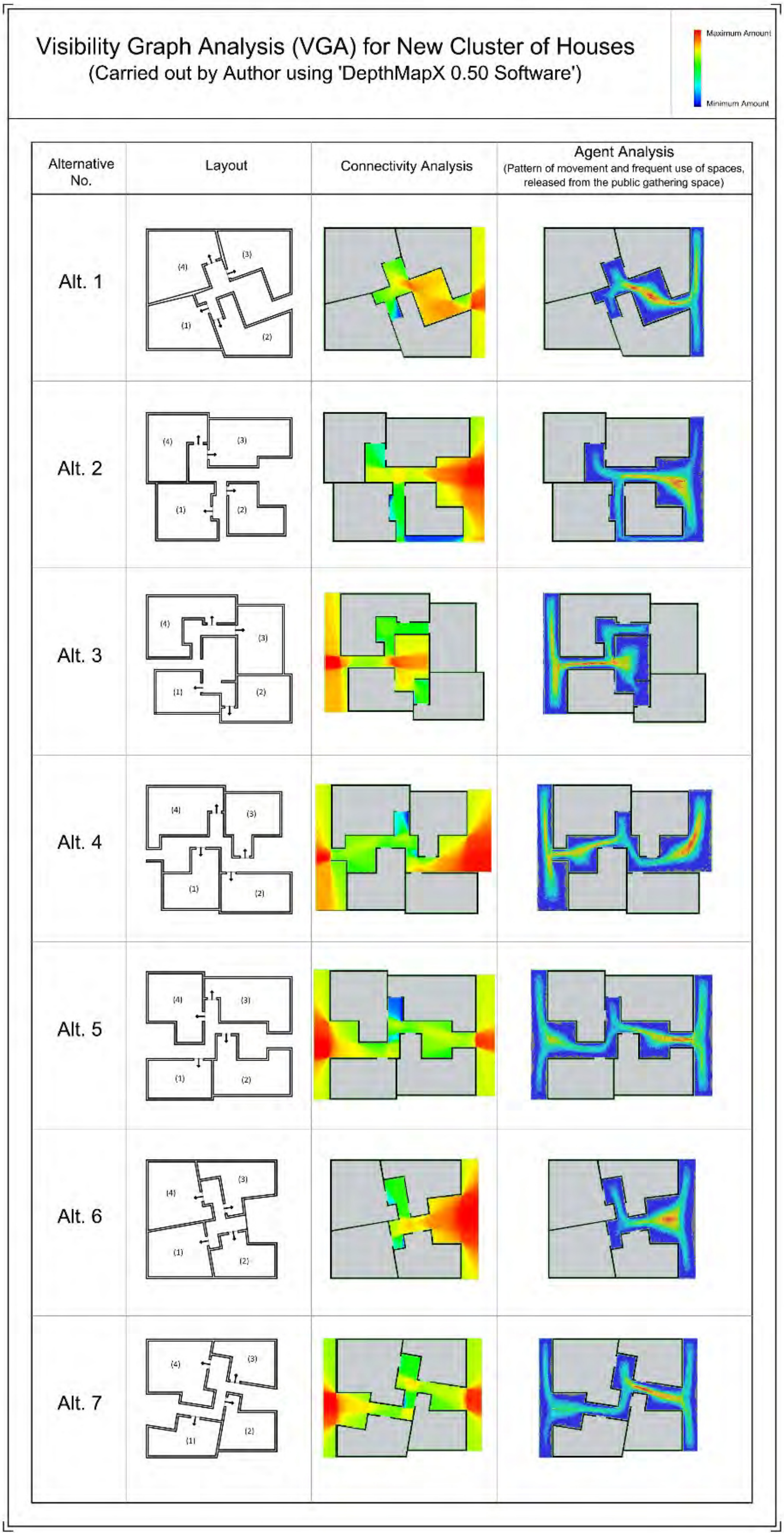
New Solutions for Clusters of Houses generated by the Constructed Grammar

The generation process of 7 new solutions for clusters of houses

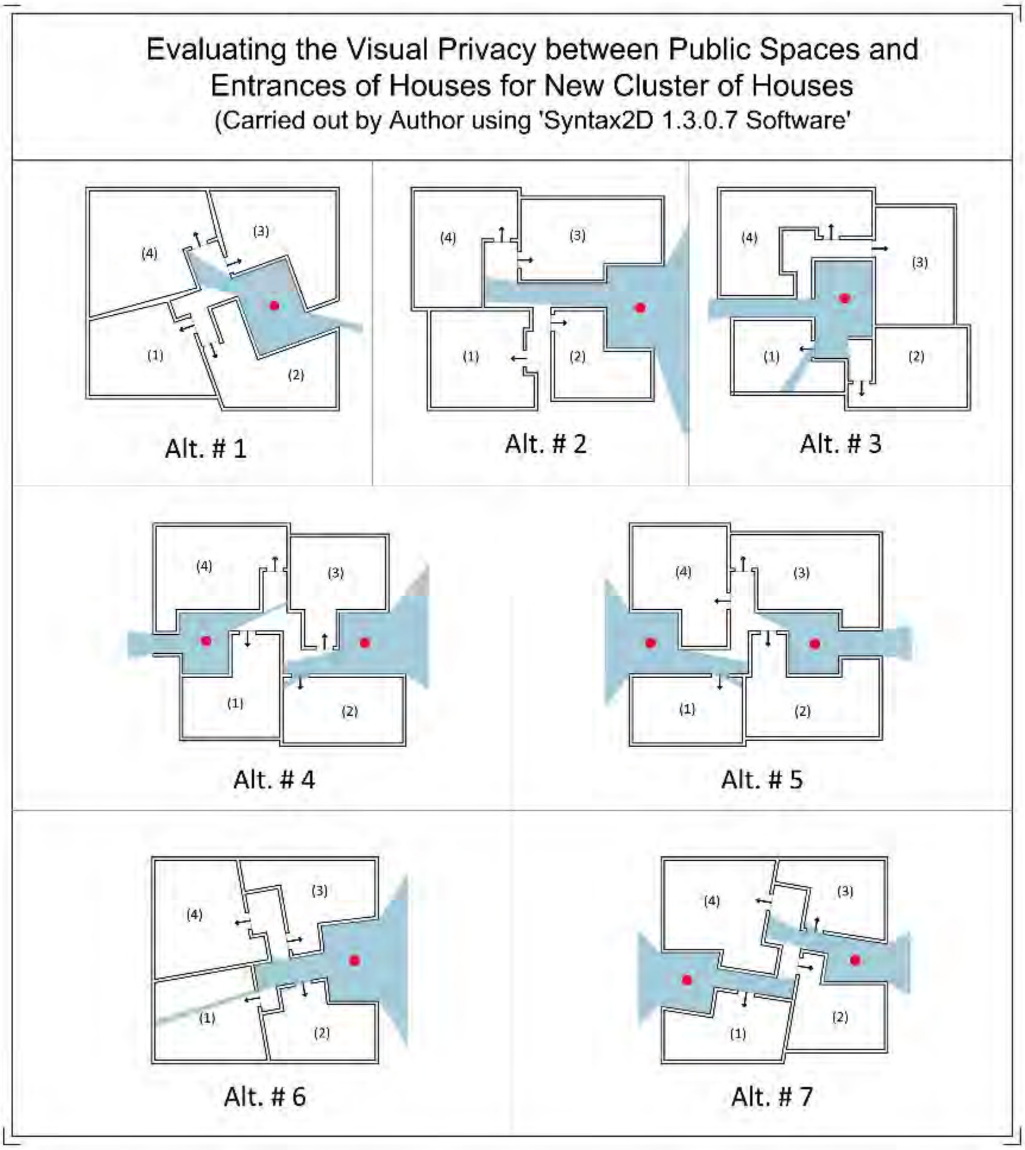




New solutions for clusters of houses generated by the constructed grammar



Visibility graph analysis for the new solutions showing connectivity values for common spaces (Produced by the Researcher, using DepthmapX software)



Evaluating the visual privacy between public spaces and
entrances of houses for the new alternatives
(Produced by the Researcher, using Syntax2D 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

1.1. Area of the Entry Hall relative to the Area of the Ground Floor

Quality	3%	5%
Social Interaction	-	+
Density and Crowding	+	-
Accessibility	-	+

1.2. Area of the Vertical Circulation Core relative to the Area of the Ground Floor

Quality	5%	10%
Accessibility	-	+
Density and Crowding	+	-

1.3. Area of the Main Public Space relative to the Area of the Ground Floor

Quality	5%	15%
Social Interaction	-	+
Density and Crowding	+	-
Human Comfort	-	+

1.4. Area of Private Courtyards relative to the Area of the Apartment

Quality	18%	28%
Social Interaction	-	+
Density and Crowding	+	-
Human Comfort	-	+

1.5. Width of Main Public Spaces

Quality	5.85 m	11.25 m
Social Interaction	-	+
Density and Crowding	+	-
Human Comfort	-	+
Safety and Security for the Family and Children	+	-

1.6. Width of Semi-Private Open Spaces

Quality	2.25 m	5.85 m
Social Interaction	-	+
Density and Crowding	+	-
Human Comfort	+	-
Safety and Security for the Family and Children	+	-
Visual Privacy	-	+

2. Configuration of Residential Units

2.1. Thickness of Shared Walls between Adjacent Apartments

Quality	30 cm	60 cm
Acoustical Privacy	-	+

2.2. Number of Floors surrounding Open Spaces

Quality	1 Floors	+4 Floors
Visual Privacy	+	-
Safety and Security	-	+
Thermal Comfort	-	+

3. Circulation Pattern

3.1. Width of Alleys between Apartments

Quality	1.15 m	3.00 m
Social Interaction	-	+
Density and Crowding	+	-
Human Comfort	+	-
Safety and Security for the Family and Children	+	-
Visual Privacy	-	+
Accessibility	-	+

3.2. Changes in Directions between Public Spaces, Alleys, & Entrances of Apartments

Quality	0°	90°
Visual Privacy	-	+
Accessibility	+	-
Human Comfort	+	-

4. Arrangement of Entrances for Apartments

4.1. Location of Entrances

Quality	connected with Main Public Spaces	connected with Alleys, Semi-private Open Spaces
Safety and Security for the Family and Children	-	+
Visual Privacy	-	+

4.2. Angle between opposite Entrances

Quality	0°	90°
Visual Privacy	-	+

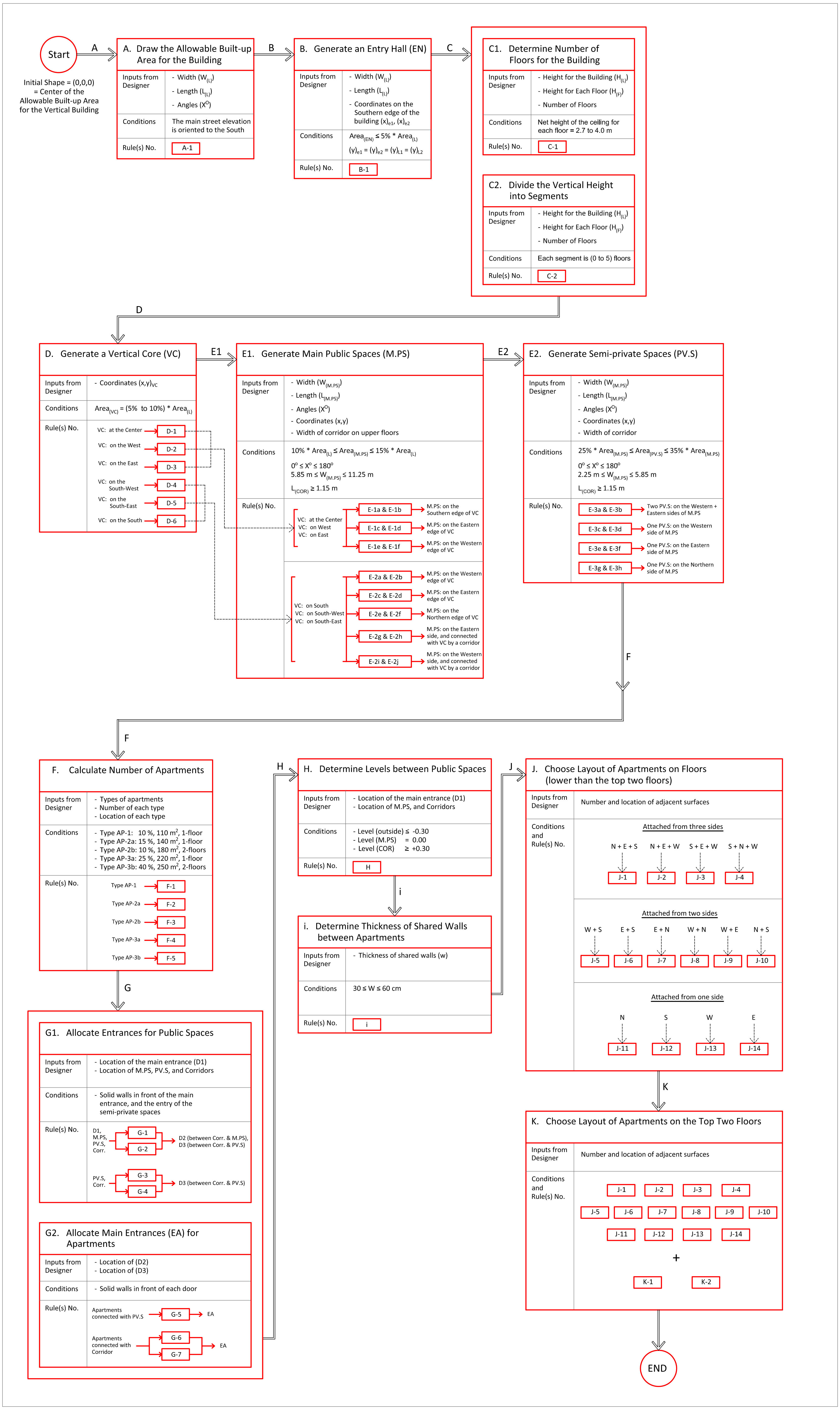
4.3. Spatial Elements opposite to Entrances

Quality	Door	Solid Wall / High Window Sill
Visual Privacy	-	+

Appendix (5-B-2)

Groups of Parametric Rules for generating a High-rise Residential Building

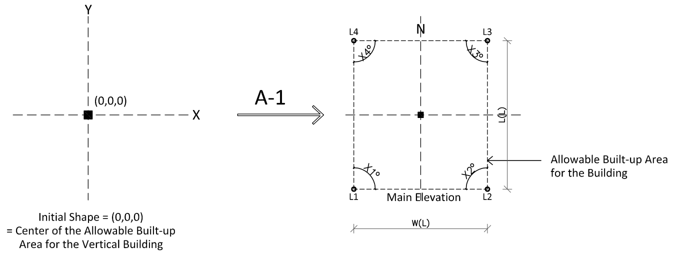
Groups of Parametric Rules for Generating a High-rise Residential Building



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

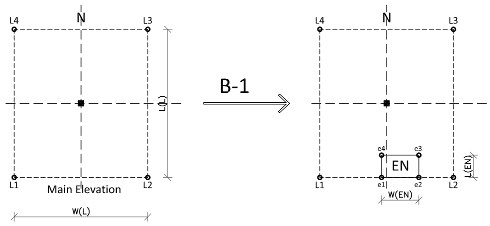


Design Parameters:

$0^{o} \leq X^{o} \leq 180^{o}$

Main Elevation is oriented to the South

Stage (B): Rules for the Configuration of an Entry Hall (EN)



Design Parameters:

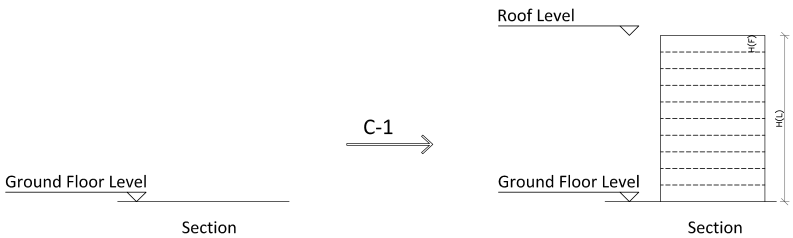
$(y)_{e1} = (y)_{e2} = (y)_{L1} = (y)_{L2}$

$(x)_{L1} \leq (x)_{e1} \leq ((x)_{L2} - W_{(EN)})$

$W_{(EN)} \leq W_{(L)}$

$Area_{(EN)} \leq 5\% * Area_{(L)}$

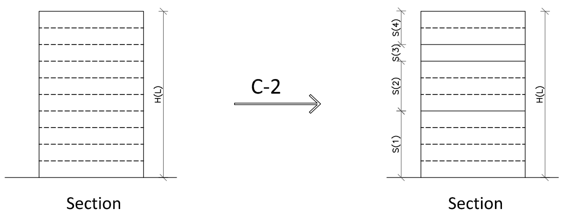
Stage (C): Rules for Dividing the Vertical Building into Segments



H(L): Allowable Height for the Building
(which depends on building regulations)

H(F): is the height for each floor

H(L) ≤ (Number of Floors * H(F))
H(F) = (2.7 to 4.0 m) + Thickness of Slab for each Floor

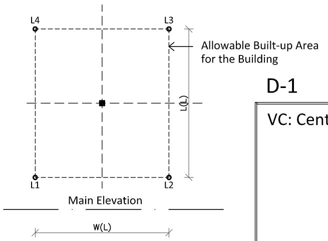


S(n) is a vertical segment, which consists of (0 to 5) floors

Stage (D): Rules for the Configuration of a Vertical Core

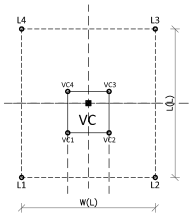
Vertical Core (VC) includes: Elevator , Staircase, and Mechanical Ducts

$5\% * Area_{(L)} \le Area_{(VC)} \le 10\% * Area_{(L)}$



D-1

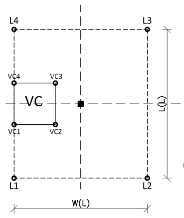
VC: Center



$(y)_{L2} \le (y)_{VC1} \le (y)_{L}$

D-2

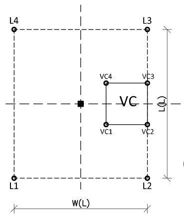
VC: West



$(x)_{VC(1)} = (x)_{VC(4)} = (x)_{L(1)}$

D-3

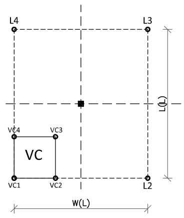
VC: East



$(x)_{VC(2)} = (x)_{VC(3)} = (x)_{L(2)}$

D-4

VC: South-West



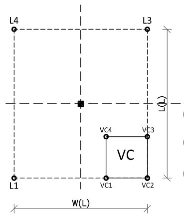
$(x,y)_{VC(1)} = (x,y)_{L(1)}$

$(x)_{VC(1)} = (x)_{VC(4)} = (x)_{L(3)}$

$(y)_{VC(1)} = (y)_{VC(2)} = (y)_{L(2)}$

D-5

VC: South-East



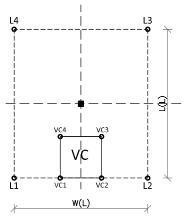
$(x,y)_{VC(2)} = (x,y)_{L(2)}$

$(x)_{VC(2)} = (x)_{VC(3)} = (x)_{L(3)}$

$(y)_{VC(1)} = (y)_{VC(2)} = (y)_{L(1)}$

D-6

VC: South



$(y)_{VC(1)} = (y)_{VC(2)} = (y)_{L(1)}$

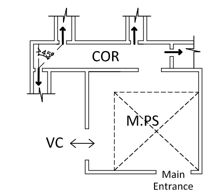
Stage (E): Rules for the Configuration of Public Spaces for the Building

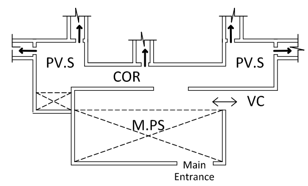
Descriptions:

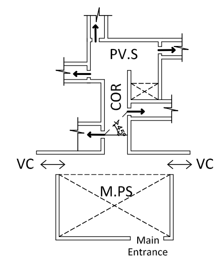
- There is a Hierarchy for the Configuration of Public Spaces on Each Floor
- Public Spaces include:
  - M.PS: A Main Gathering Area (connected with the vertical circulation and/or the main entrance for the building)
  - PV.S: A Semi-Private Space (connected with the entrance of each Apartment)
  - COR: Corridors (connecting the M.PS with PV.S). Houses could be directly connected with corridors.

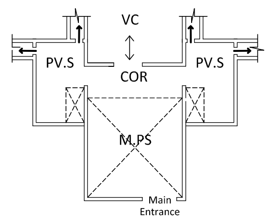
$10\% * Area_{(L)} \le Area_{(M.PS)} \le 15\% * Area_{(L)}$

Samples for topological relationships between public spaces and apartments

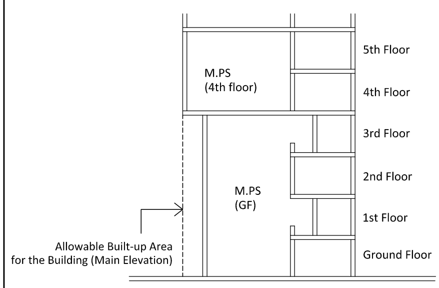








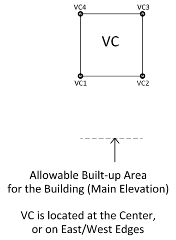
- M.PS is 1 to 5 storey atrium.
- PVS is 1 to 5 storey atrium.
- Dimensions of MPS and PVS on upper segments could be changed.

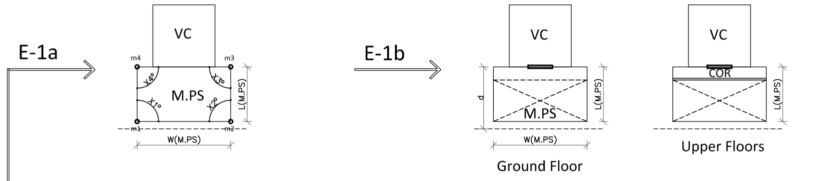


Section

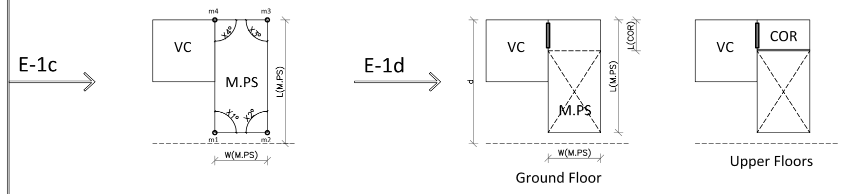
Rules for Generating Main Pubic Space (M.PS)

* The Entry Hall could be overlapped with the Main Public Space

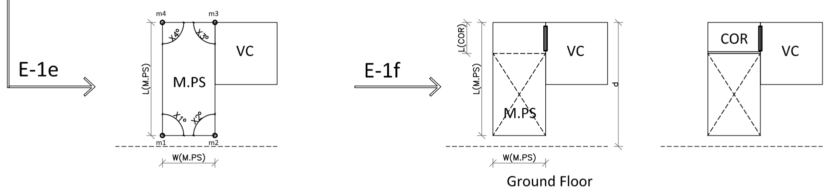




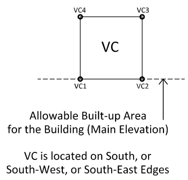
$0^o \le X^o \le 180^o$
$5.85\ m \le W_{(M.PS)} \le 11.25\ m$
$(y)_{VC(1)} = (y)_{VC(2)} = (y)_{m4} = (y)_{m3}$
$(y)_{L2} \le (y)_{m2} < (y)_{VC2}$
$L_{(M.PS)} \le d$
On upper floors:
$L_{(COR)} \ge 1.15\ m$

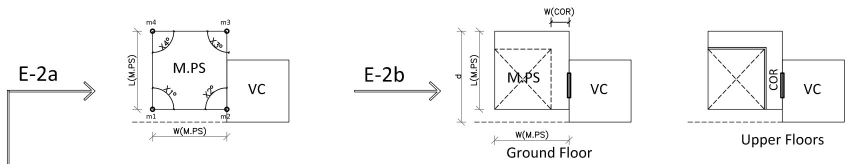


$0^o \le X^o \le 180^o$
$5.85\ m \le W_{(M.PS)} \le 11.25\ m$
$(x)_{m1} = (x)_{VC(2)} = (x)_{m4}$
$(y)_{L2} \le (y)_{m2} \le (y)_{VC2}$
$L_{(M.PS)} \le d$
On upper floors:
$L_{(COR)} \ge 1.15\ m$

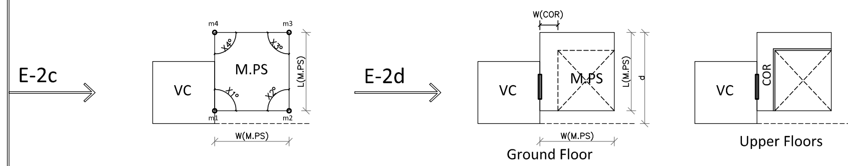


$0^o \le X^o \le 180^o$
$5.85\ m \le W_{(M.PS)} \le 11.25\ m$
$(x)_{m2} = (x)_{VC(1)} = (x)_{m3}$
$(y)_{L2} \le (y)_{m2} \le (y)_{VC1}$
$L_{(M.PS)} \le d$
On upper floors:
$L_{(COR)} \ge 1.15\ m$

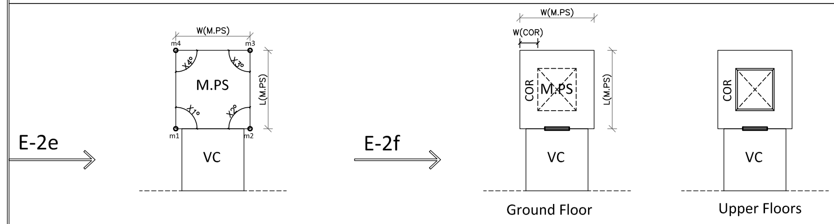




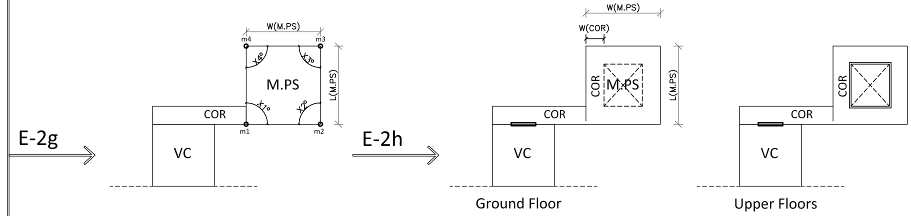
$0^o \le X^o \le 180^o$
$5.85\ m \le W_{(M.PS)} \le 11.25\ m$
$(x)_{m2} = (x)_{VC(1)} = (x)_{m3}$
$(y)_{L2} \le (y)_{m2} \le (y)_{VC}$
$L_{(M.PS)} \le d$
On upper floors:
$L_{(COR)} \ge 1.15\ m$
$W_{(COR)} \ge 1.15\ m$



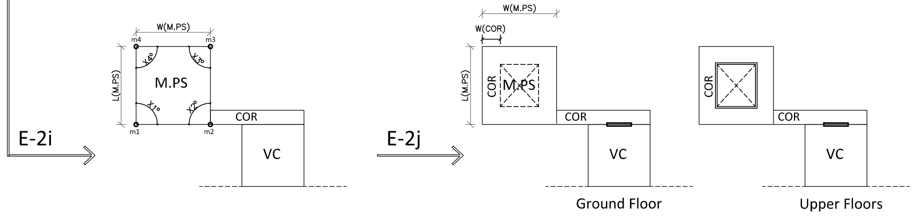
$0^o \le X^o \le 180^o$
$5.85\ m \le W_{(M.PS)} \le 11.25\ m$
$(x)_{m1} = (x)_{VC(2)} = (x)_{m4}$
$(y)_{L2} \le (y)_{m2} \le (y)_{VC}$
$L_{(M.PS)} \le d$
On upper floors:
$L_{(COR)} \ge 1.15\ m$
$W_{(COR)} \ge 1.15\ m$



$0^o \le X^o \le 180^o$
$5.85\ m \le W_{(M.PS)} \le 11.25\ m$
$(y)_{m1} = (x)_{VC(3)} = (y)_{m2}$
On upper floors:
$L_{(COR)} \ge 1.15\ m$
$W_{(COR)} \ge 1.15\ m$

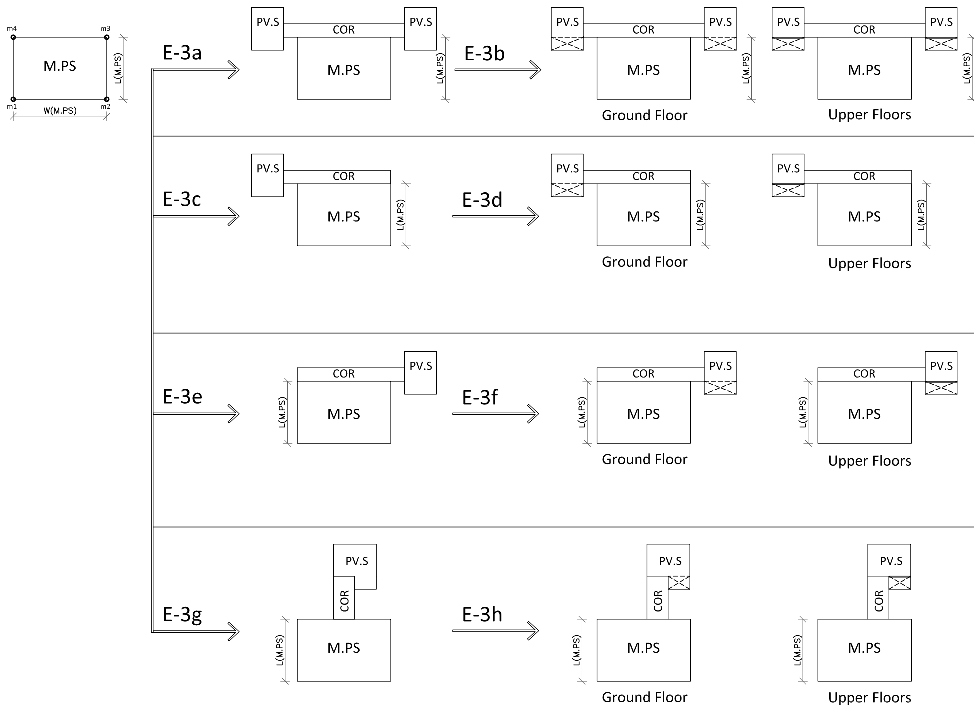


$0^o \le X^o \le 180^o$
$5.85\ m \le W_{(M.PS)} \le 11.25\ m$
$(x)_{VC(3)} \le (x)_{m1}$
$(y)_{VC(3)} = (y)_{VC(4)} = (y)_{m1} = (y)_{m2}$
On upper floors:
$L_{(COR)} \ge 1.15\ m$
$W_{(COR)} \ge 1.15\ m$



$0^o \le X^o \le 180^o$
$5.85\ m \le W_{(M.PS)} \le 11.25\ m$
$(x)_{m2} \le (x)_{VC(4)}$
$(y)_{VC(3)} = (y)_{VC(4)} = (y)_{m1} = (y)_{m2}$
$Width_{(COR)} \ge 1.15\ m$

Rules for Generating Semi-Private Spaces (PV.S)



E-3a / E-3b:

$0^o \leq X^o \leq 180^o$
$2.25\ m \leq W_{(PV.S)} \leq 5.85\ m$
$25\% * Area_{(M.PS)} \leq Area_{(PV.S)} = 35\% * Area_{(M.PS)}$
$Width_{(COR)} \geq 1.15\ m$
$(x,y)_{COR.1} = (x,y)_{m4}$
$(x,y)_{COR.2} = (x,y)_{m3}$

E-3c / E-3d:

$0^o \leq X^o \leq 180^o$
$2.25\ m \leq W_{(PV.S)} \leq 5.85\ m$
$25\% * Area_{(M.PS)} \leq Area_{(PV.S)} = 35\% * Area_{(M.PS)}$
$Width_{(COR)} \geq 1.15\ m$
$(x,y)_{COR.1} = (x,y)_{m4}$
$(x,y)_{COR.2} = (x,y)_{m3}$

E-3e / E-3f:

$0^o \leq X^o \leq 180^o$
$2.25\ m \leq W_{(PV.S)} \leq 5.85\ m$
$25\% * Area_{(M.PS)} \leq Area_{(PV.S)} = 35\% * Area_{(M.PS)}$
$Width_{(COR)} \geq 1.15\ m$
$(x,y)_{COR.1} = (x,y)_{m4}$
$(x,y)_{COR.2} = (x,y)_{m3}$

E-3g / E-3h:

$0^o \leq X^o \leq 180^o$
$2.25\ m \leq W_{(PV.S)} \leq 5.85\ m$
$25\% * Area_{(M.PS)} \leq Area_{(PV.S)} = 35\% * Area_{(M.PS)}$
$Width_{(COR)} \geq 1.15\ m$
$(y)_{m4} \leq (y)_{COR.1} \leq (y)_{m3}$

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^2	100 - 110 m^2	10 %	2 - 4
Type (AP-2a)	Single Floor	110 - 140 m^2	110 - 140 m^2	15 %	2 - 4
Type (AP-2b)	Two Floors	140 - 180 m^2	70 - 90 m^2	10 %	4 - 6
Type (AP-3a)	Single Floor	180 - 220 m^2	180 - 220 m^2	25 %	4 - 6
Type (AP-3b)	Two Floors	220 - 250 m^2	110 - 125 m^2	40 %	5 - 8

The maximum number of apartments on each floor is: Five apartments, which could be from the same type, or different types

Area of Apartments = (Allowable Built-up Area for the Building − Area of Vertical Circulation − Area of Public Spaces and Corridors) * 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 %

Number of Apartments (Type AP-2a) = $\frac{\text{Total Area of (Type AP-2a)}}{140}$

Rule F-3

Total Area of (Type AP-2b) = Area of Apartments * 10 %

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 %

Number of Apartments (Type AP-3a) = $\frac{\text{Total Area of (Type AP-3a)}}{220}$

Rule F-5

Total Area of (Type AP-3b) = Area of Apartments * 40 %

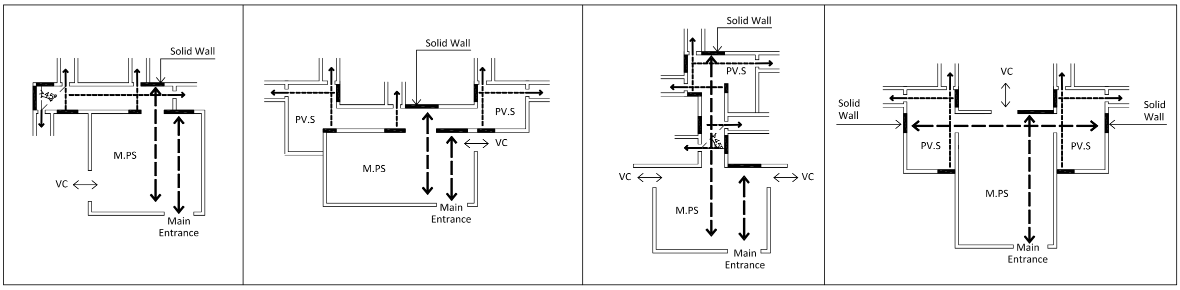
Number of Apartments (Type AP-3b) = $\frac{\text{Total Area of (Type AP-3b)}}{250}$

Stage (G): Rules for Allocating Entrances on the Same Floor

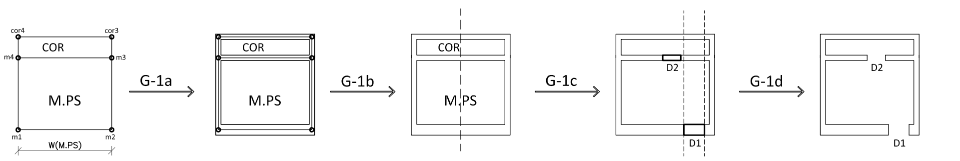
Descriptions:

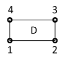
- Walls in front of main entrances are solid walls.
- Walls in front of the entry of the semi-private spaces are solid walls.
- Apartments are connected with corridors or semi-private spaces.
- Entrances for apartments are not connected with the main public space.
- Wall that is directly located in front of the entrance of any apartment is a solid wall.

Strategies for achieving Visual Privacy



G1: Rules for Allocating Openings between Public Spaces





D1: Main Entrance for the Building

D2: Door between Corridor and Main Public Space

D3: Door between Corridor and Semi-private Space

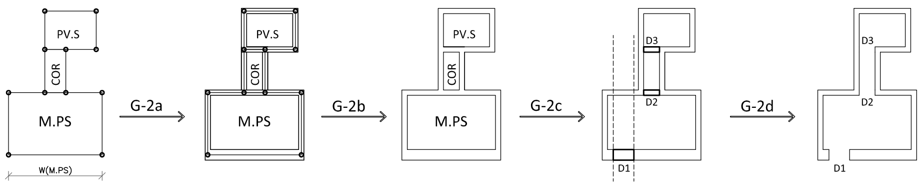
Internal wall thickness = 15 cm

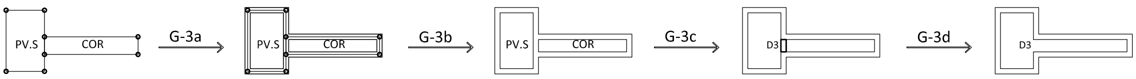
External wall thickness = 35-40 cm

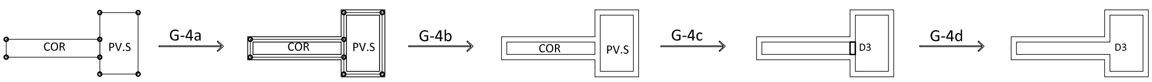
If $(x)_{D1.1} \le (W_{(M.PS)}/2)$, $(x)_{D2.1} > (x)_{D1.2}$

If $(x)_{D1.1} > (W_{(M.PS)}/2)$, $(x)_{D2.2} < (x)_{D1.1}$

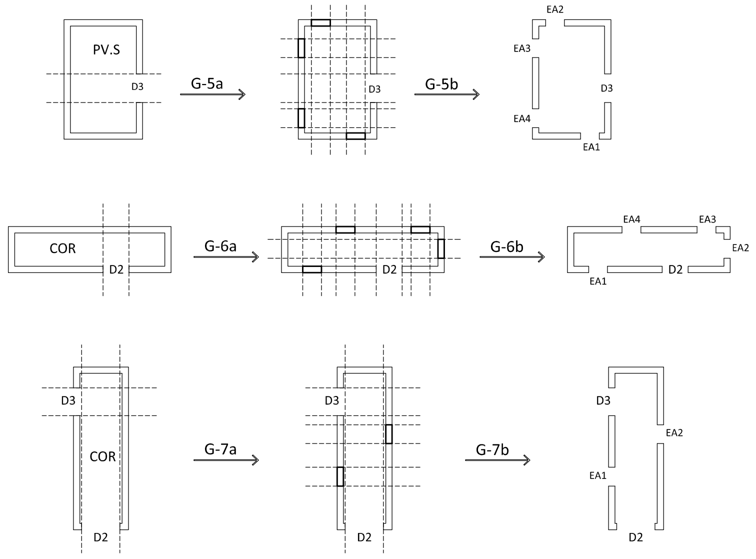
Wall opposite to any door is a solid wall







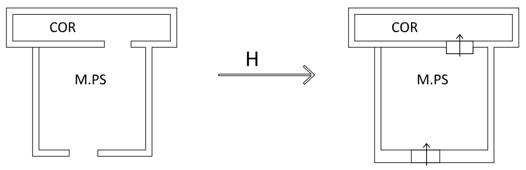
G2: Rules for Allocating Main Entrances (EA) for Apartments



- 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

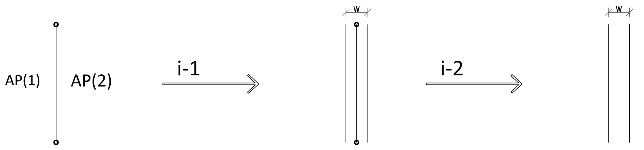
Stage (H): Rules for Achieving Hygiene between Public Spaces and Apartments



Level (outside) ≤ -0.30
Level (M.PS) = 0.00
Level (COR) ≥ +0.30

Stage (i): Rules for Achieving Acoustic Privacy between Apartments

Shared Wall between Apartments

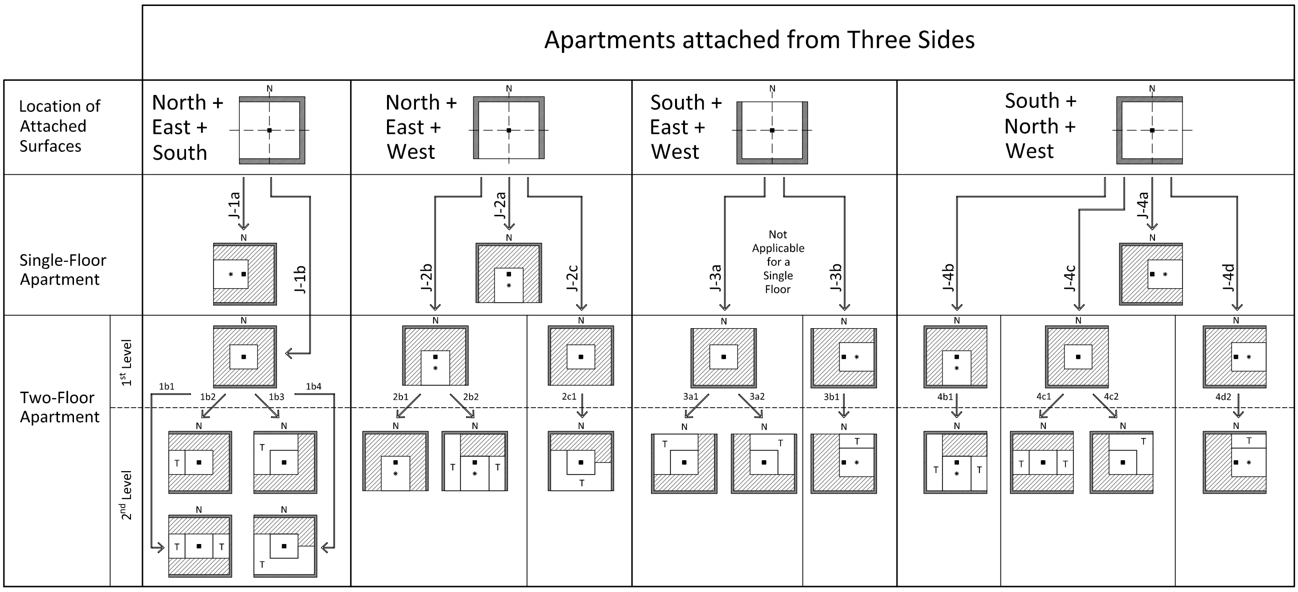


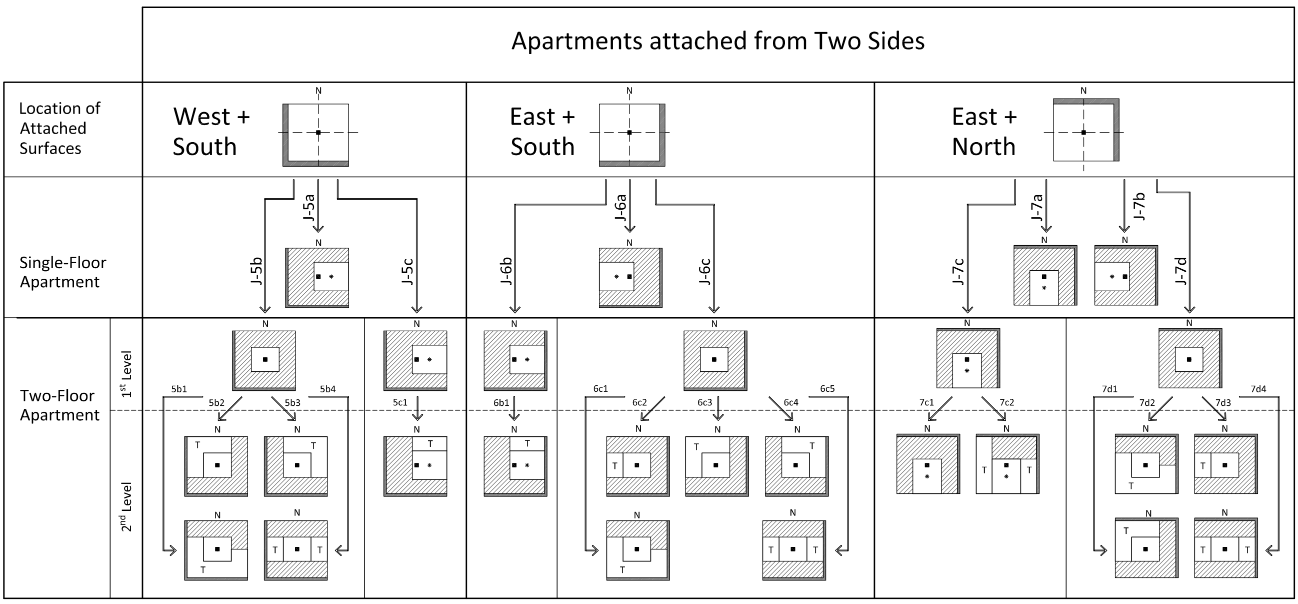
AP : Apartment

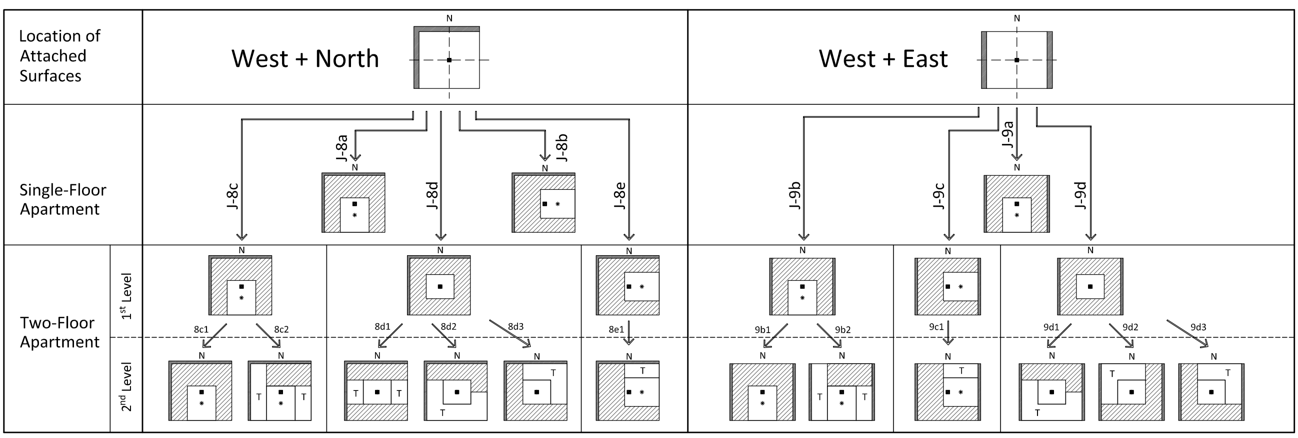
30 ≤ W ≤ 60 cm

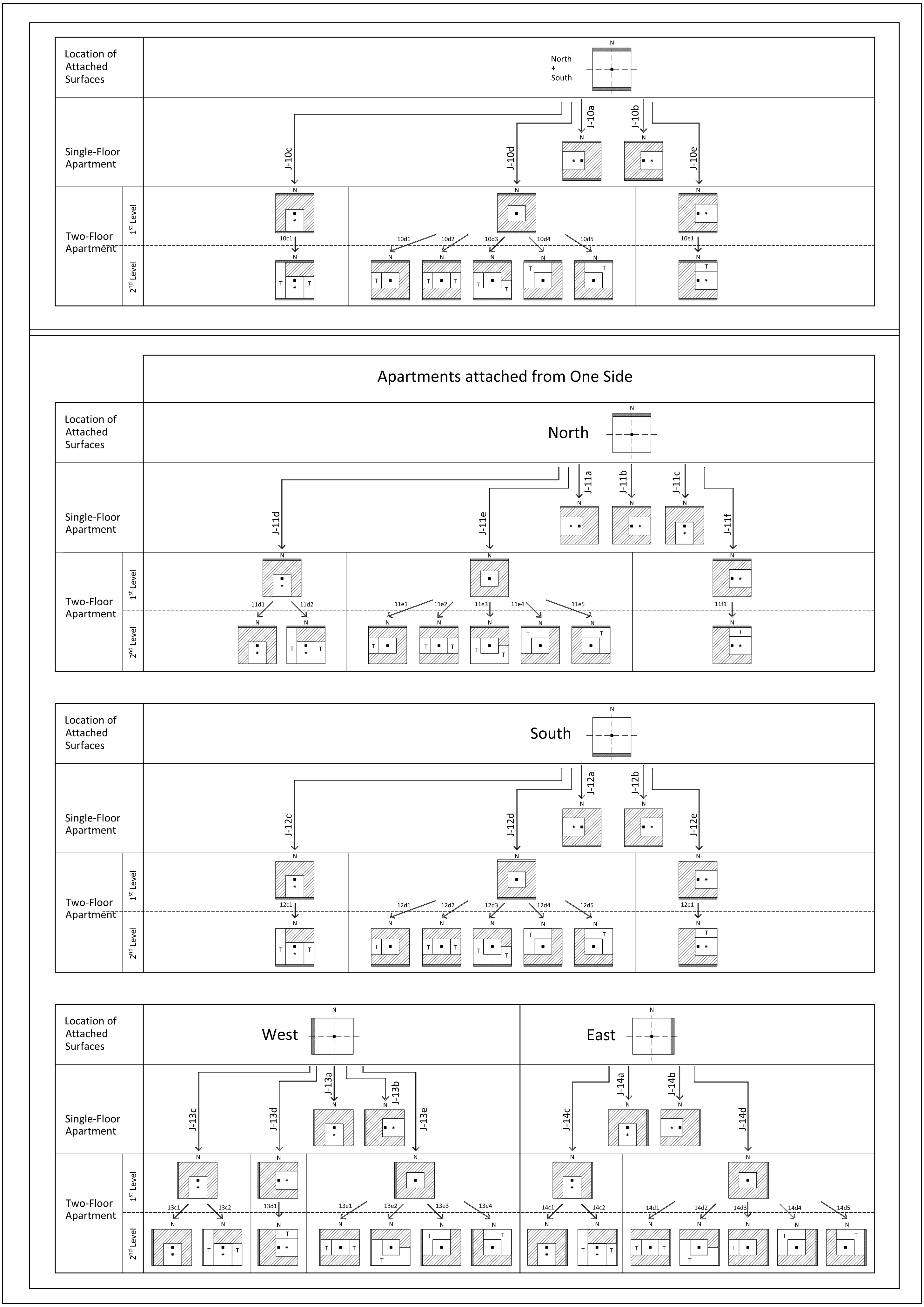
Stage (J): Rules showing Layout of Apartments that are located on Floors lower than the Top Two Floors

Typologies of Apartments (based on number and location of shared surfaces with adjacent apartments)





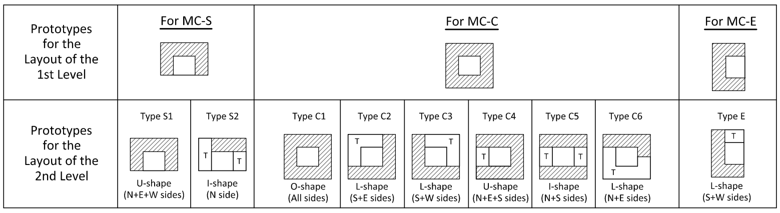




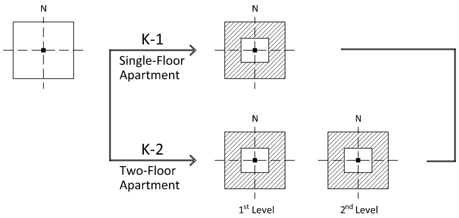
Location of Attached Surfaces
North + South
Single-Floor Apartment
J-10a
J-10b
J-10c
J-10d
J-10e
Two-Floor Apartment
1st Level
2nd Level
10c1
10d1
10d2
10d3
10d4
10d5
10e1
Apartments attached from One Side
Location of Attached Surfaces
North
Single-Floor Apartment
J-11a
J-11b
J-11c
J-11d
J-11e
J-11f
Two-Floor Apartment
1st Level
2nd Level
11d1
11d2
11e1
11e2
11e3
11e4
11e5
11f1
Location of Attached Surfaces
South
Single-Floor Apartment
J-12a
J-12b
J-12c
J-12d
J-12e
Two-Floor Apartment
1st Level
2nd Level
12c1
12d1
12d2
12d3
12d4
12d5
12e1
Location of Attached Surfaces
West
East
Single-Floor Apartment
J-13a
J-13b
J-13c
J-13d
J-13e
J-14a
J-14b
J-14c
J-14d
Two-Floor Apartment
1st Level
2nd Level
13c1
13c2
13d1
13e1
13e2
13e3
13e4
14c1
14c2
14d1
14d2
14d3
14d4
14d5

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



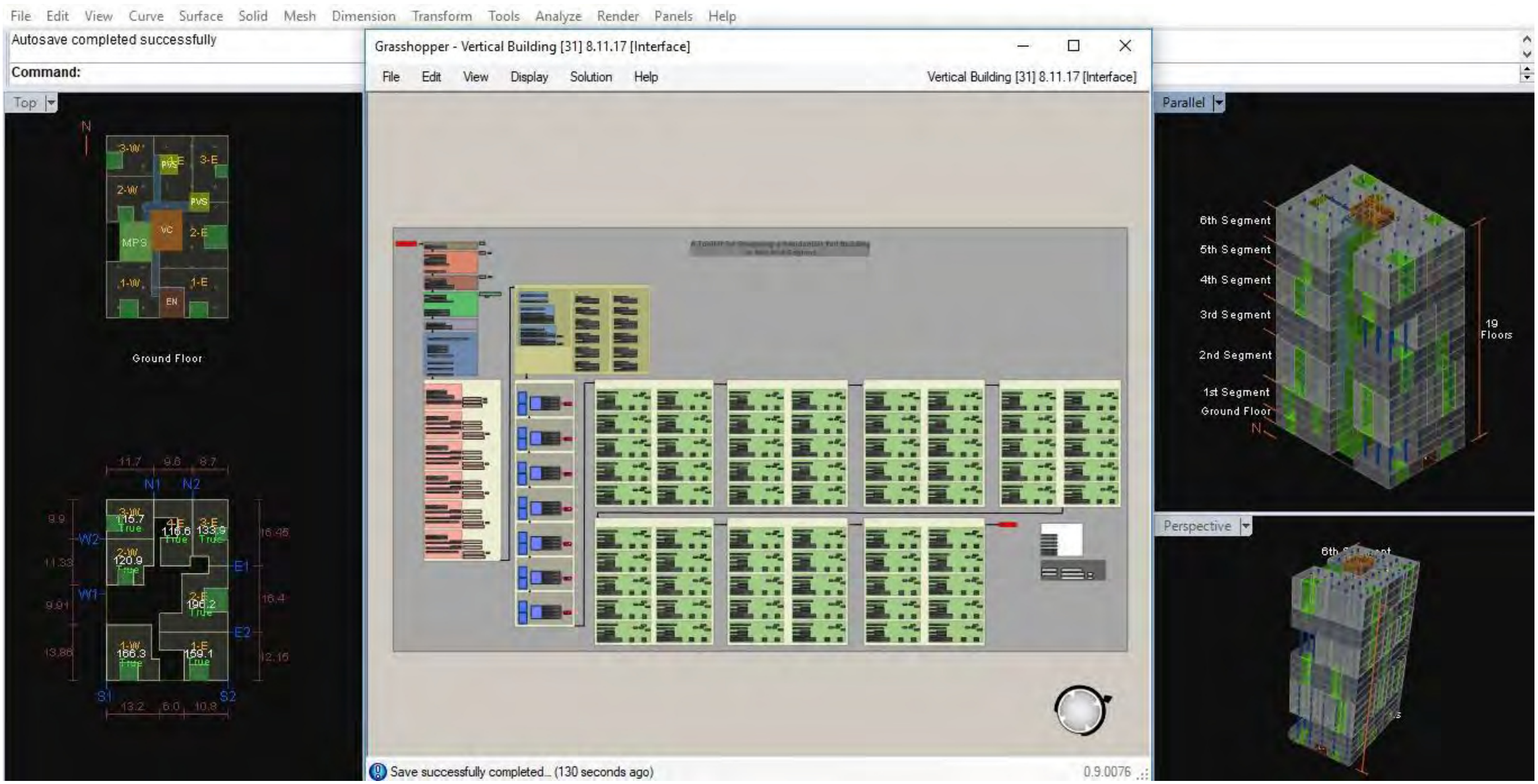
All rules that are illustrated in Stage (J) (with the same conditions), in addition to the following rules (K-1, K-2), are applicable for the top two floors.



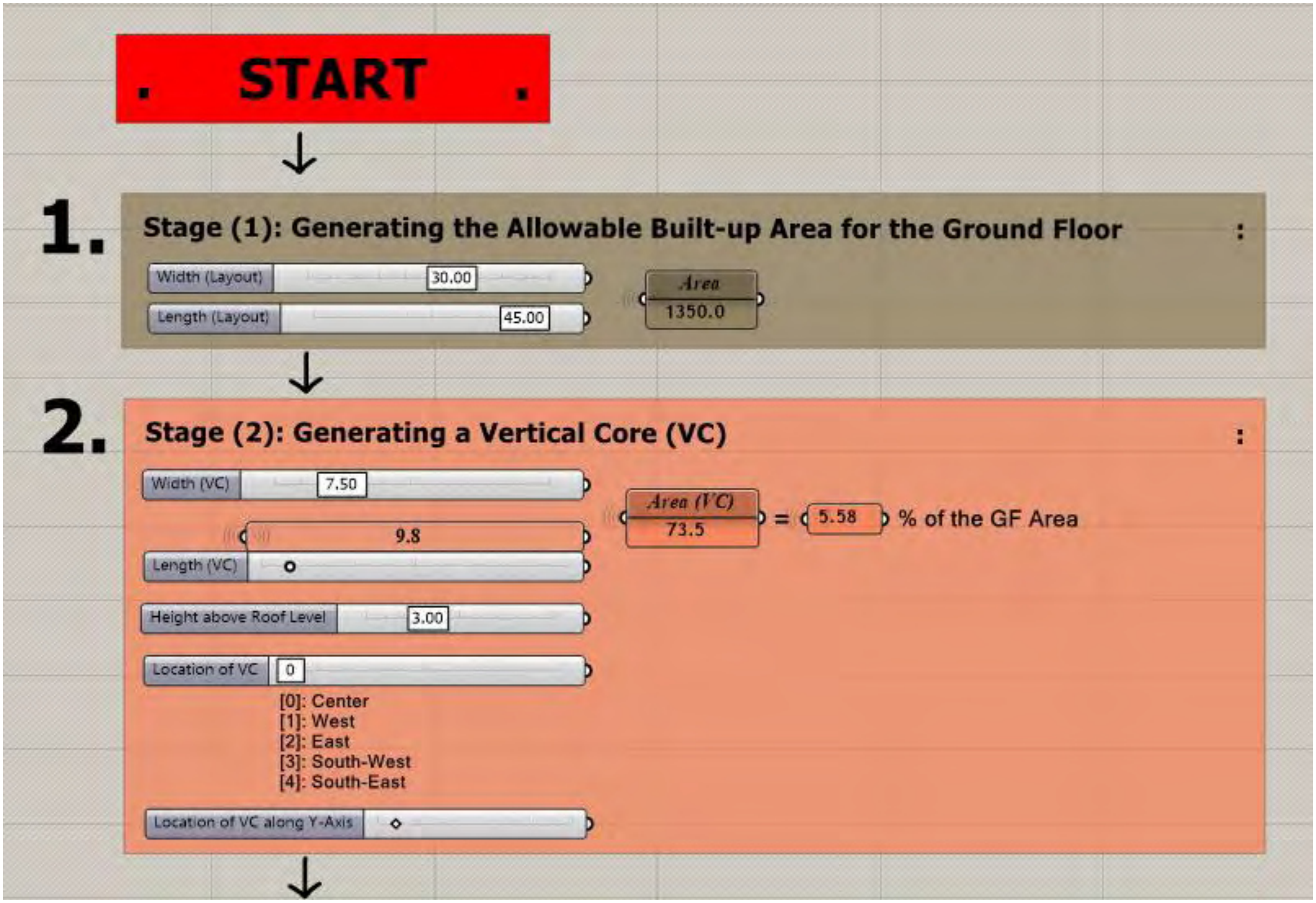
When these rules are applied, NO additional floors could be added above the roof of the apartment.

Appendix (5-B-4)

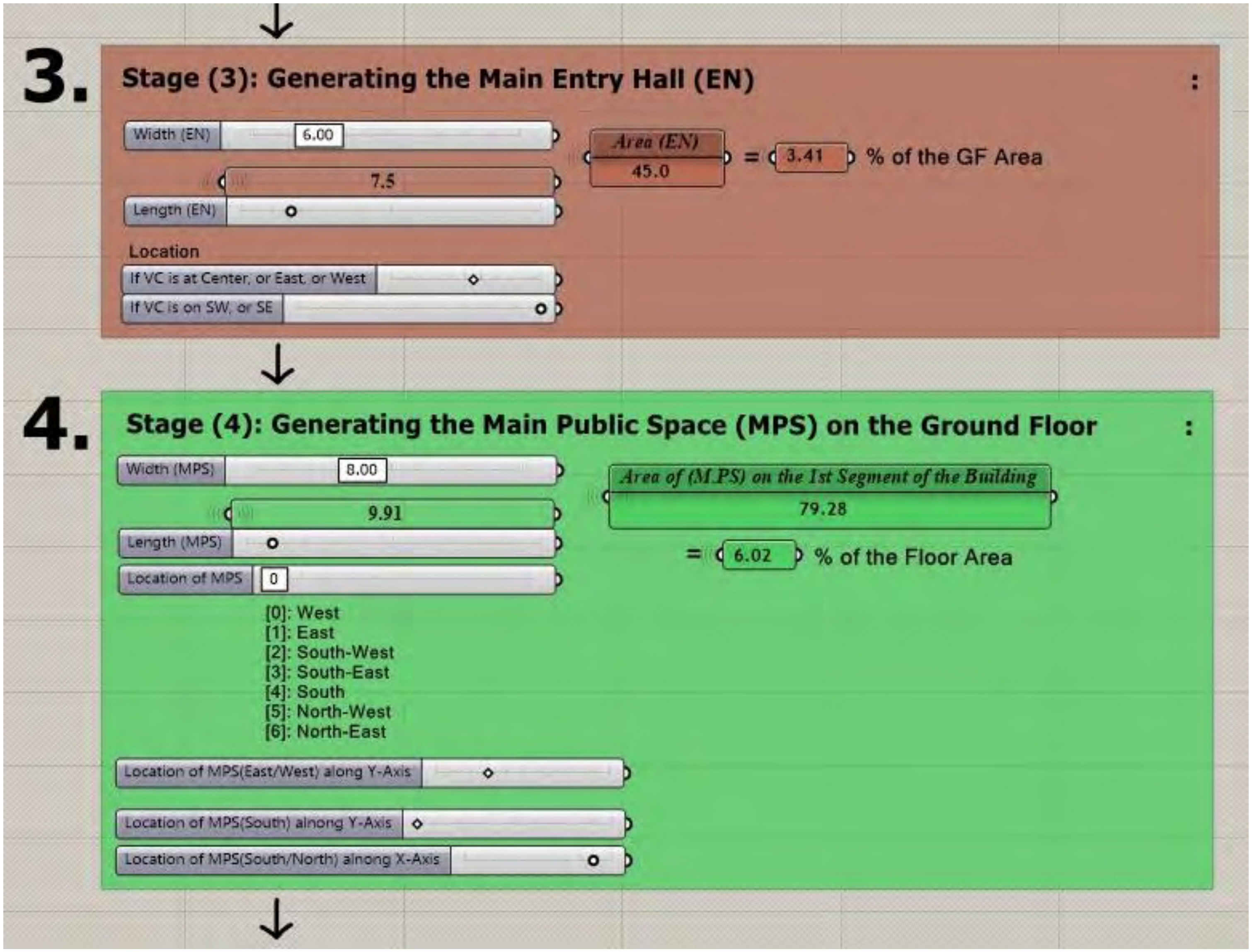
Screenshots for Components of the Computational Model for the Generation of Socially-Sustainable High-rise Buildings, using Rhino/Grasshopper



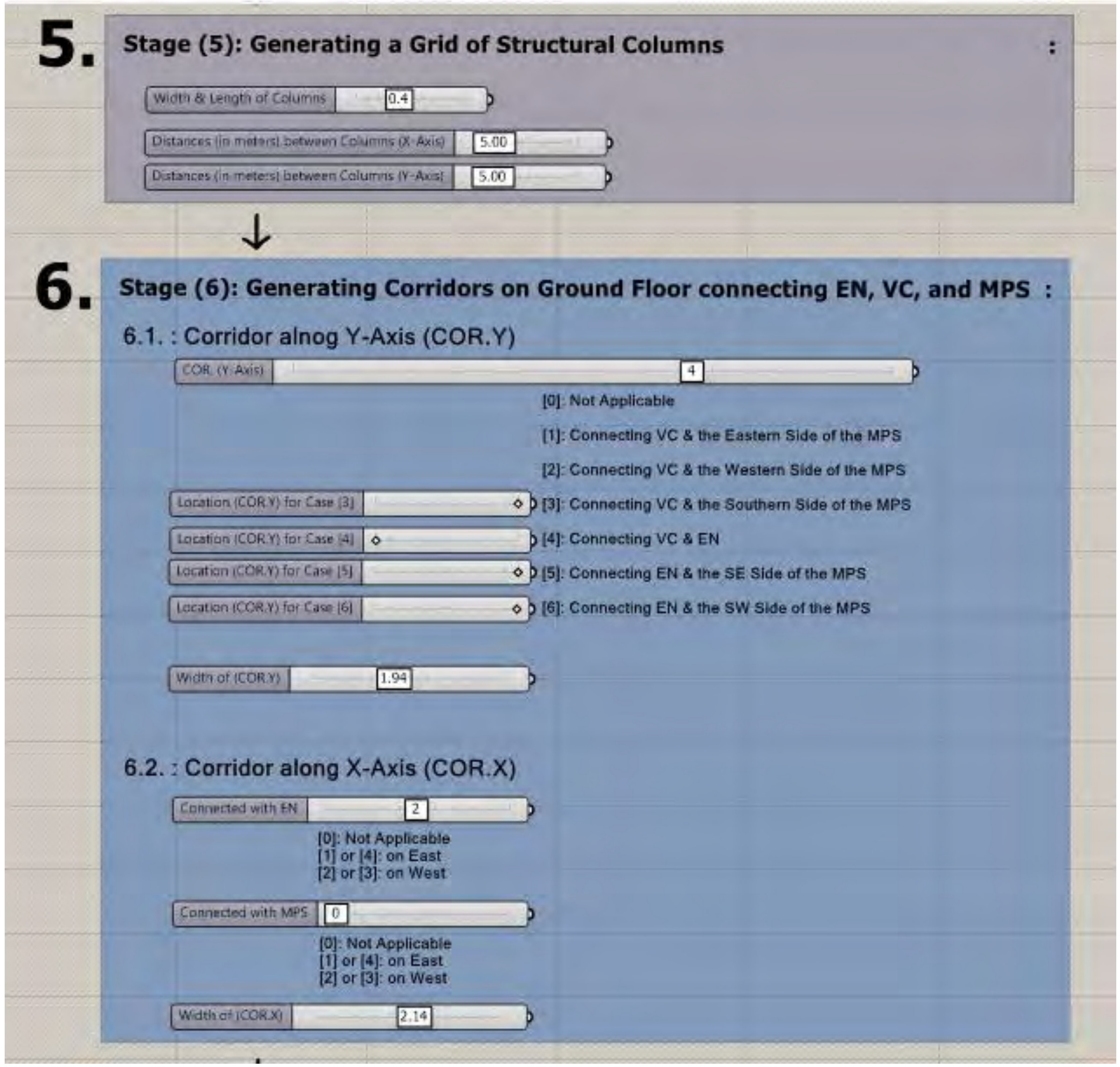
A screenshot showing the overall interface for the user for design a high-rise residential building



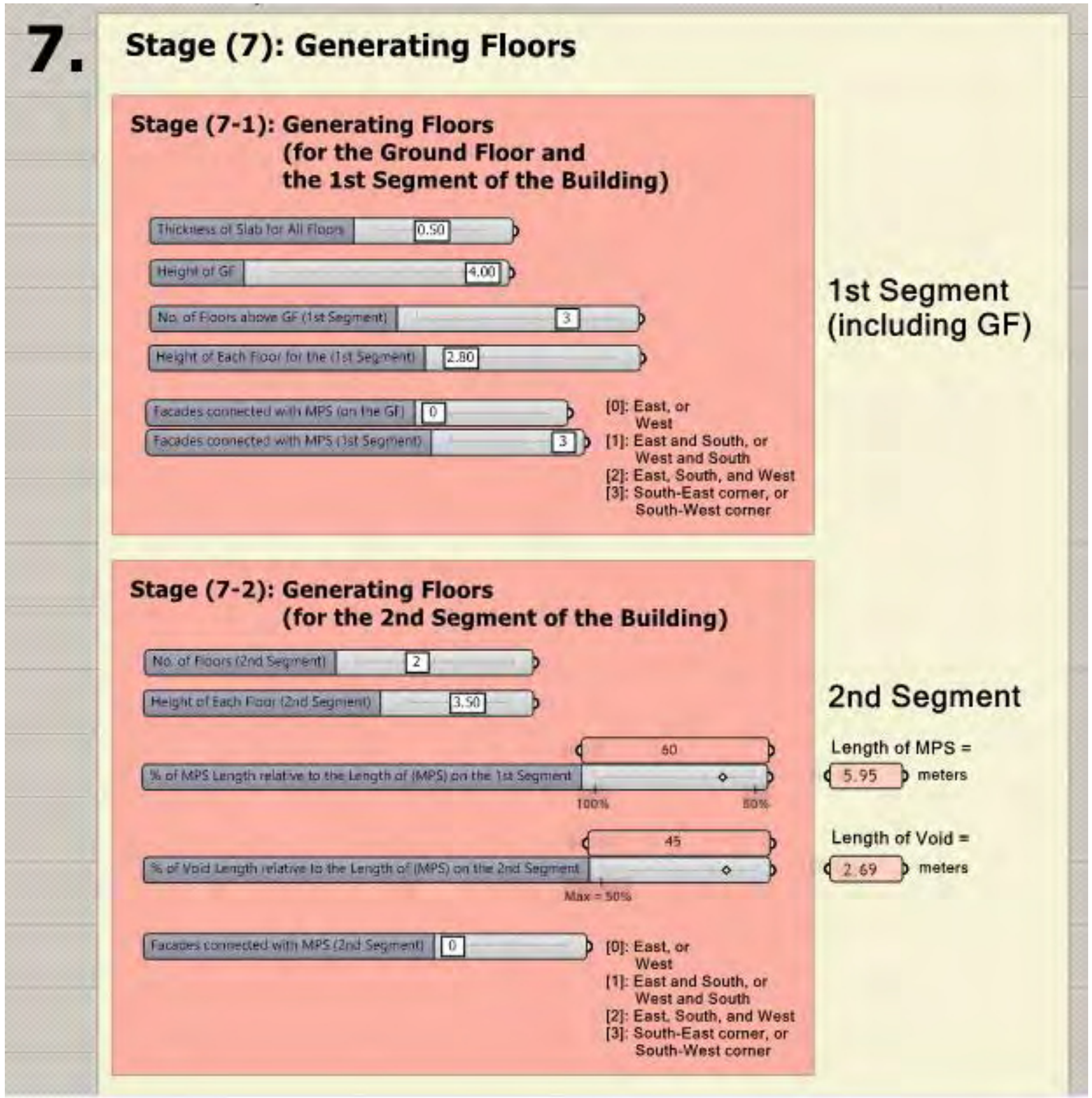
A screenshot showing inputs to be selected by the user for stages (1 and 2)



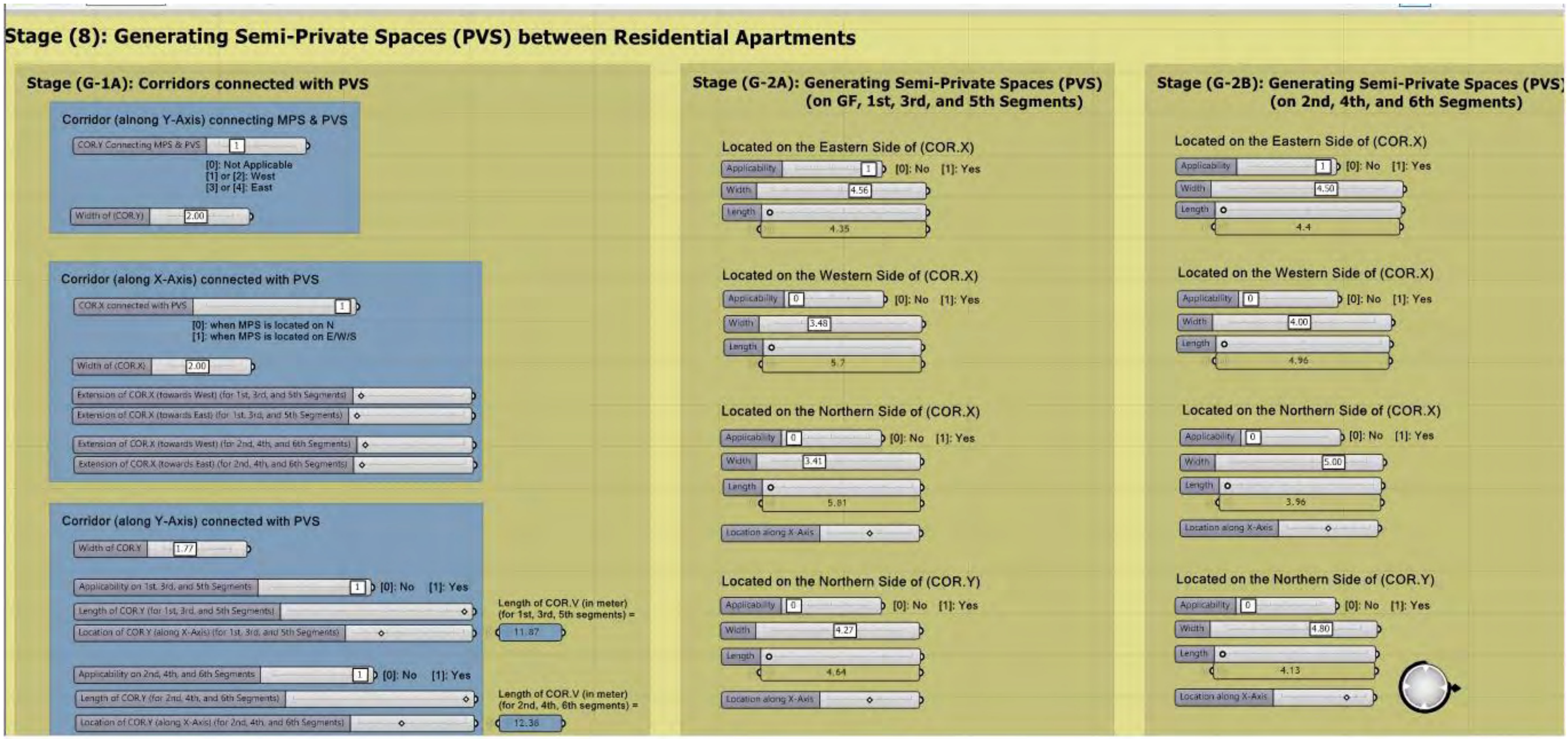
A screenshot showing inputs to be selected by the user for stages (3 and 4)



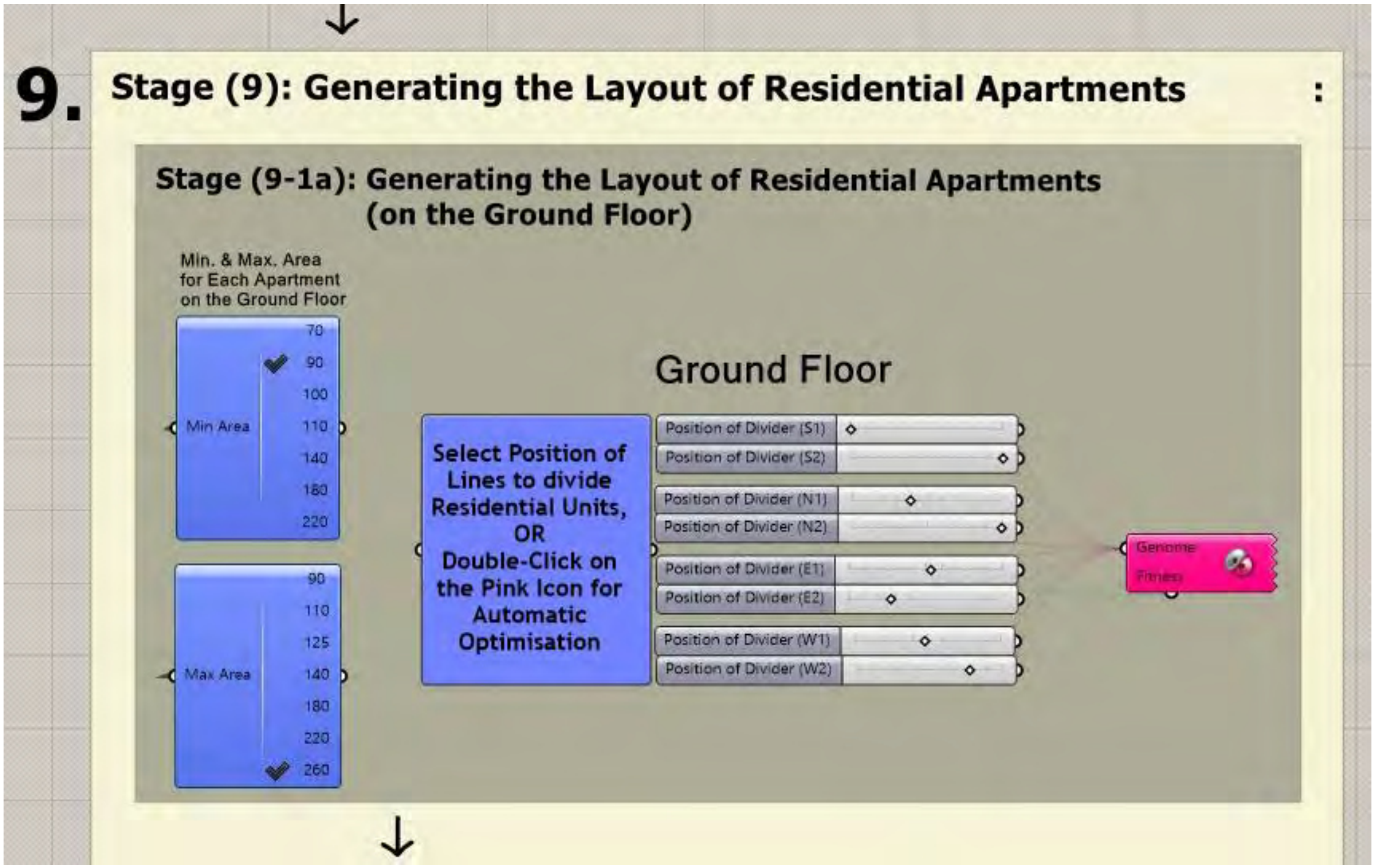
A screenshot showing inputs to be selected by the user for stages (5 and 6)



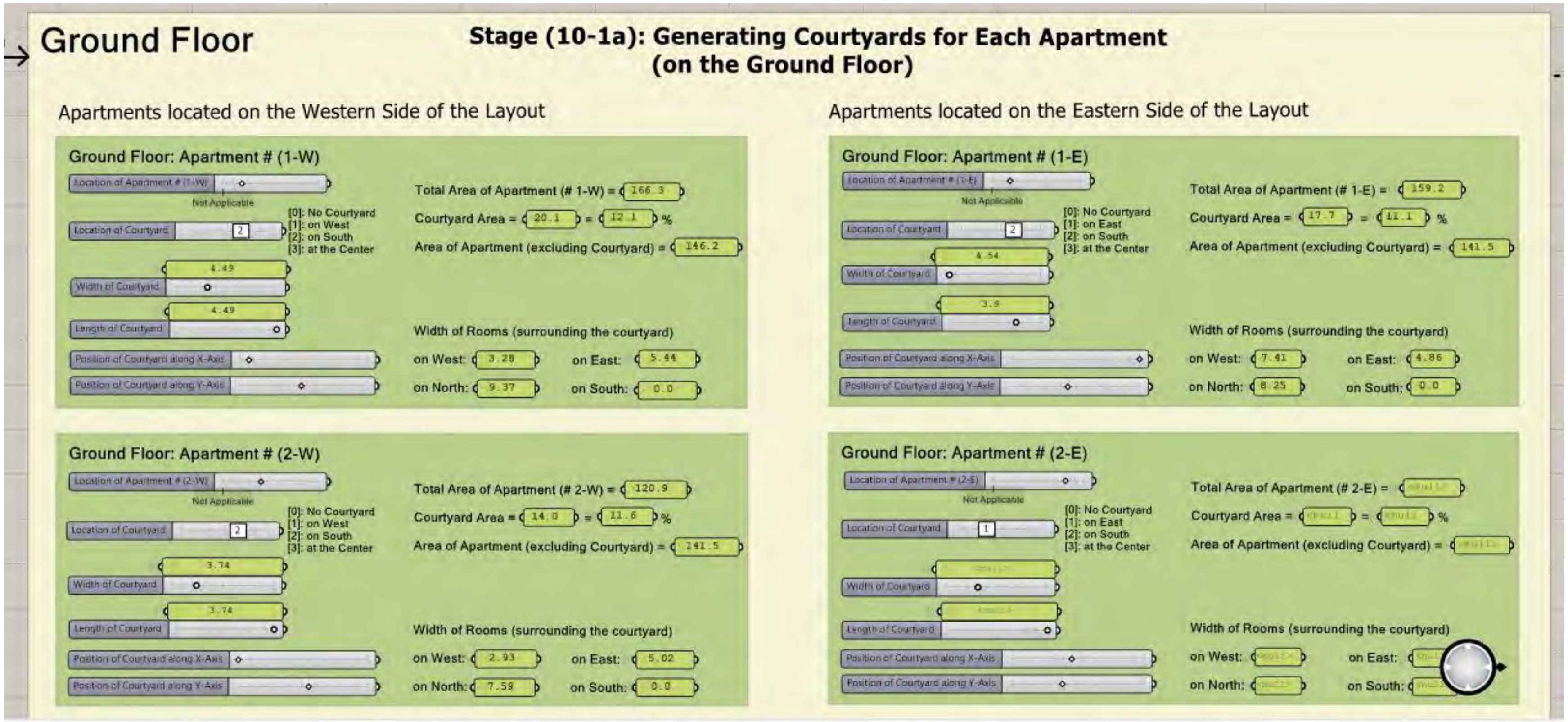
A screenshot showing inputs to be selected by the user for stage (7)



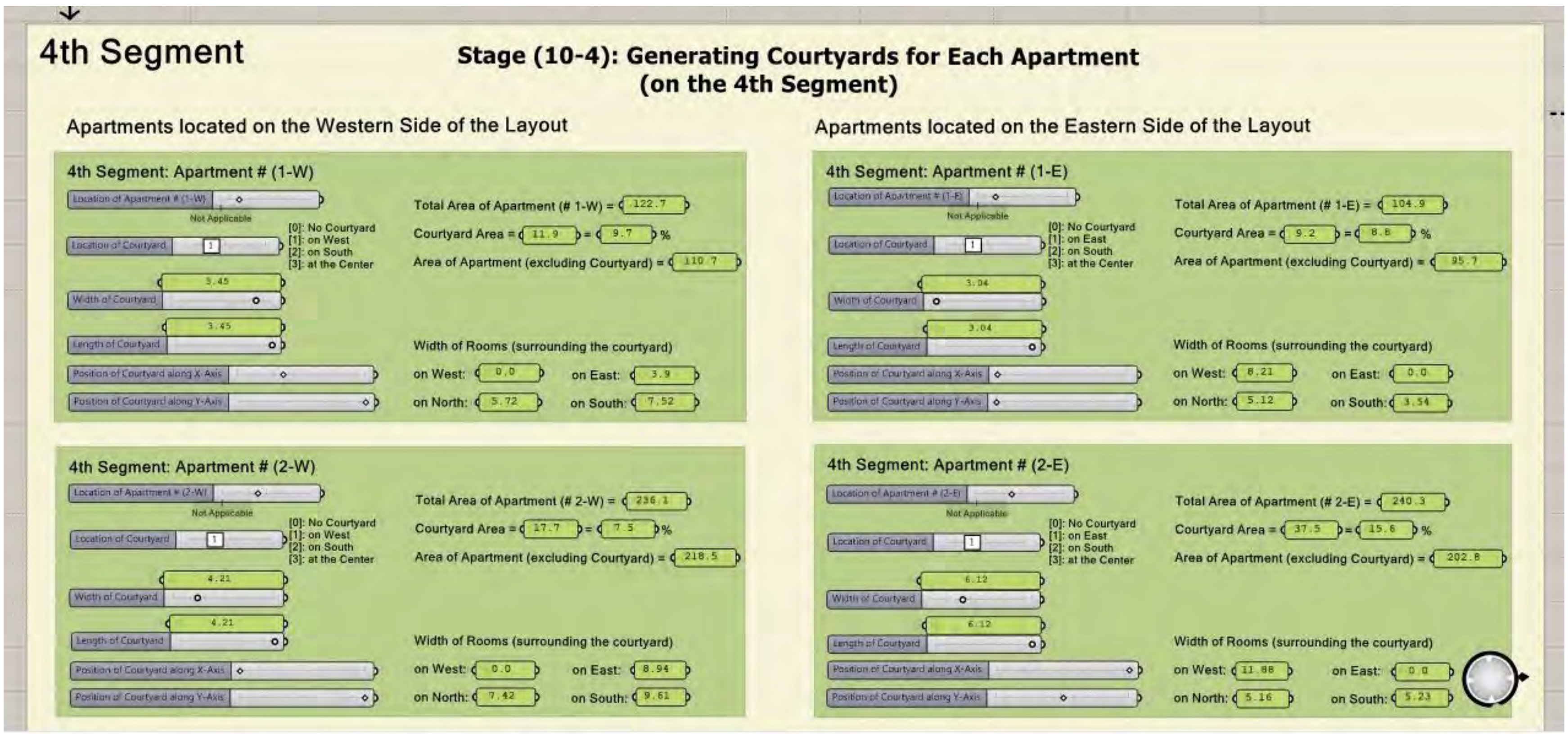
A screenshot showing inputs to be selected by the user for stage (8)



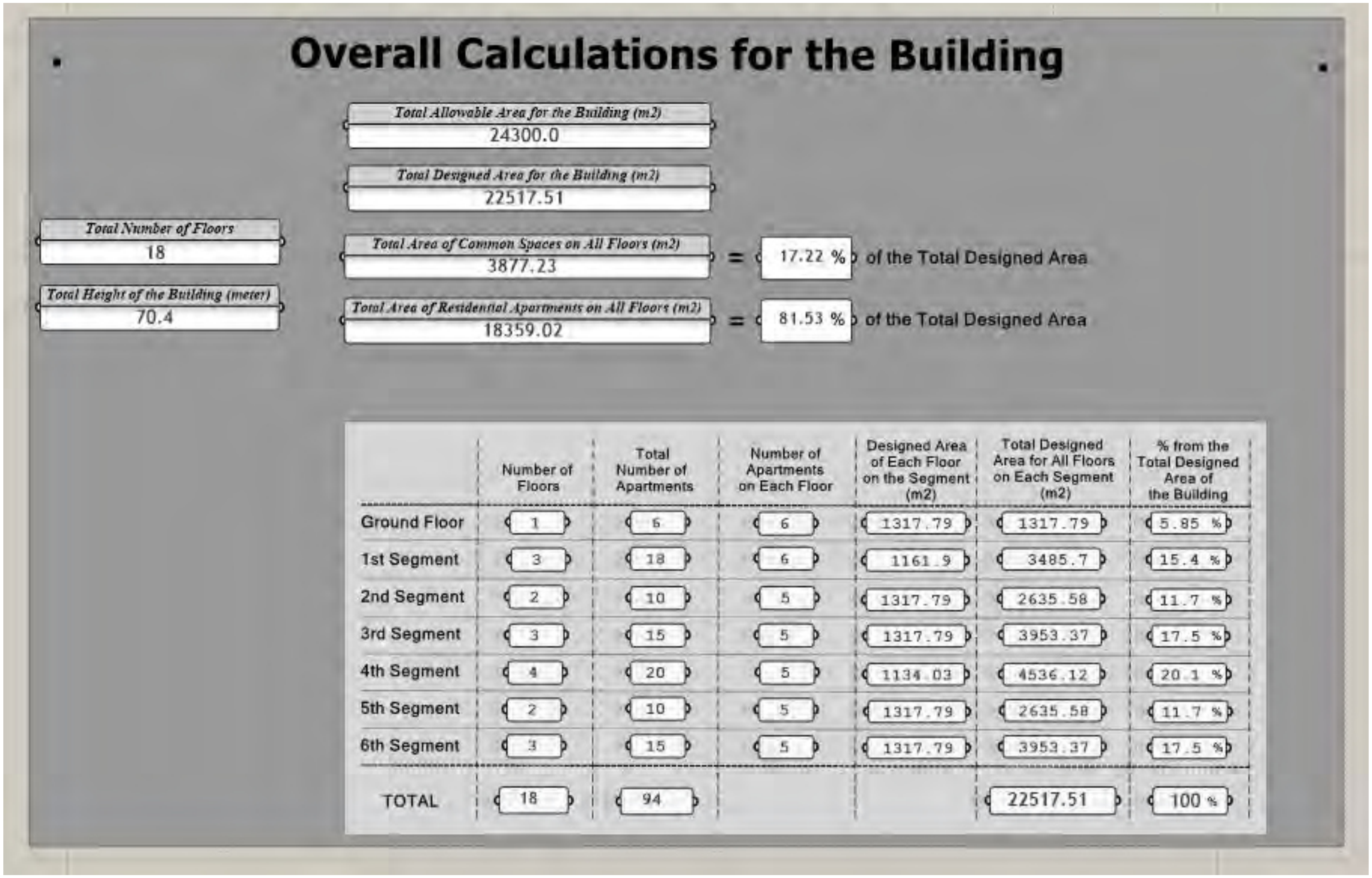
A screenshot showing inputs to be selected by the user for stage (9)



A screenshot showing inputs to be selected by the user for stage (10)



A screenshot showing inputs to be selected by the user for stage (10)



Overall Calculations for the Building

Total Allowable Area for the Building (m2): 24300.0

Total Designed Area for the Building (m2): 22517.51

Total Number of Floors: 18

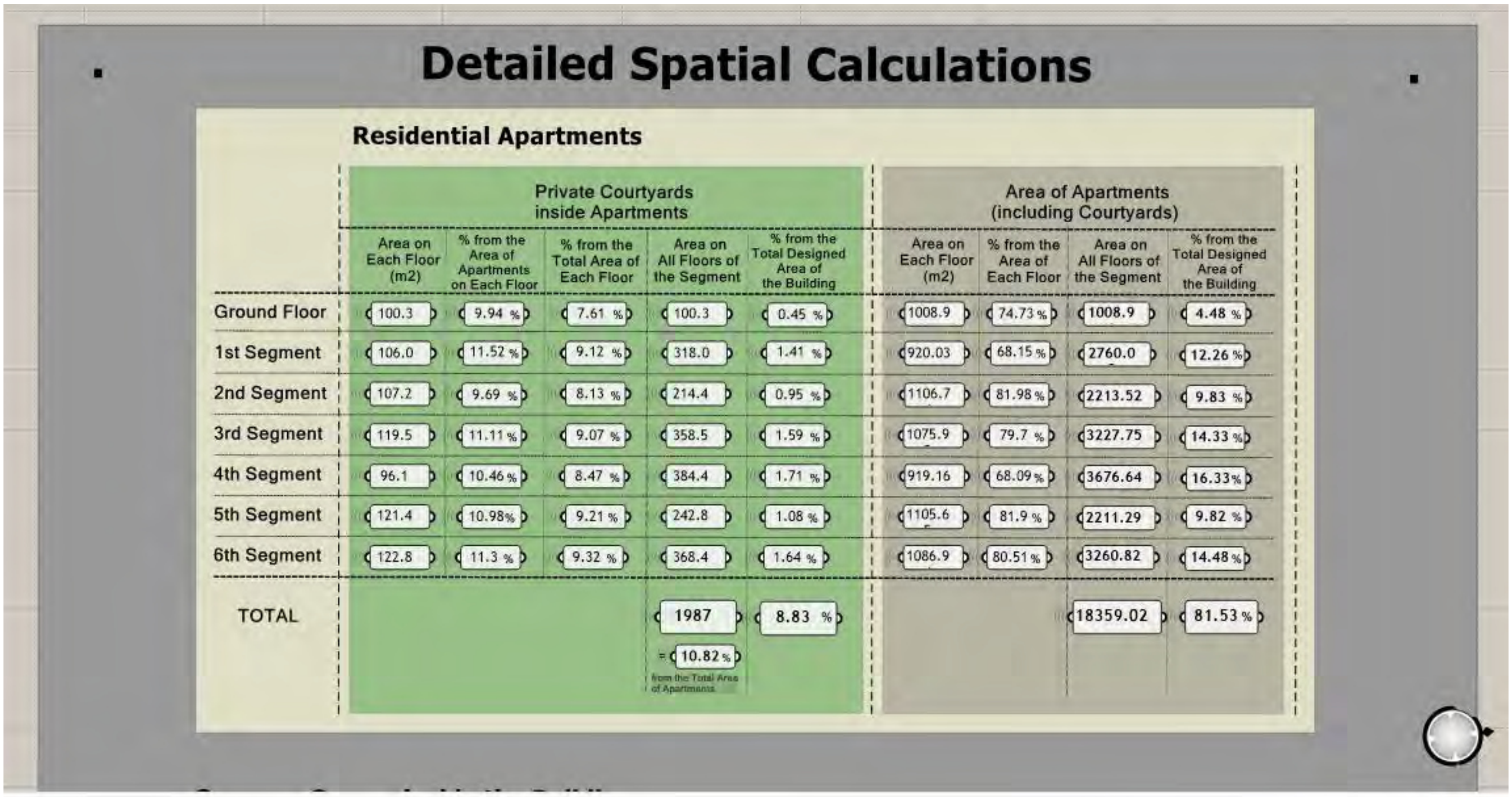
Total Height of the Building (meter): 70.4

Total Area of Common Spaces on All Floors (m2): 3877.23 = 17.22 % of the Total Designed Area

Total Area of Residential Apartments on All Floors (m2): 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 (m2)	Total Designed Area for All Floors on Each Segment (m2)	% 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 %
TOTAL	18	94			22517.51	100 %

A screenshot showing outputs carried out by the system for calculating the overall areas for the building

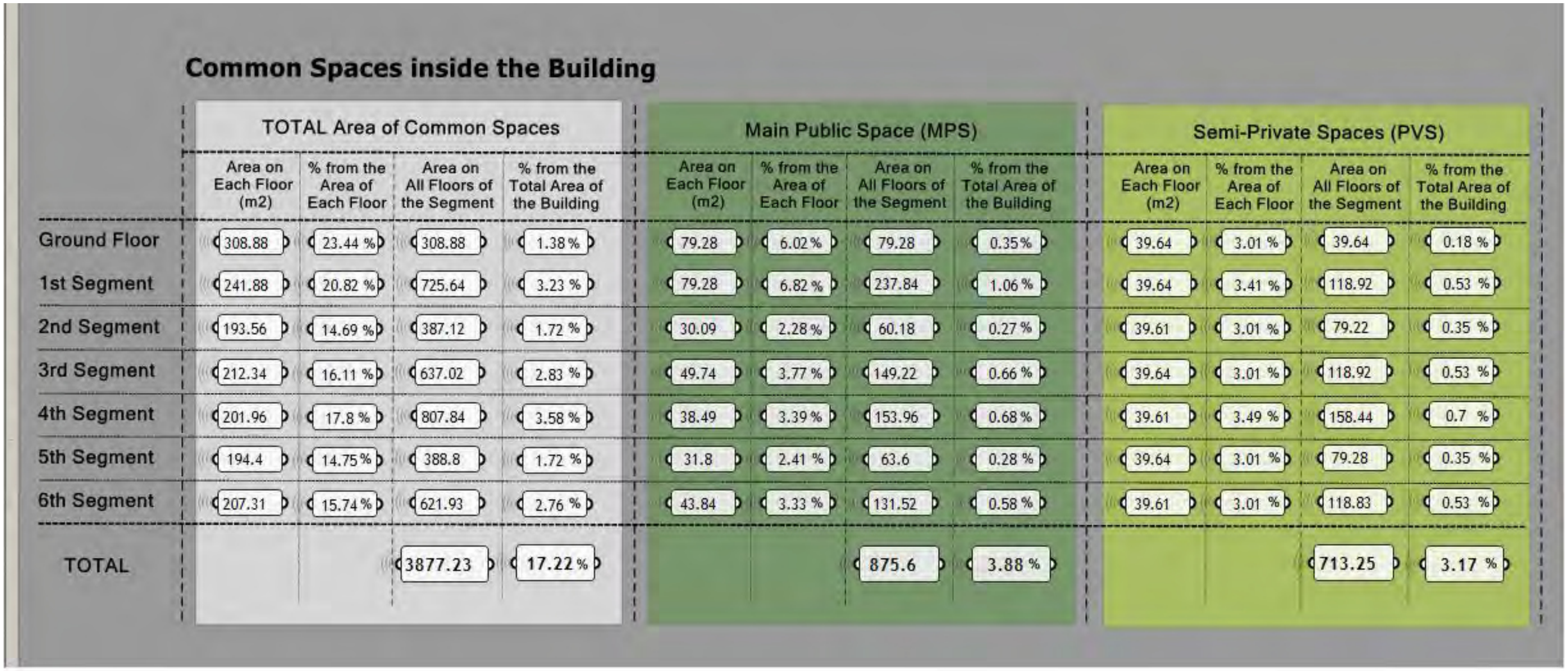


Detailed Spatial Calculations

Residential Apartments

	Private Courtyards inside Apartments					Area of Apartments (including Courtyards)			
	Area on Each Floor (m2)	% 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 (m2)	% 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	74.73 %	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 = 10.82 % from the Total Area of Apartments	8.83 %			18359.02	81.53 %

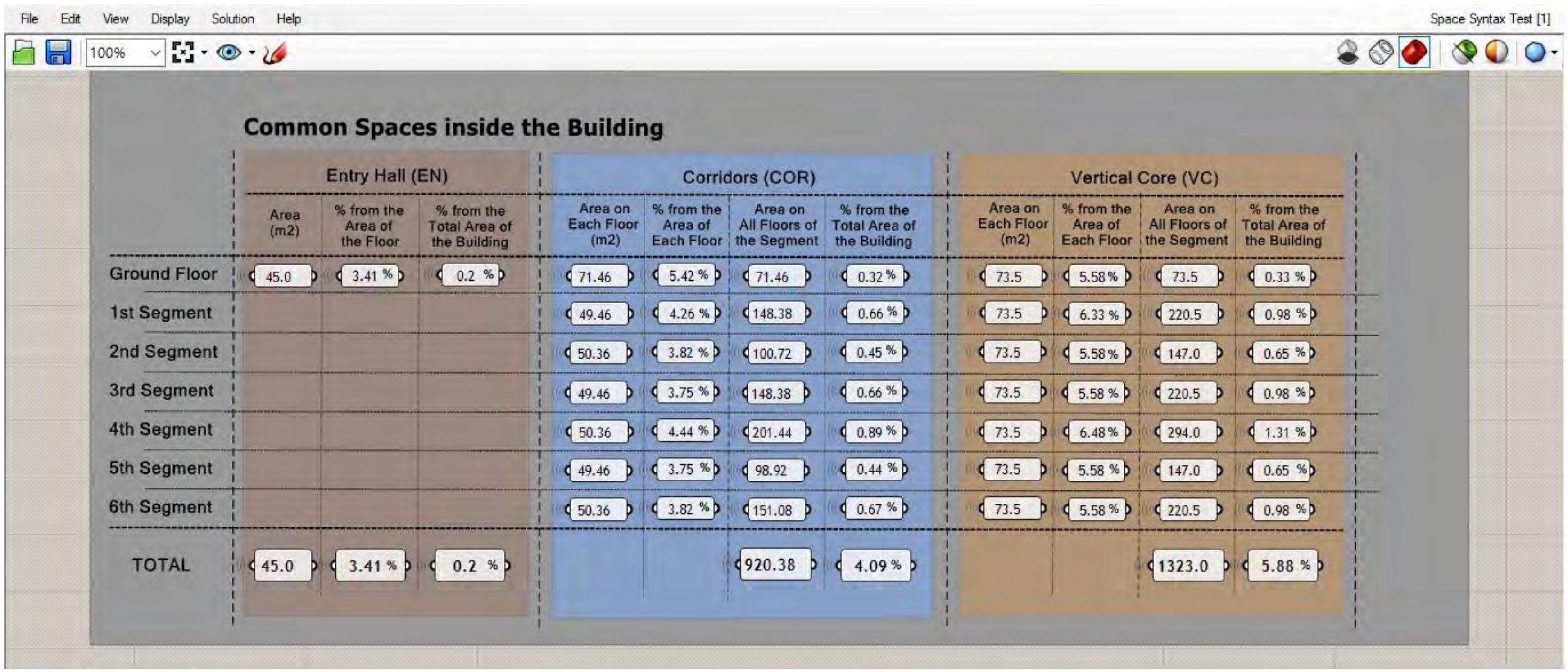
A screenshot showing outputs carried out by the system for calculating areas of apartments



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 %
TOTAL			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)

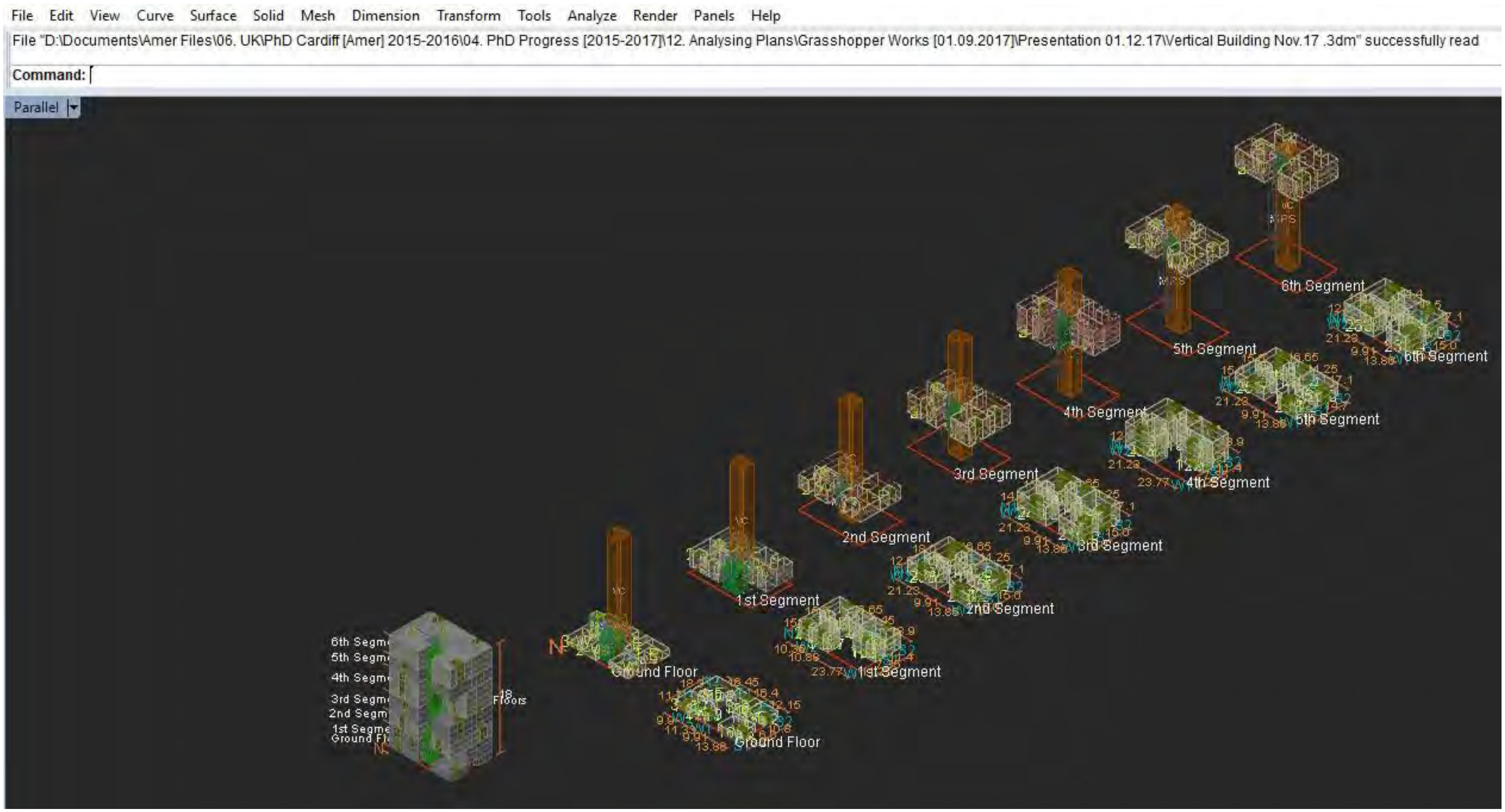


Common Spaces inside the Building

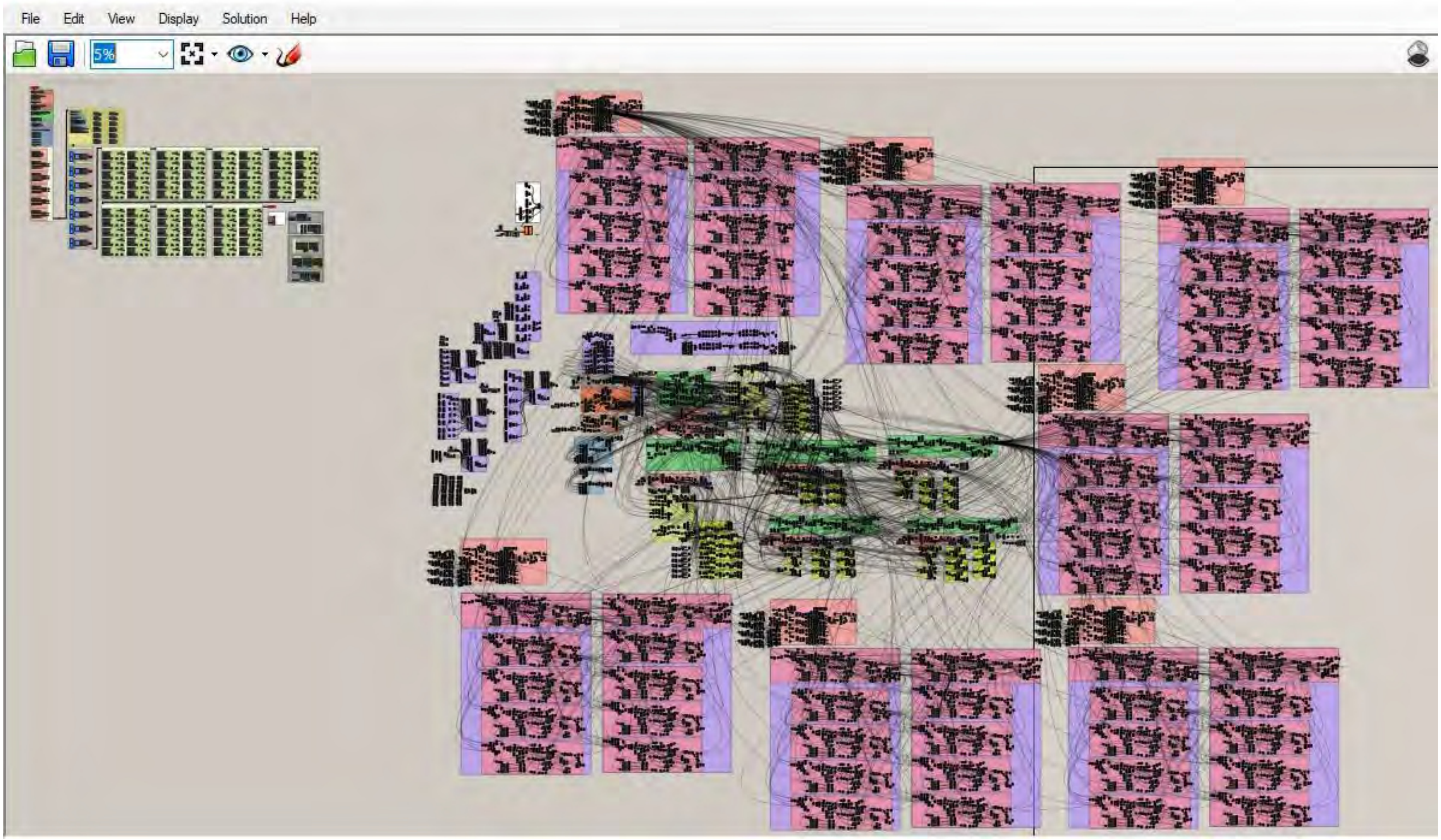
	Entry Hall (EN)			Corridors (COR)				Vertical Core (VC)			
	Area (m2)	% from the Area of the Floor	% from the Total Area of the Building	Area on Each Floor (m2)	% from the Area of Each Floor	Area on All Floors of the Segment	% from the Total Area of the Building	Area on Each Floor (m2)	% from the Area 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 %
TOTAL	45.0	3.41 %	0.2 %			920.38	4.09 %			1323.0	5.88 %

A screenshot showing outputs carried out by the system for calculating areas of common spaces (part 2)

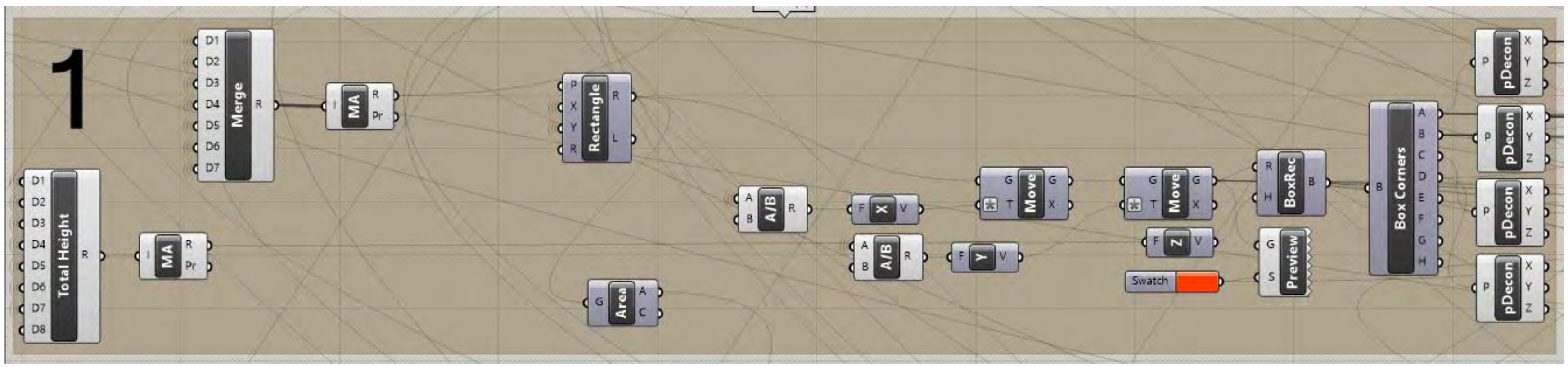
A screenshot showing the generated layouts for all segments carried out by the system



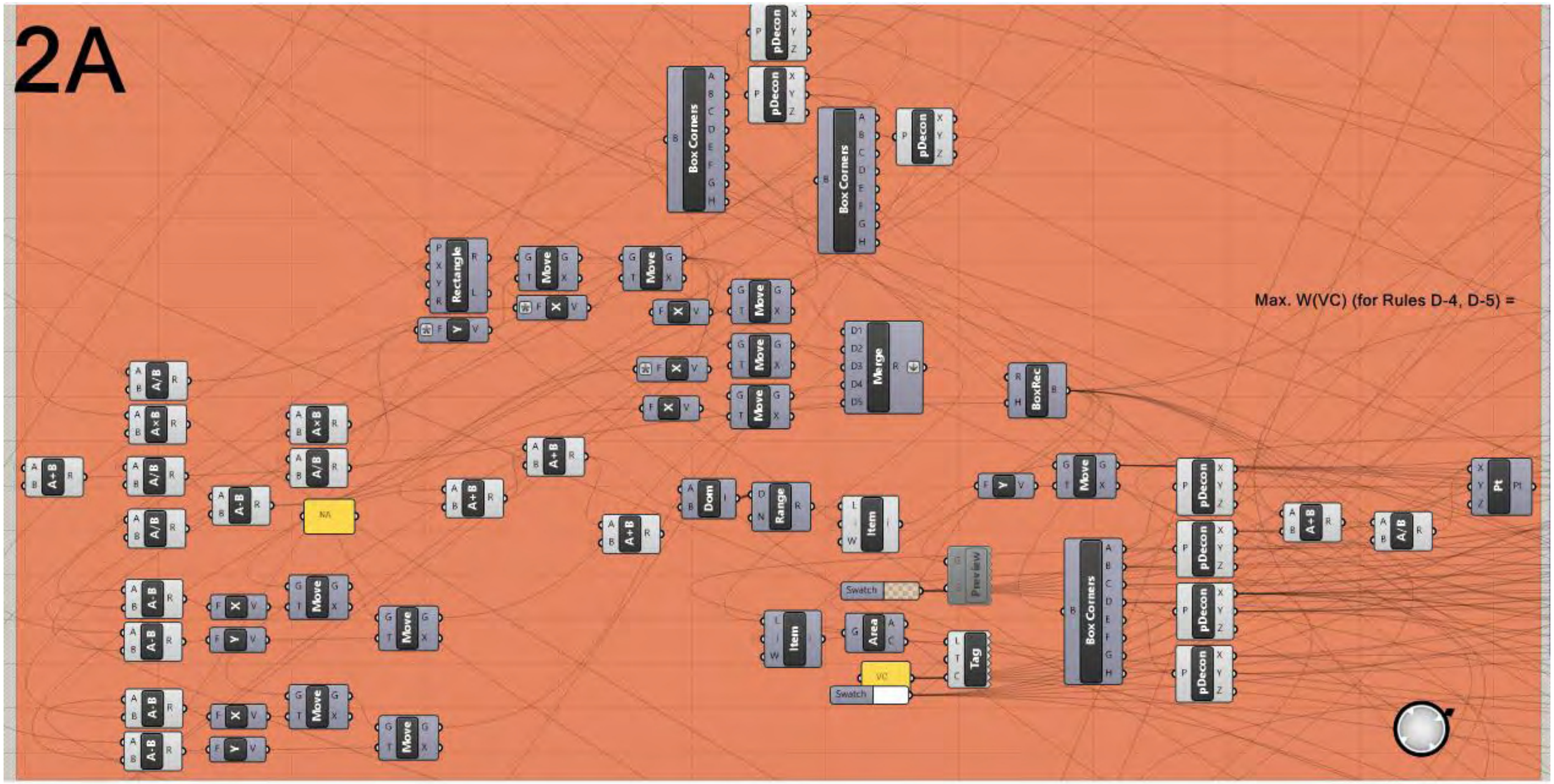
A screenshot showing the generated three-dimensional views for the building and for each segment carried out by the system



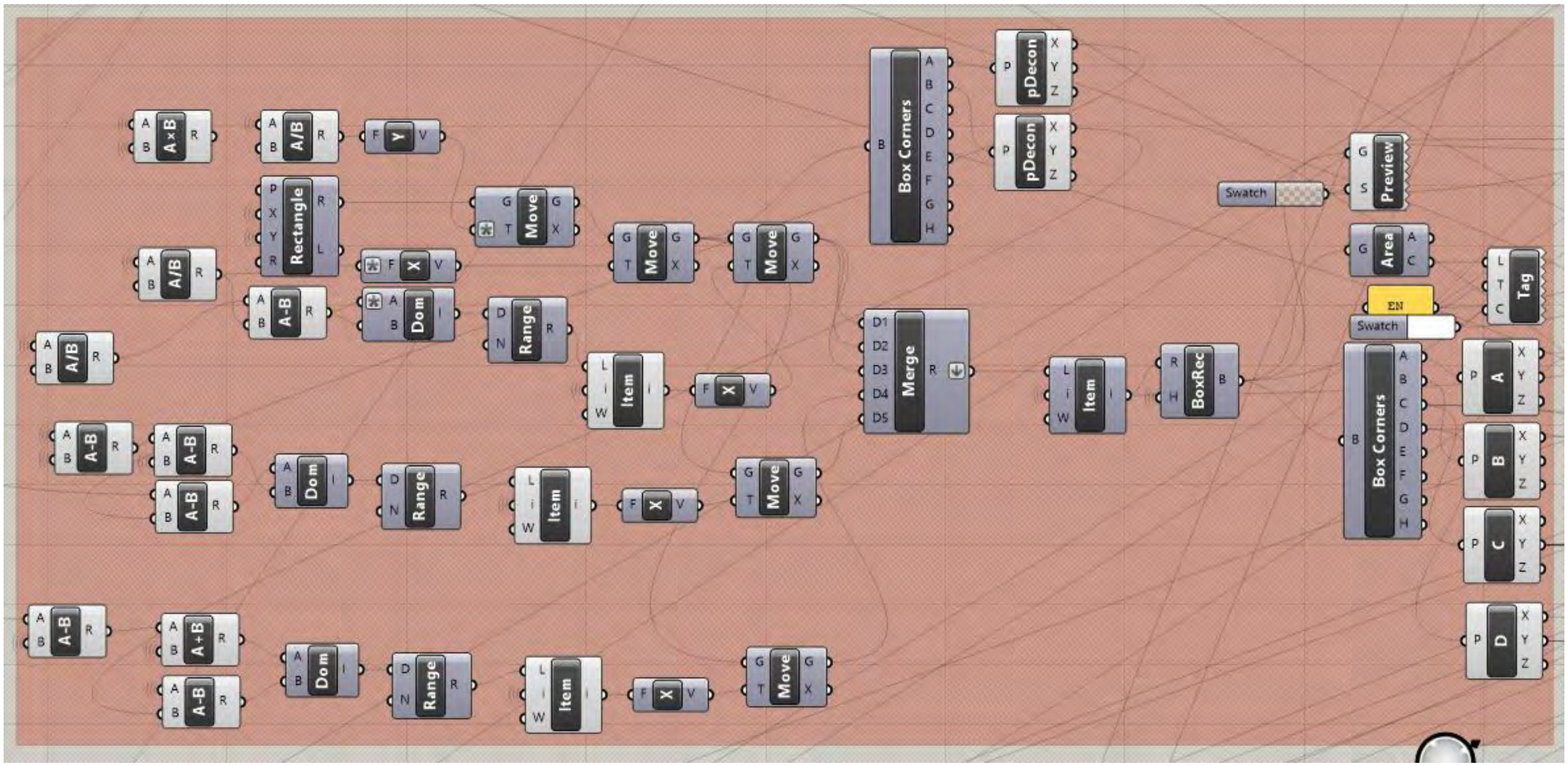
A screenshot showing components for generating a high-rise residential building



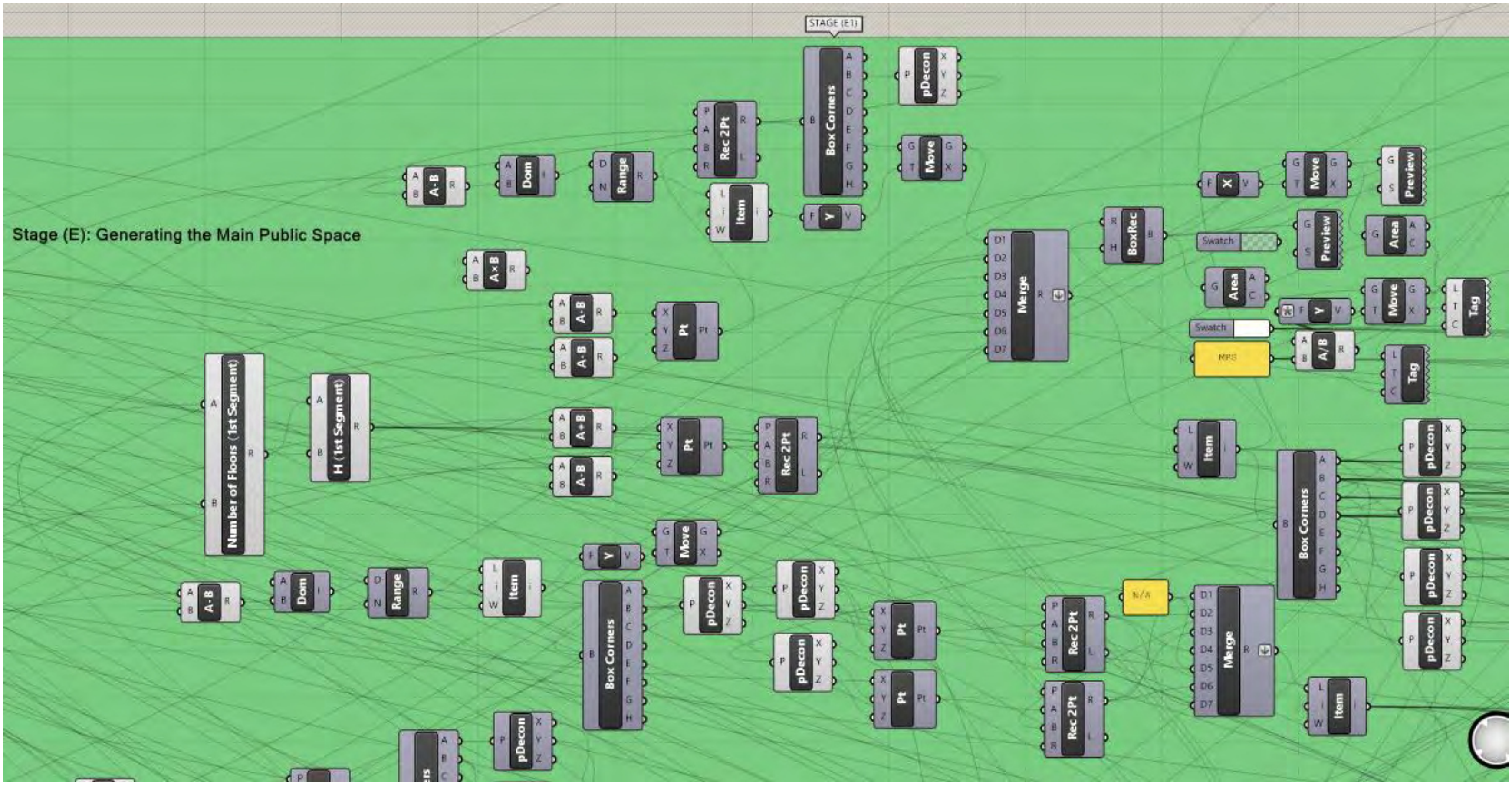
A screenshot showing components for carrying out stage (1) for generating the overall layout of the building



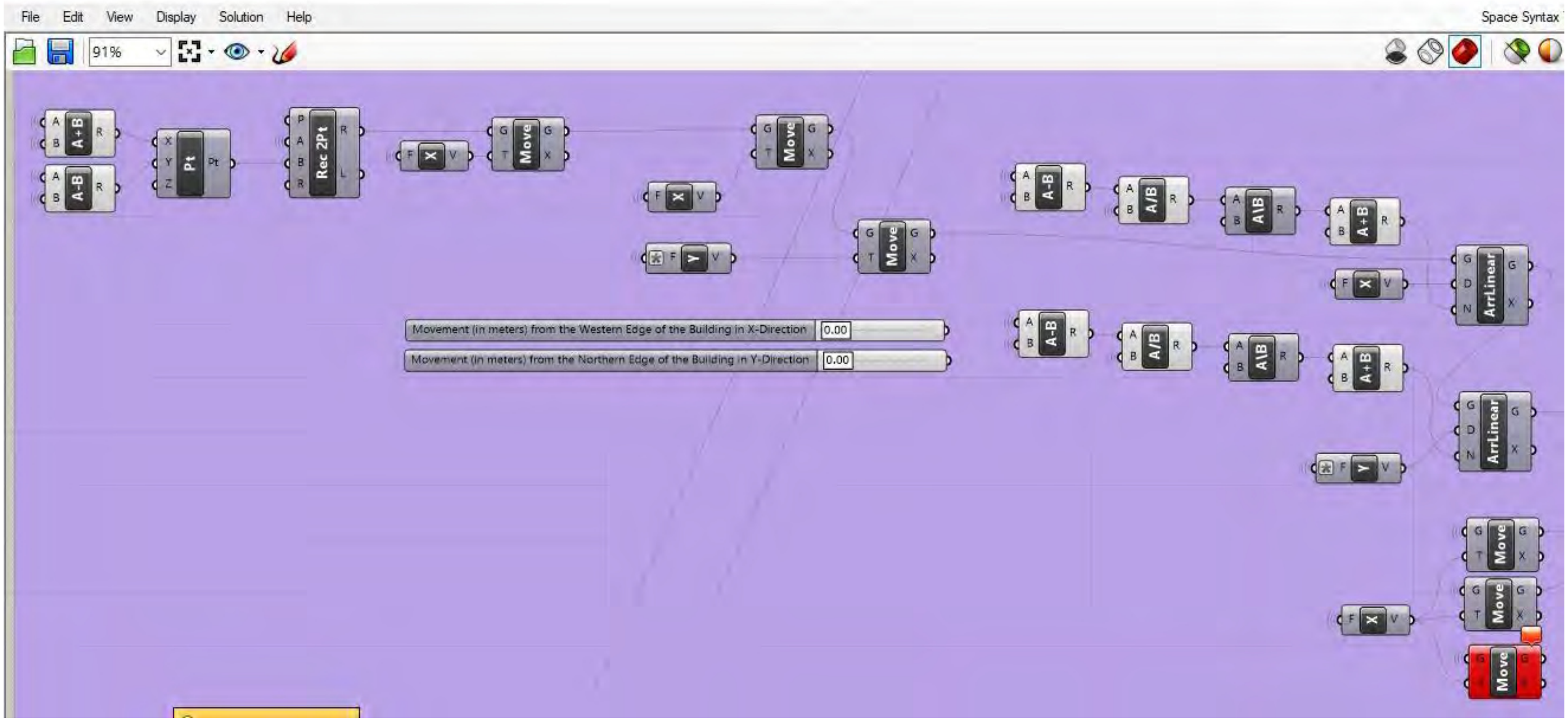
A screenshot showing components for carrying out stage (2) for generating the vertical circulation core (VC)



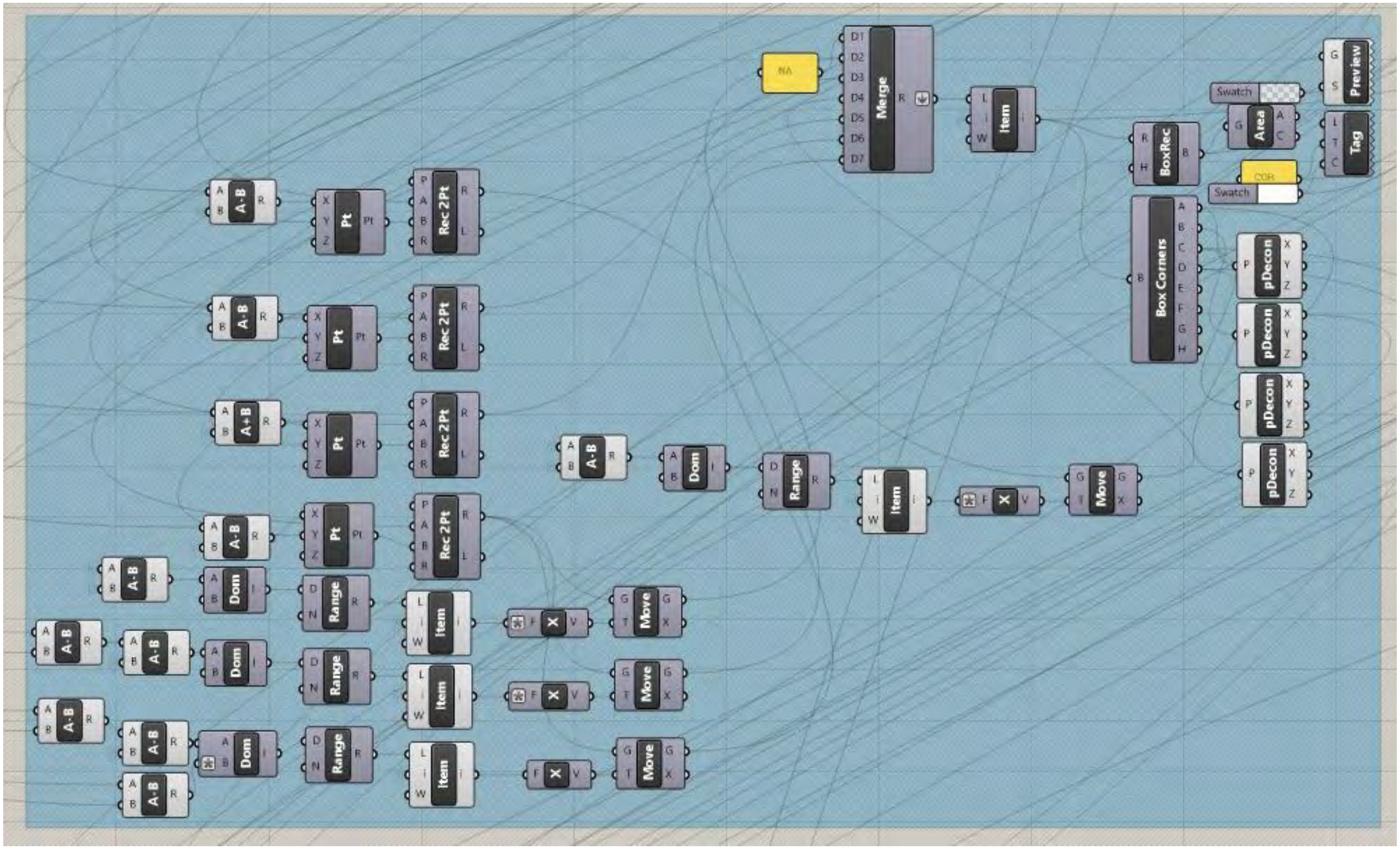
A screenshot showing components for carrying out stage (3) for generating the main entry hall (EN)



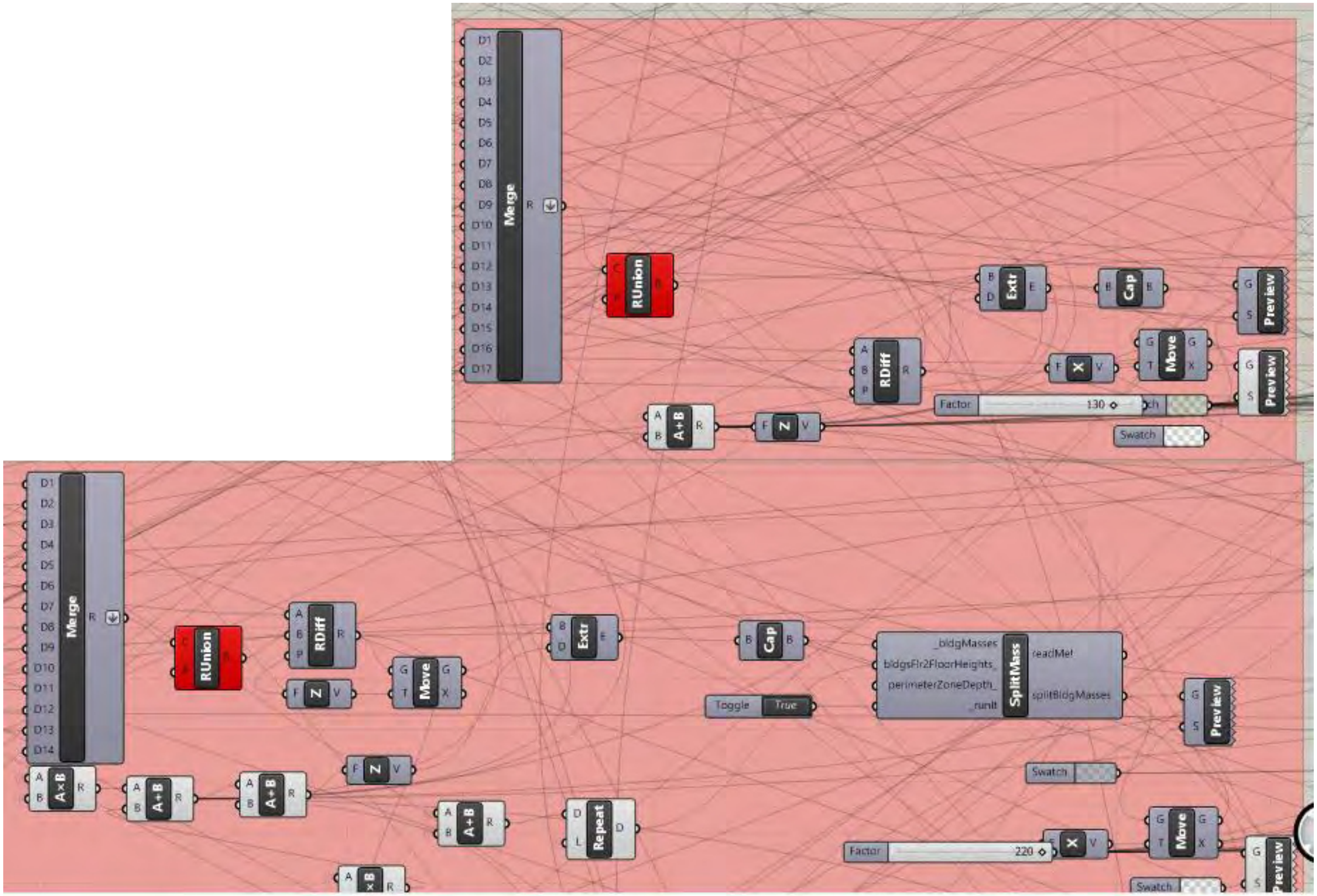
A screenshot showing components for carrying out stage (4) for generating the main public space (MPS)



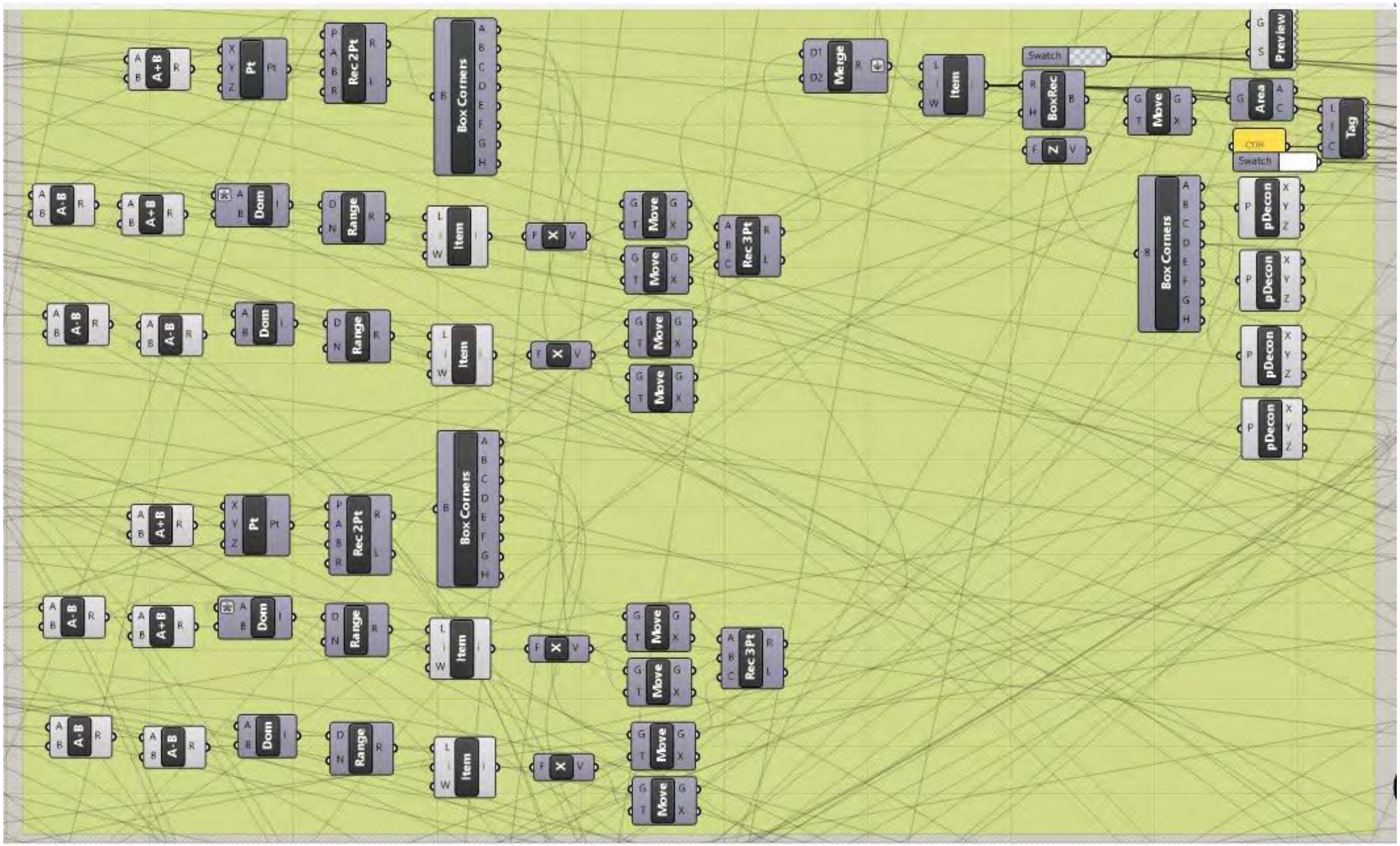
A screenshot showing components for carrying out stage (5) for generating structural columns



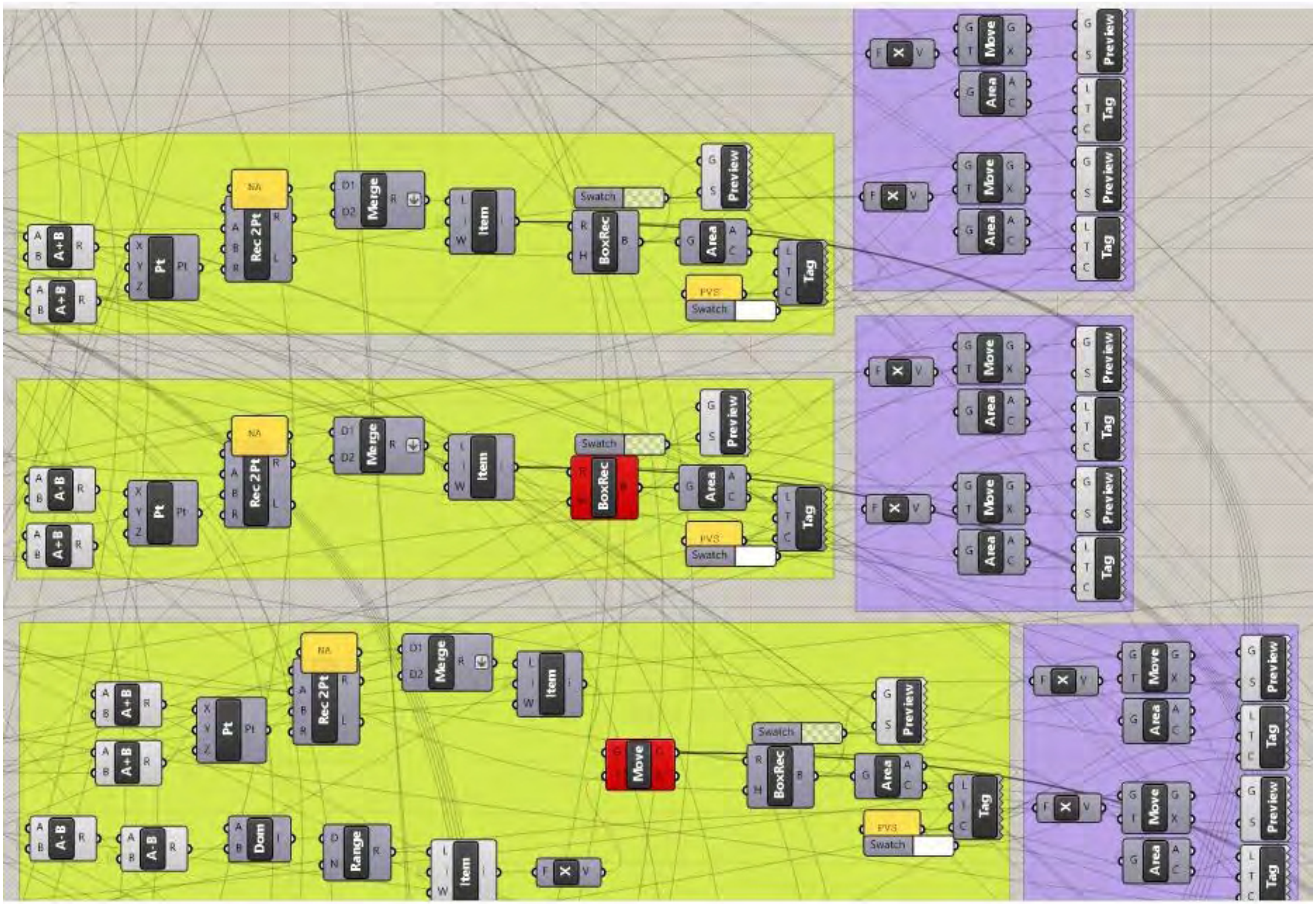
A screenshot showing components for carrying out stage (6) for generating corridors (COR)



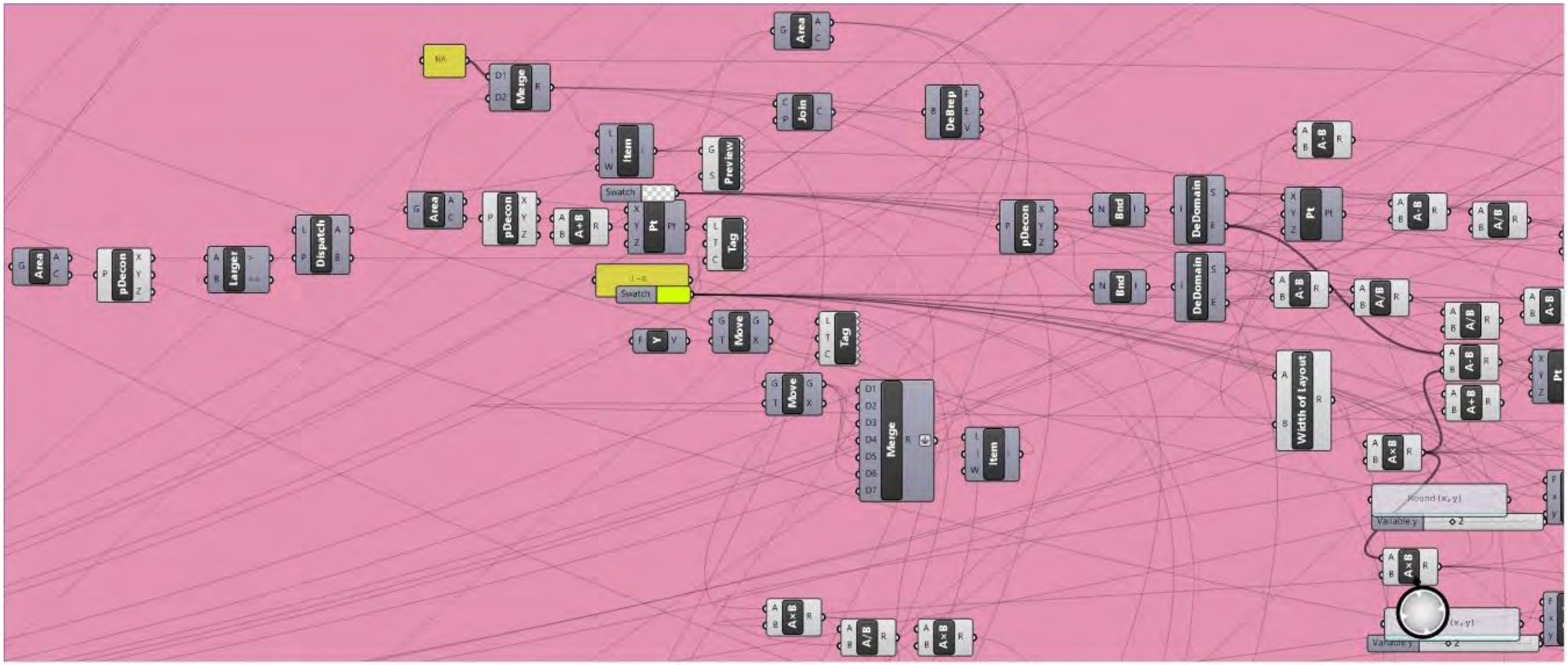
A screenshot showing components for carrying out stage (7) for generating the overall layout of residential units



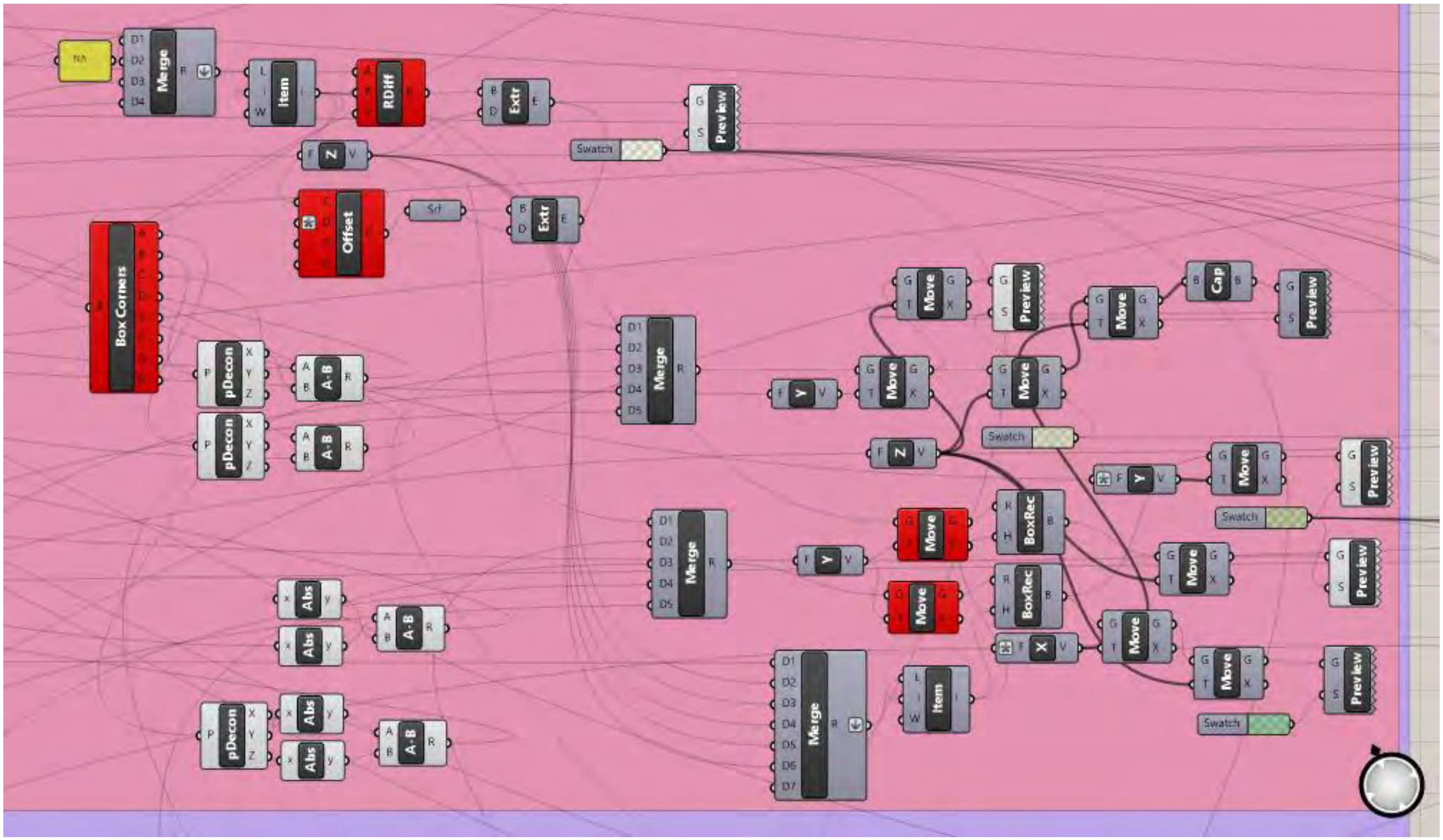
A screenshot showing components for carrying out stage (8) for generating corridors connected with semi-private spaces (PVS)



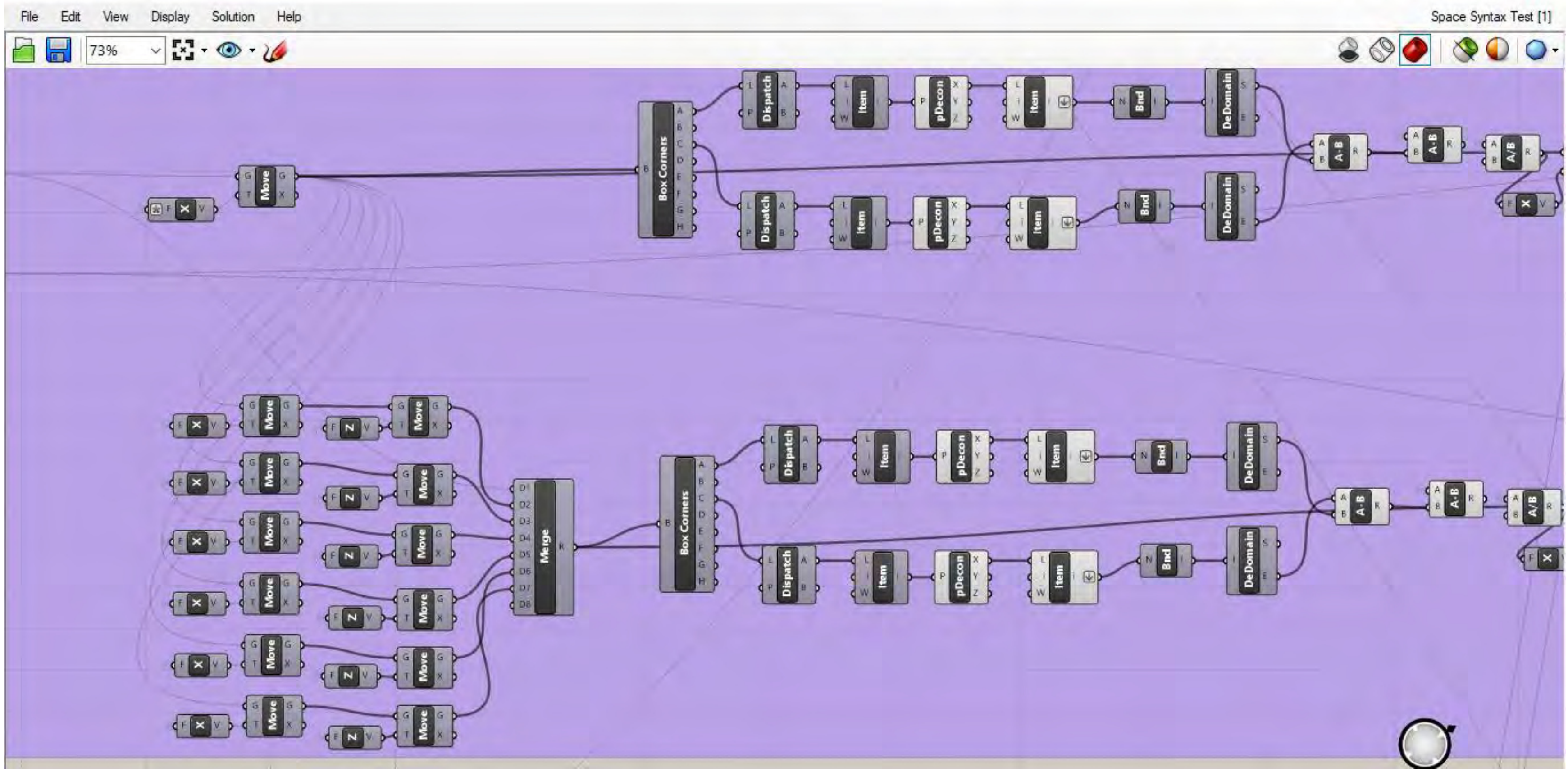
A screenshot showing components for carrying out stage (8) for generating semi-private spaces (PVS)



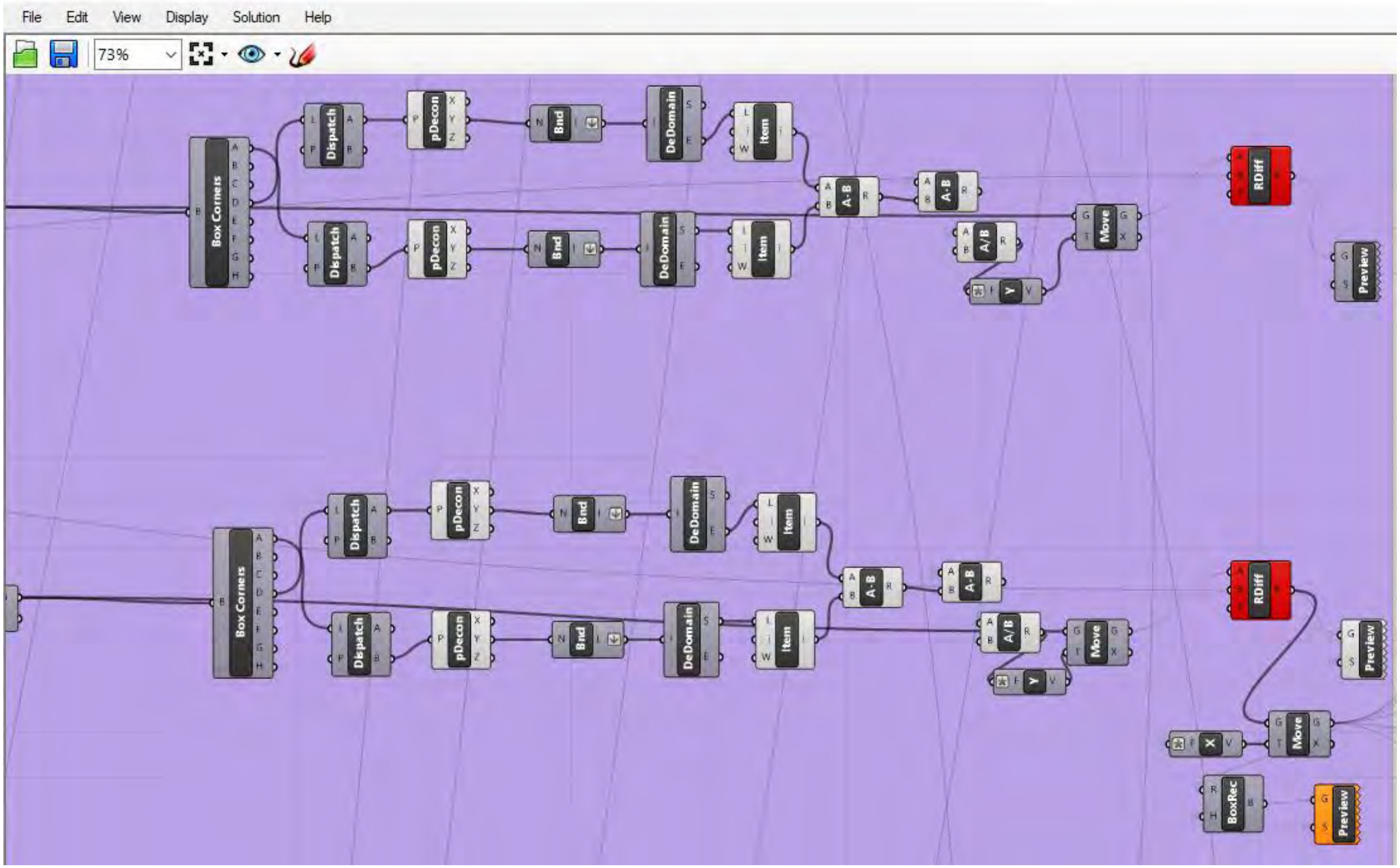
A screenshot showing part of the components for carrying out stages (9 and 10) for generating apartments



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

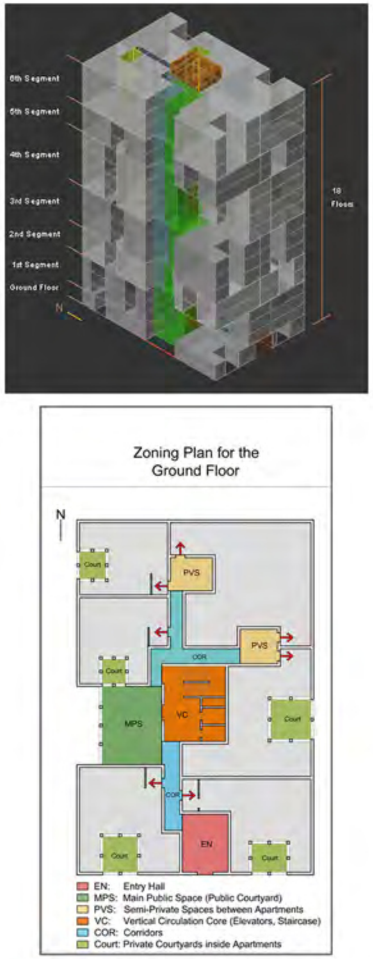


A screenshot showing part of the components for carrying out stages (9 and 10) for generating apartments

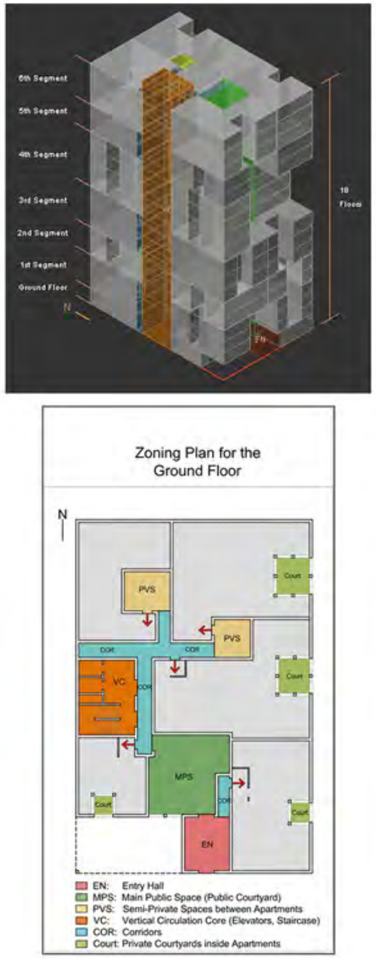
Appendix (5-C-1)

Three-Dimensional Views for All Cases generated by the Researcher

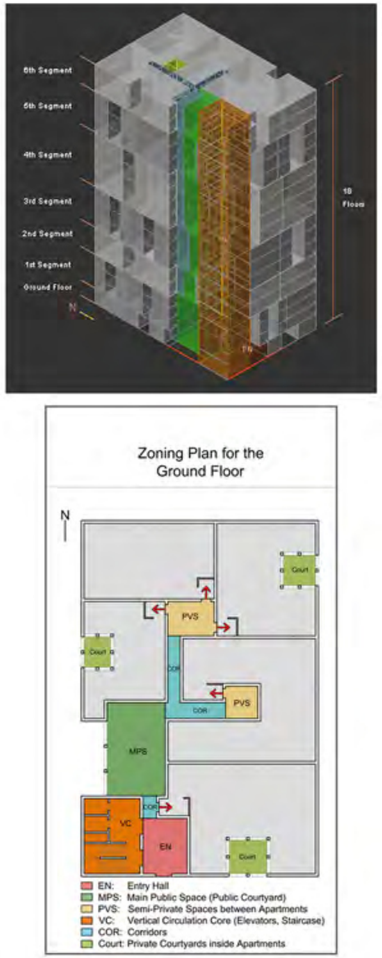
Case #1



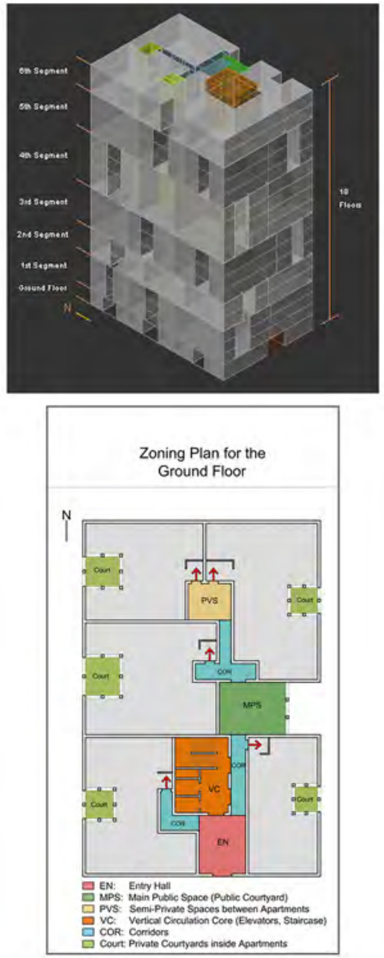
Case #2



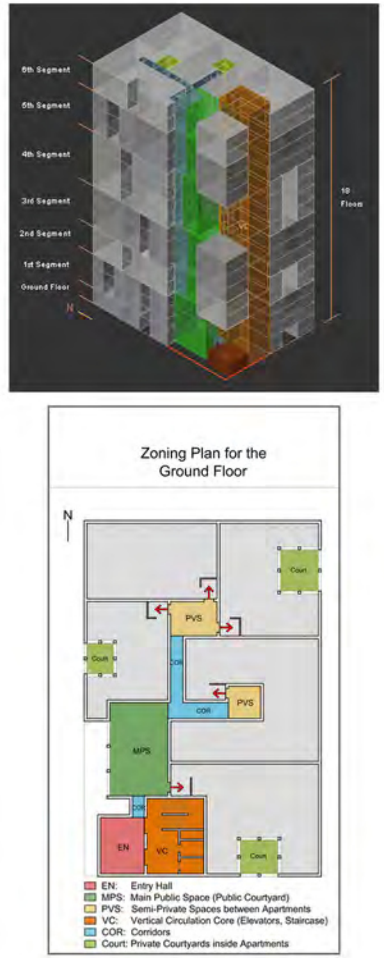
Case #3



Case #4



Case #5

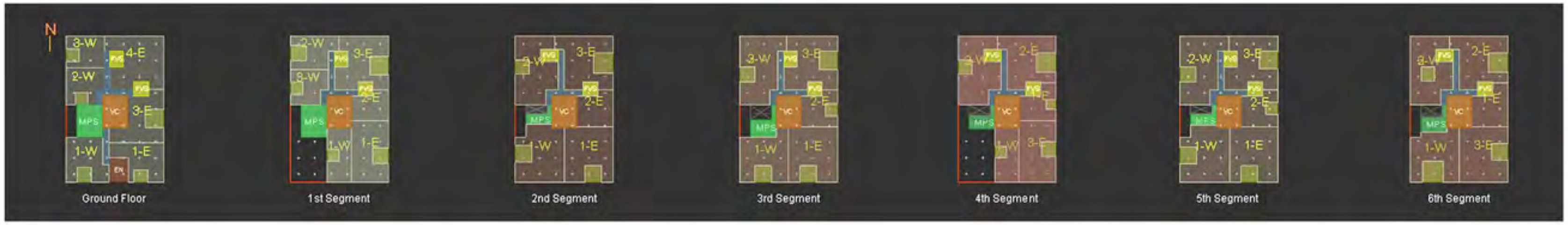


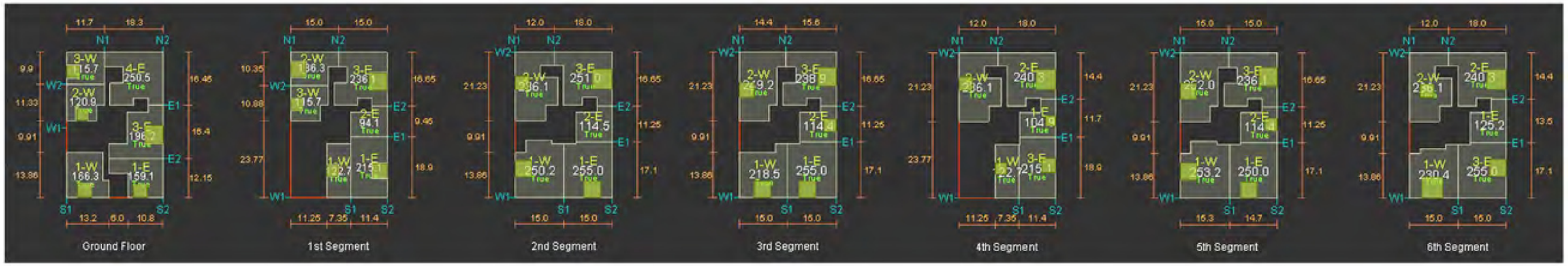
<u>Appendix (5-C-2)</u>

A Detailed Spatial Analysis for All Cases generated by the Researcher

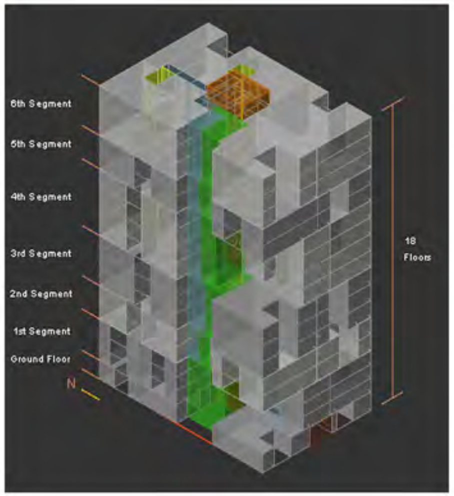
Case No. 1

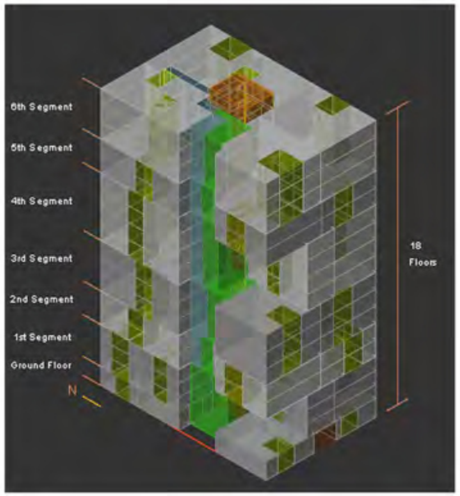
Floors Plans and Three-Dimensional Views

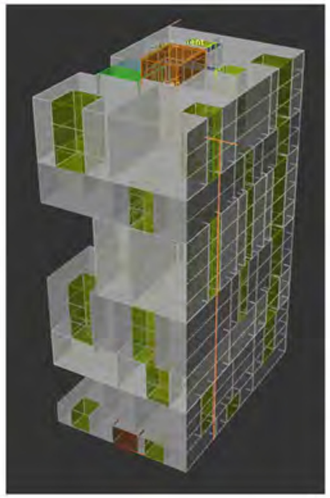




- EN: Entry Hall
- MPS: Main Public Space (Public Courtyard)
- PVS: Semi-Private Spaces between Apartments
- VC: Vertical Circulation Core (Elevators, Staircase)
- COR: Corridors
- Court: Private Courtyards inside Apartments





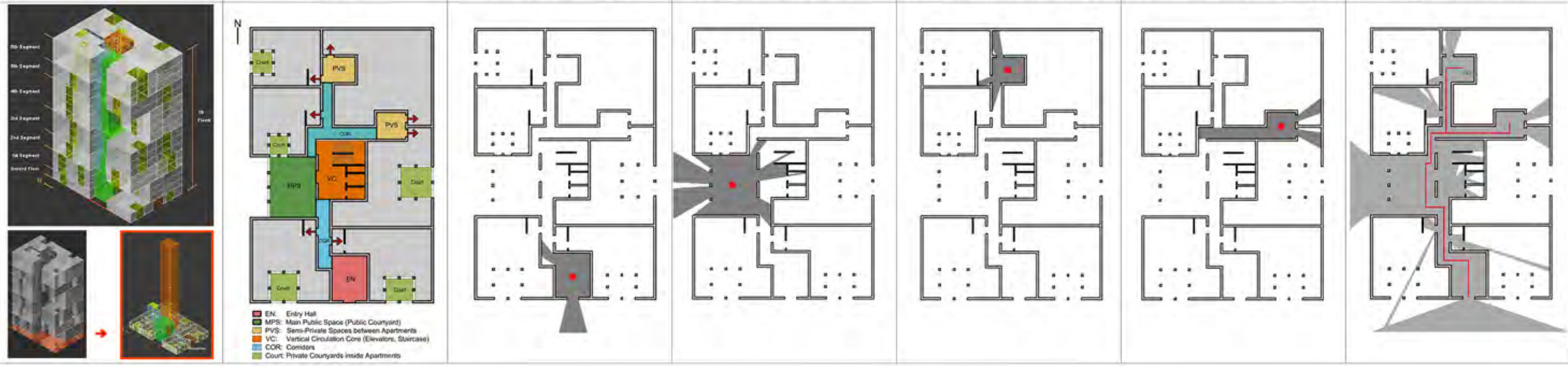


Case No. (1): Ground Floor

Visibility Study for the Ground Floor

(Carried out by Author using 'Syntax2D 1.3.0.7 Software')

Three-Dimensional Views	Zoning Plan for the Ground Floor	Visual Fields from the Center of the Main Entry Hall	Visual Fields from the Center of the Main Public Space	Visual Fields from the Center of the Semi-private Space [1]	Visual Fields from the Center of the Semi-private Space [2]	Visual Fields along the Circulation Path for Residents

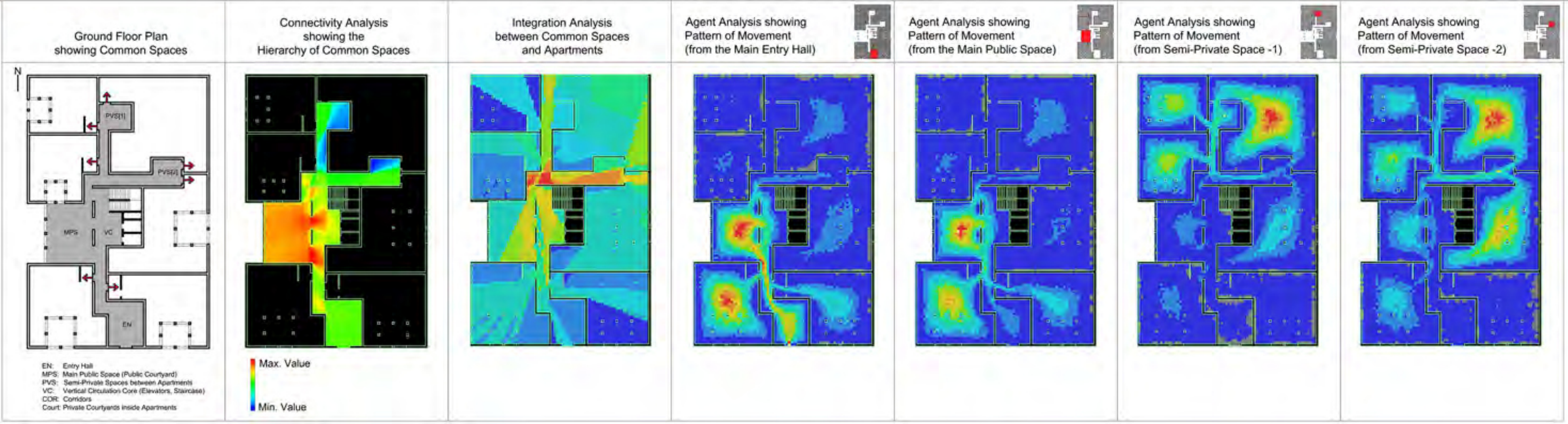


Case No. (1): Ground Floor

Syntactic Analysis (using Visibility Graph Analysis - VGA) for the Ground Floor

(Carried out by Author using 'DepthMapX 0.50 Software')

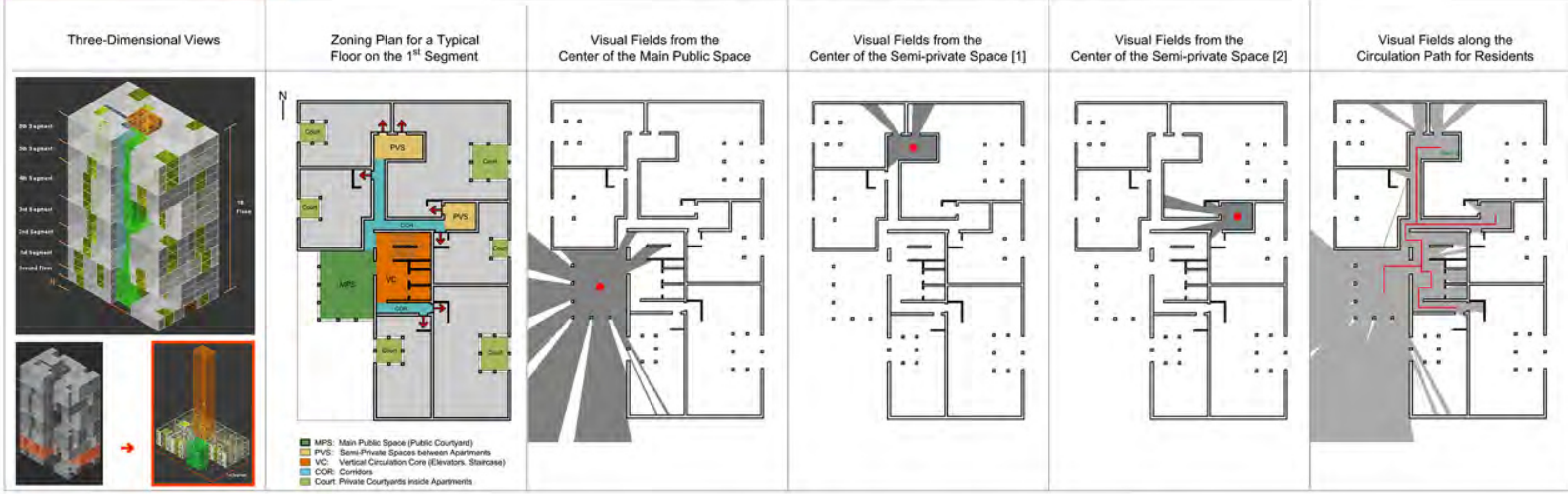
Ground Floor Plan showing Common Spaces	Connectivity Analysis showing the Hierarchy of Common Spaces	Integration Analysis between Common Spaces and Apartments	Agent Analysis showing Pattern of Movement (from the Main Entry Hall)	Agent Analysis showing Pattern of Movement (from the Main Public Space)	Agent Analysis showing Pattern of Movement (from Semi-Private Space -1)	Agent Analysis showing Pattern of Movement (from Semi-Private Space -2)



Case No. (1): 1st Segment

Visibility Study for a Typical Floor located on the 1st Segment

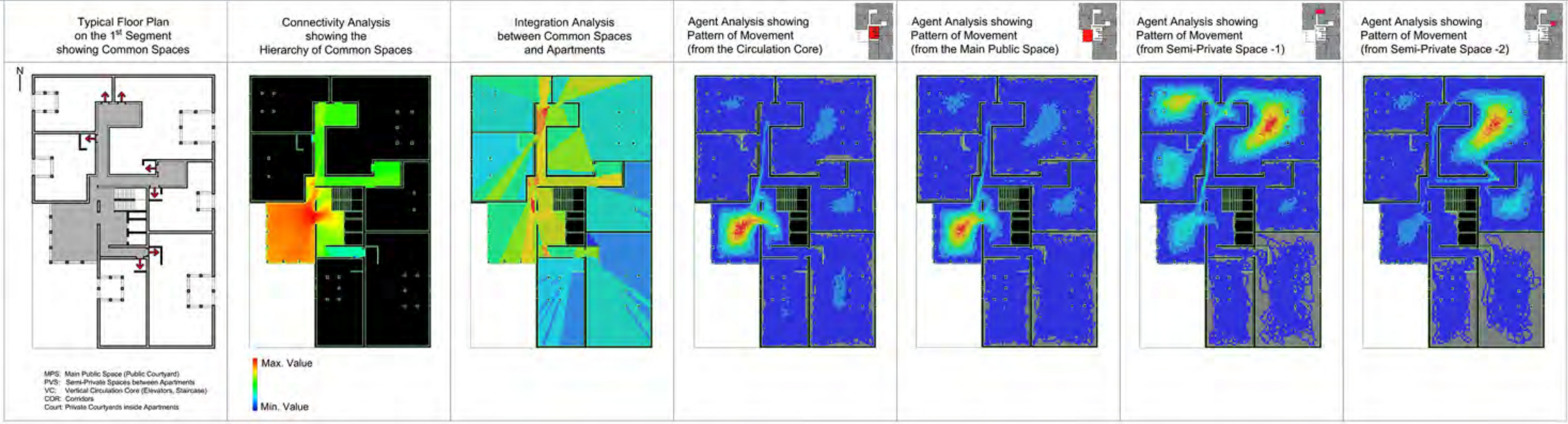
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



Case No. (1): 1st Segment

Syntactic Analysis (using Visibility Graph Analysis - VGA) for a Typical Floor located on the 1st Segment

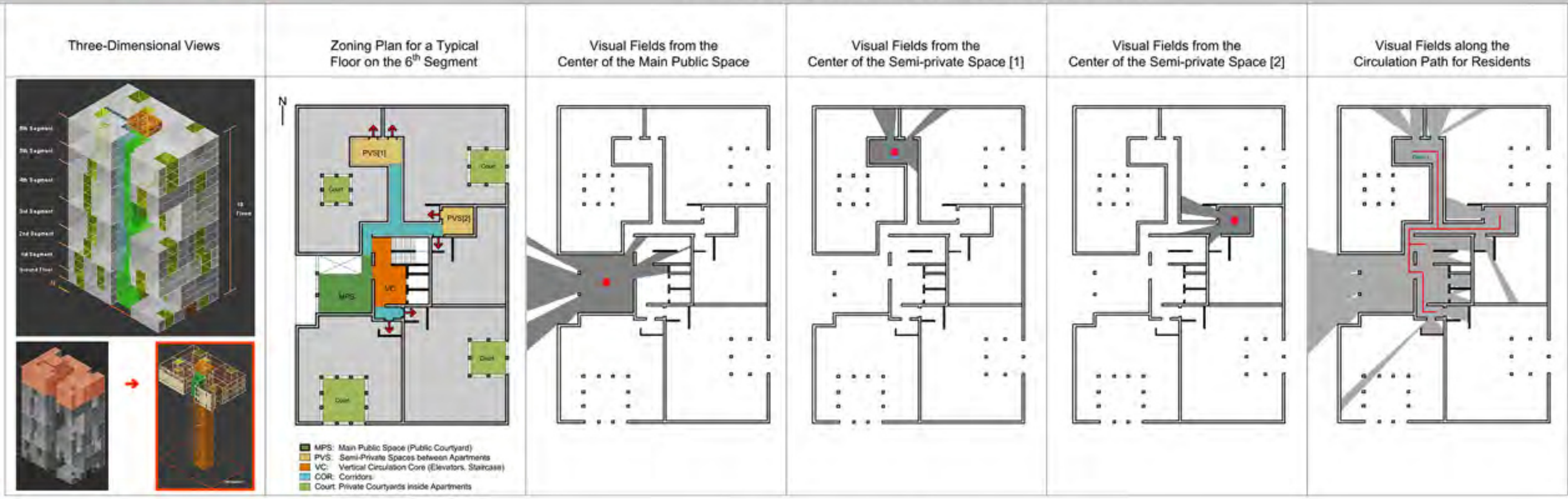
(Carried out by Author using 'DepthMapX 0.50 Software')



Case No. (1): 6th Segment

Visibility Study for a Typical Floor located on the 6th Segment

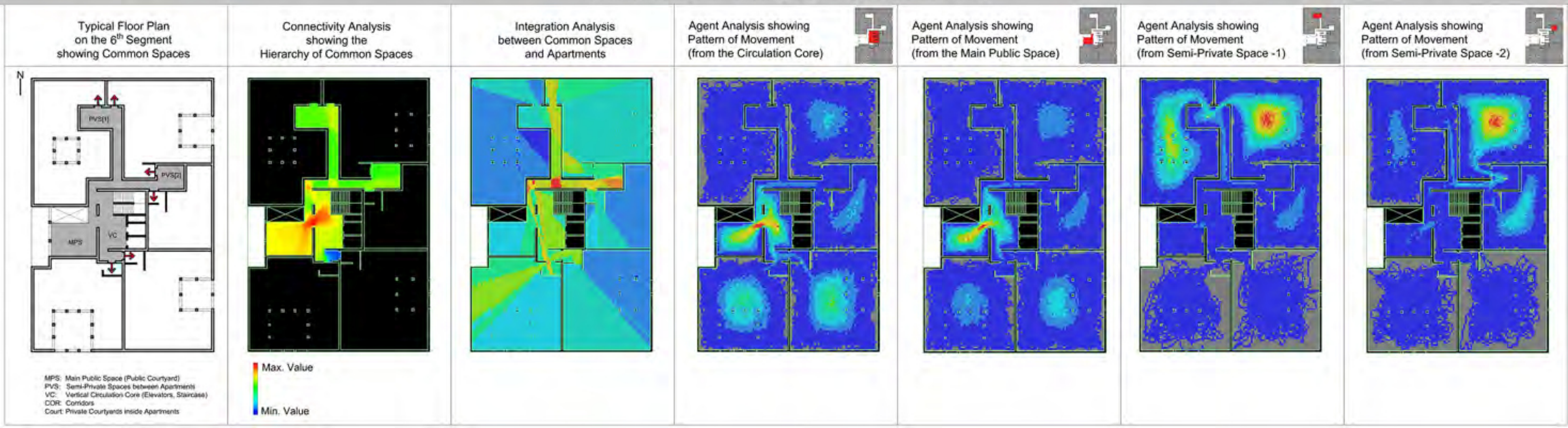
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



Case No. (1): 6th Segment

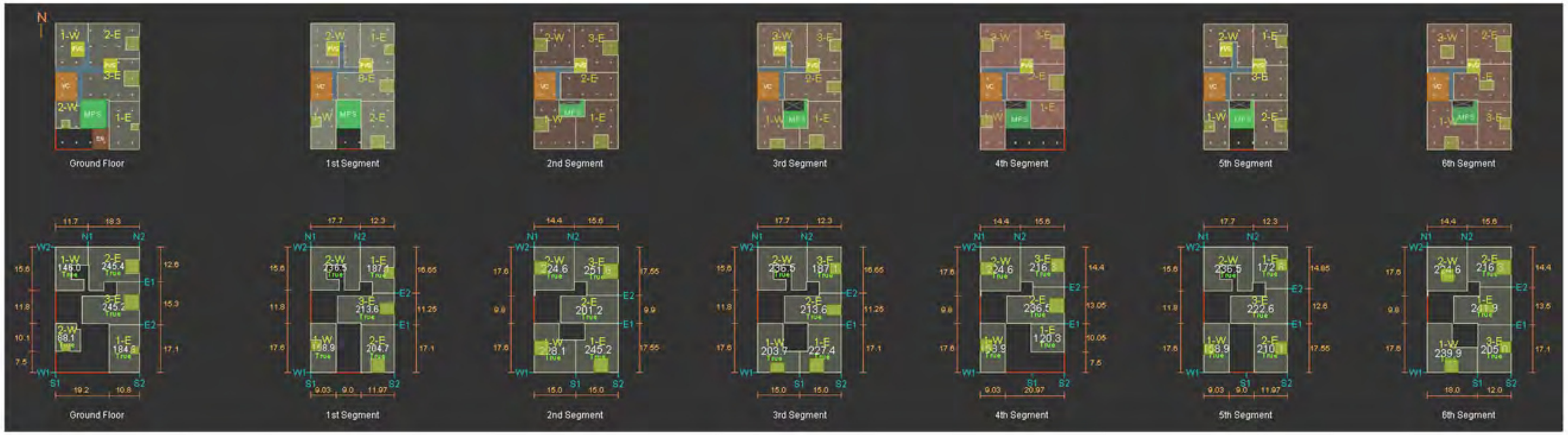
Syntactic Analysis (using Visibility Graph Analysis - VGA) for a Typical Floor located on the 6th Segment

(Carried out by Author using 'DepthMapX 0.50 Software')

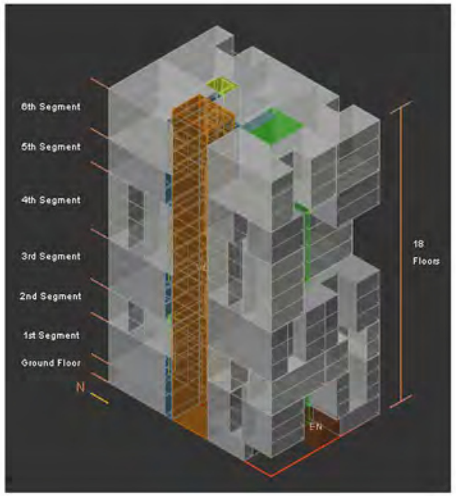


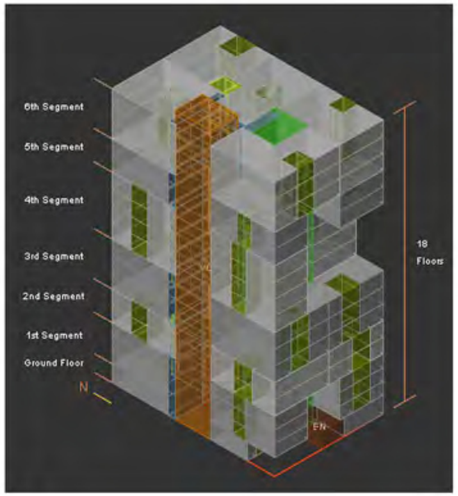
Case No. 2

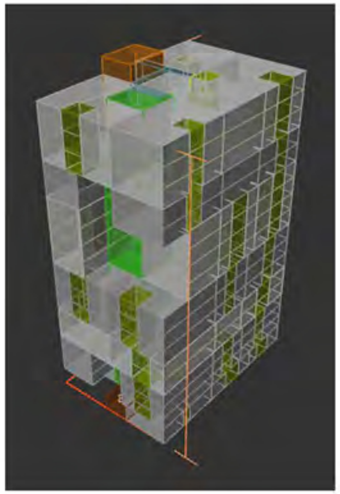
Floors Plans and Three-Dimensional Views



- 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





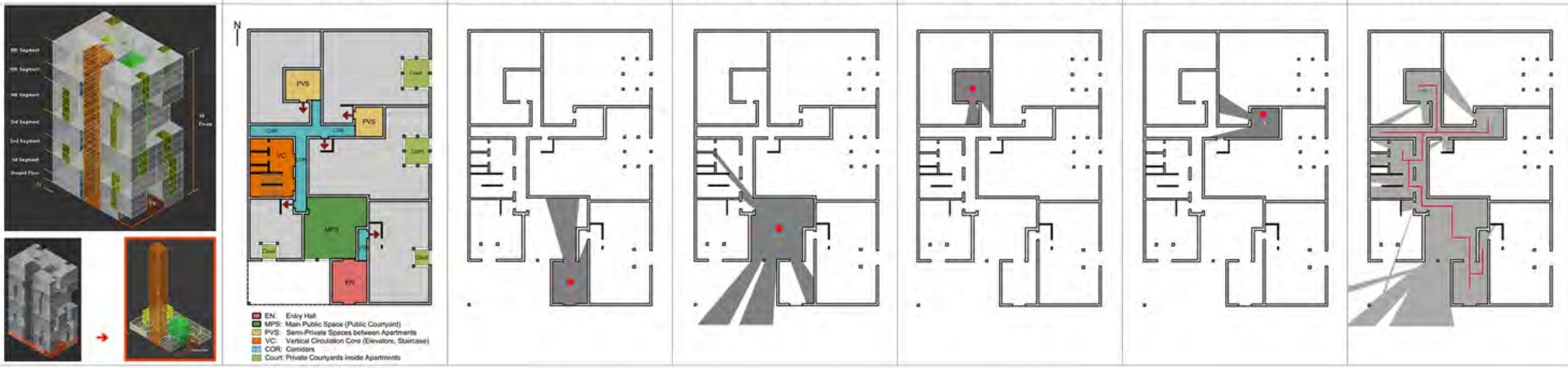


Case No. (2): Ground Floor

Visibility Study for the Ground Floor

(Carried out by Author using 'Syntax2D 1.3.0.7 Software')

Three-Dimensional Views	Zoning Plan for the Ground Floor	Visual Fields from the Center of the Main Entry Hall	Visual Fields from the Center of the Main Public Space	Visual Fields from the Center of the Semi-private Space [1]	Visual Fields from the Center of the Semi-private Space [2]	Visual Fields along the Circulation Path for Residents

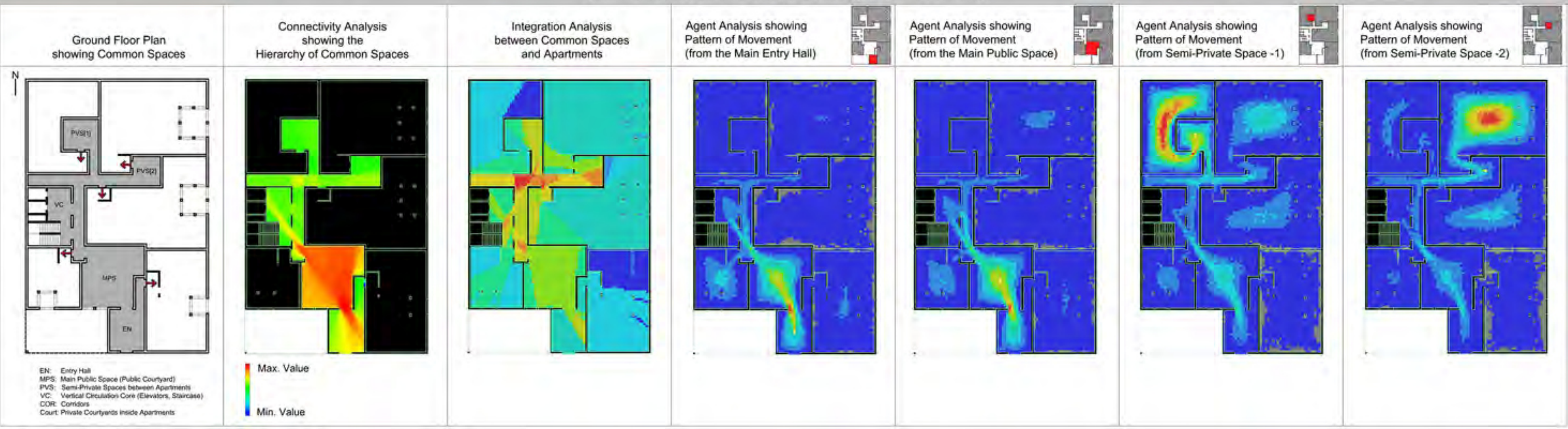


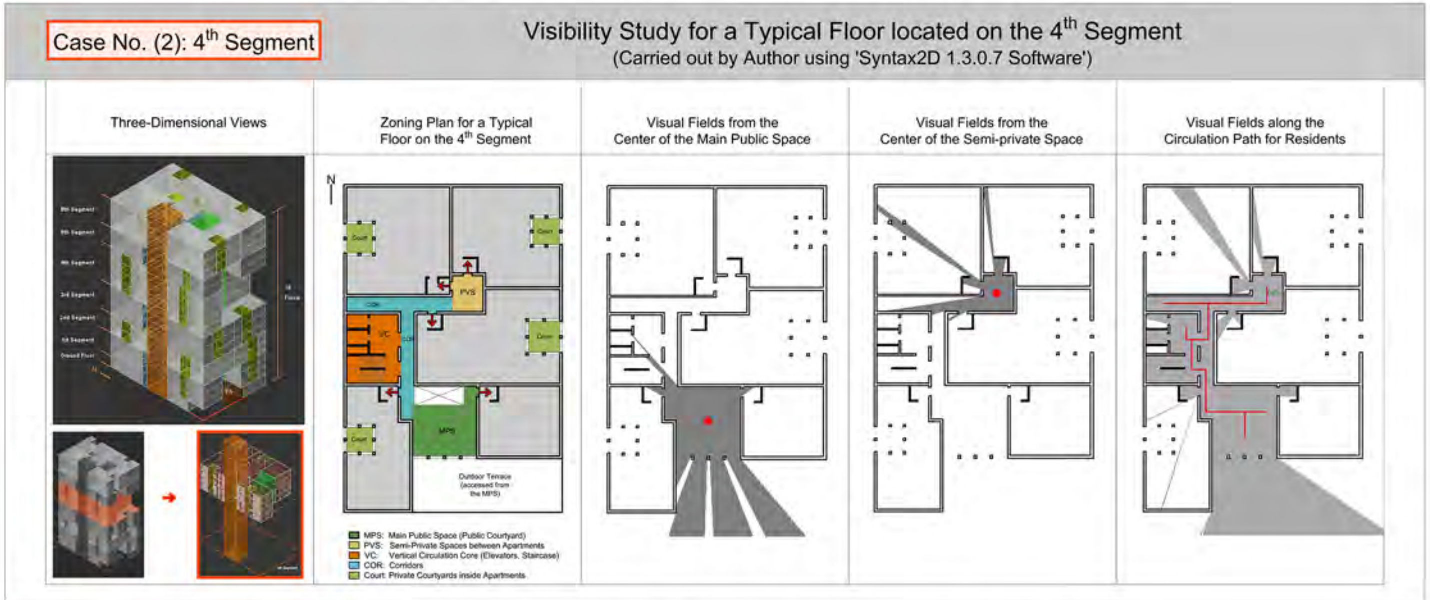
Case No. (2): Ground Floor

Syntactic Analysis (using Visibility Graph Analysis - VGA) for the Ground Floor

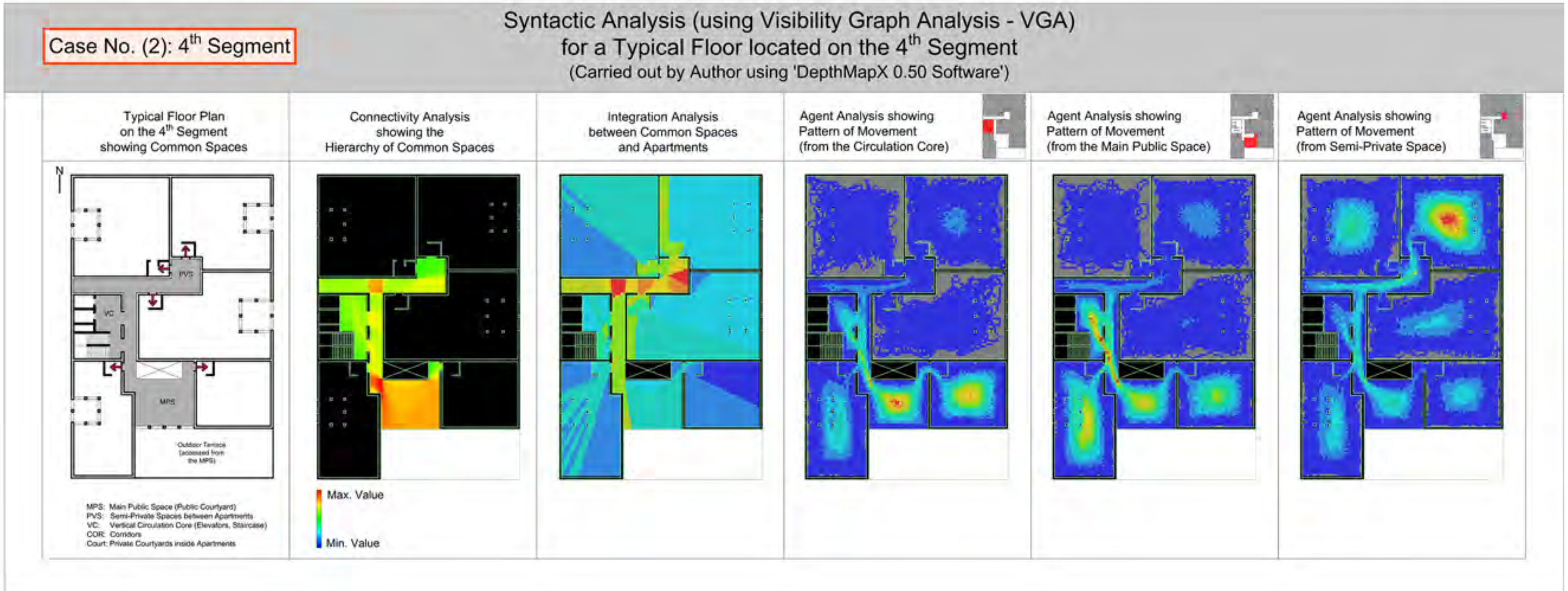
(Carried out by Author using 'DepthMapX 0.50 Software')

Ground Floor Plan showing Common Spaces	Connectivity Analysis showing the Hierarchy of Common Spaces	Integration Analysis between Common Spaces and Apartments	Agent Analysis showing Pattern of Movement (from the Main Entry Hall)	Agent Analysis showing Pattern of Movement (from the Main Public Space)	Agent Analysis showing Pattern of Movement (from Semi-Private Space -1)	Agent Analysis showing Pattern of Movement (from Semi-Private Space -2)

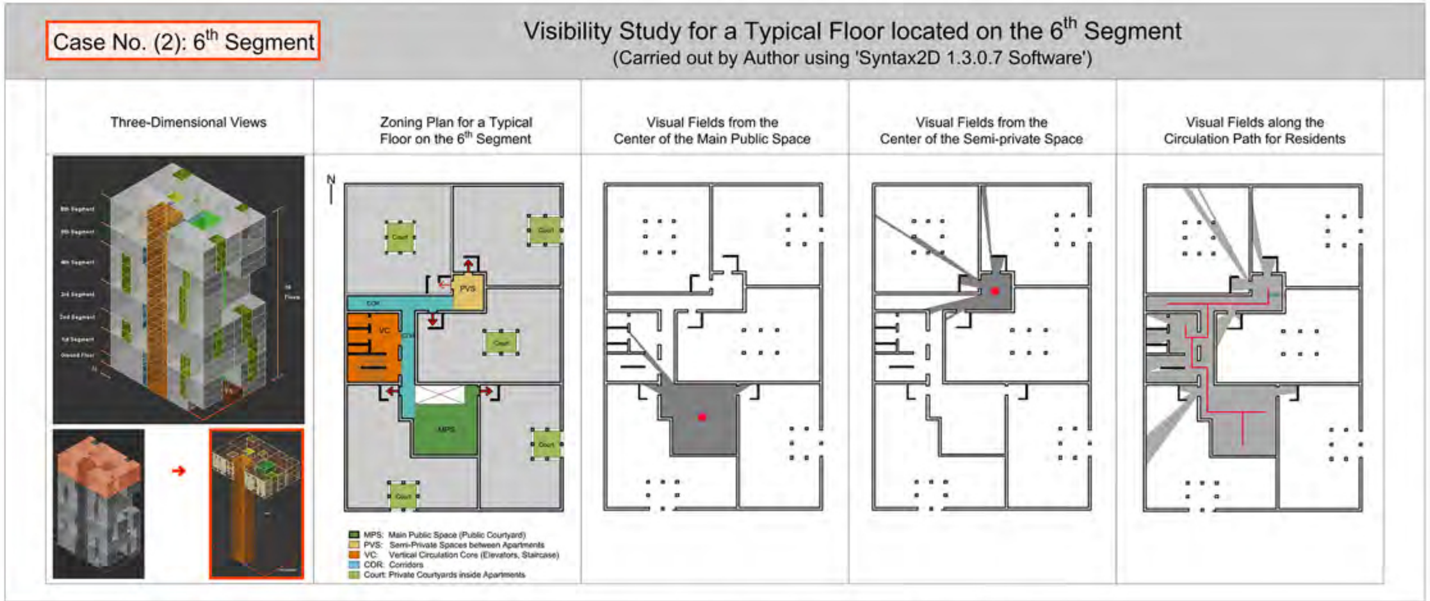




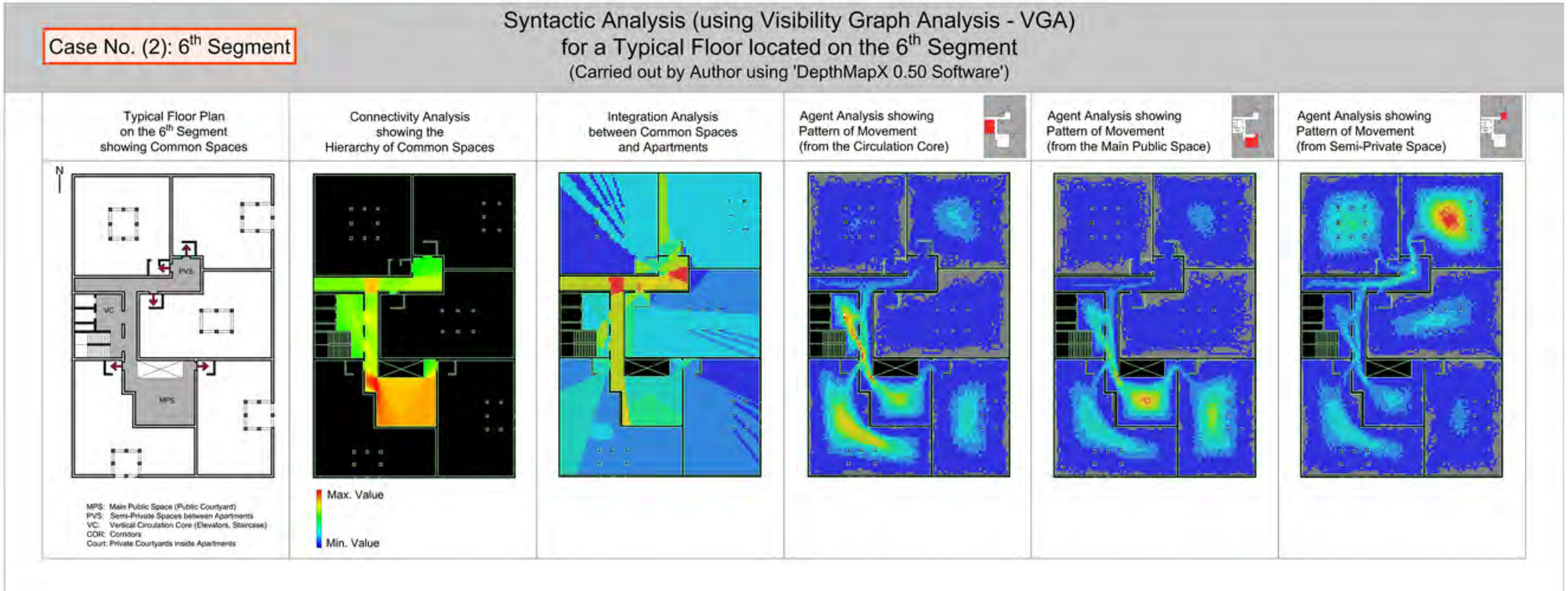
Case No. (2): 4th Segment
Visibility Study for a Typical Floor located on the 4th Segment
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')
Three-Dimensional Views
Zoning Plan for a Typical Floor on the 4th Segment
Visual Fields from the Center of the Main Public Space
Visual Fields from the Center of the Semi-private Space
Visual Fields along the Circulation Path for Residents
N
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. (2): 4th Segment
Syntactic Analysis (using Visibility Graph Analysis - VGA)
for a Typical Floor located on the 4th Segment
(Carried out by Author using 'DepthMapX 0.50 Software')
Typical Floor Plan on the 4th Segment showing Common Spaces
Connectivity Analysis showing the Hierarchy of Common Spaces
Integration Analysis between Common Spaces and Apartments
Agent Analysis showing Pattern of Movement (from the Circulation Core)
Agent Analysis showing Pattern of Movement (from the Main Public Space)
Agent Analysis showing Pattern of Movement (from Semi-Private Space)
N
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
Max. Value
Min. Value



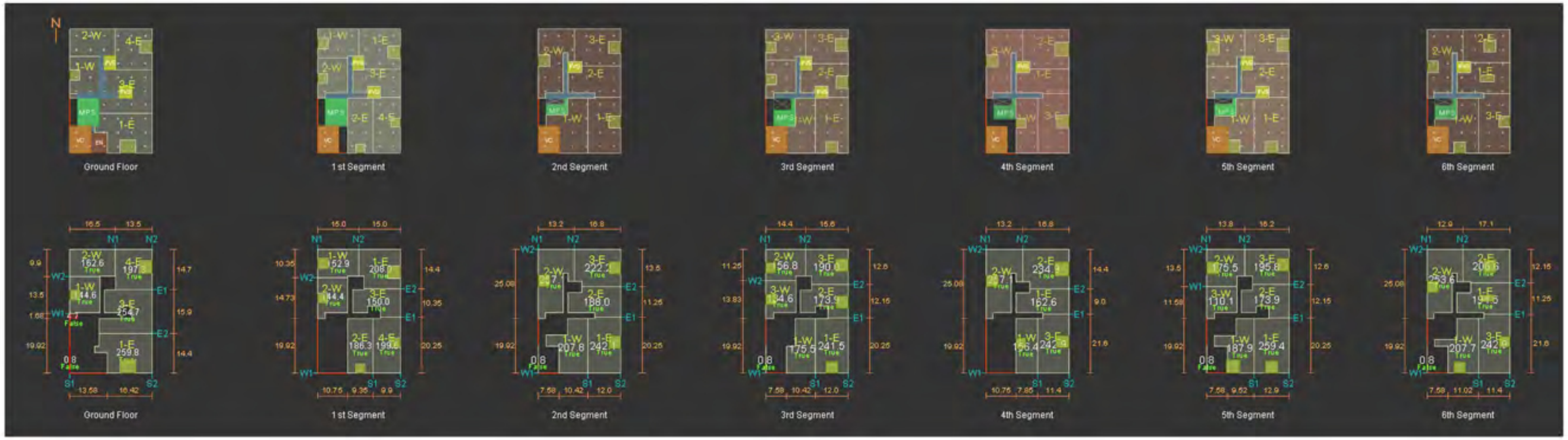
Case No. (2): 6th Segment
Visibility Study for a Typical Floor located on the 6th Segment
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')
Three-Dimensional Views
Zoning Plan for a Typical Floor on the 6th Segment
Visual Fields from the Center of the Main Public Space
Visual Fields from the Center of the Semi-private Space
Visual Fields along the Circulation Path for Residents
N
PVS
VC
COR
MPS
Court
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



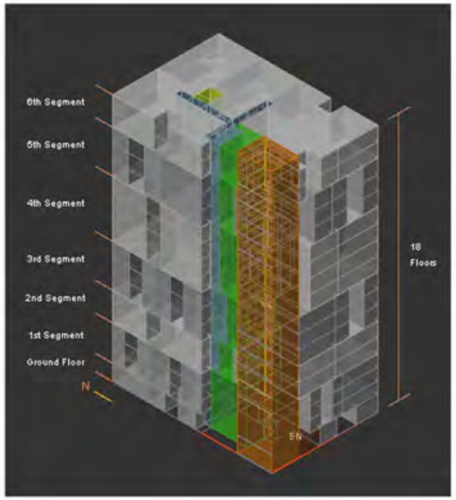
Case No. (2): 6th Segment
Syntactic Analysis (using Visibility Graph Analysis - VGA)
for a Typical Floor located on the 6th Segment
(Carried out by Author using 'DepthMapX 0.50 Software')
Typical Floor Plan on the 6th Segment showing Common Spaces
Connectivity Analysis showing the Hierarchy of Common Spaces
Integration Analysis between Common Spaces and Apartments
Agent Analysis showing Pattern of Movement (from the Circulation Core)
Agent Analysis showing Pattern of Movement (from the Main Public Space)
Agent Analysis showing Pattern of Movement (from Semi-Private Space)
N
PVS
VC
MPS
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
Max. Value
Min. Value

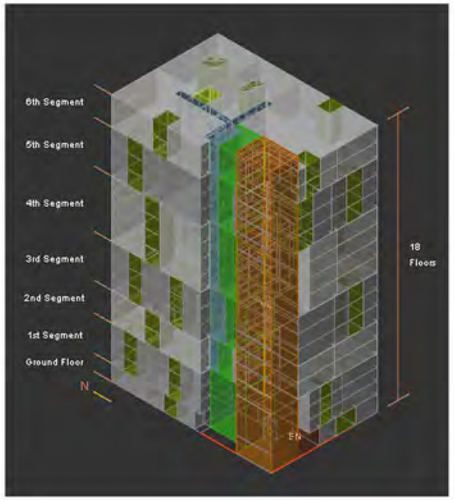
Case No. 3

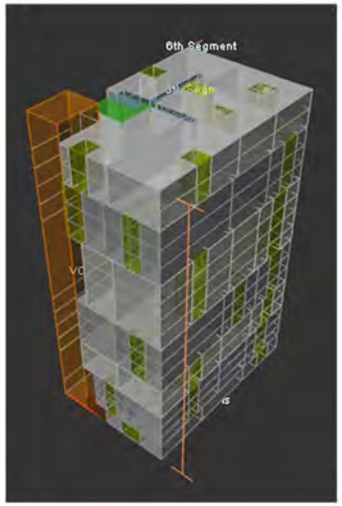
Floors Plans and Three-Dimensional Views



- 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





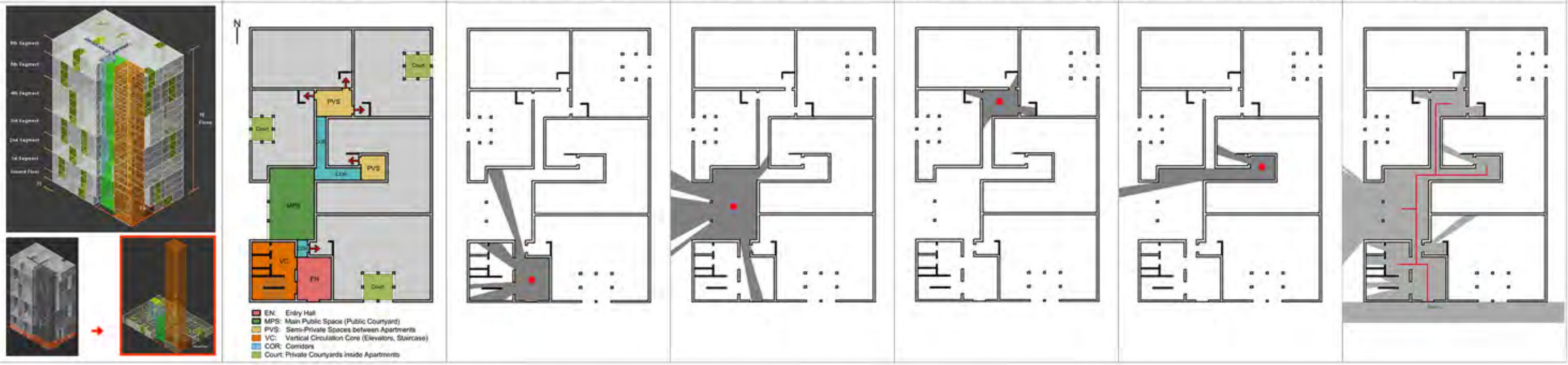


Case No. (3): Ground Floor

Visibility Study for the Ground Floor

(Carried out by Author using 'Syntax2D 1.3.0.7 Software')

Three-Dimensional Views	Zoning Plan for the Ground Floor	Visual Fields from the Center of the Main Entry Hall	Visual Fields from the Center of the Main Public Space	Visual Fields from the Center of the Semi-private Space [1]	Visual Fields from the Center of the Semi-private Space [2]	Visual Fields along the Circulation Path for Residents

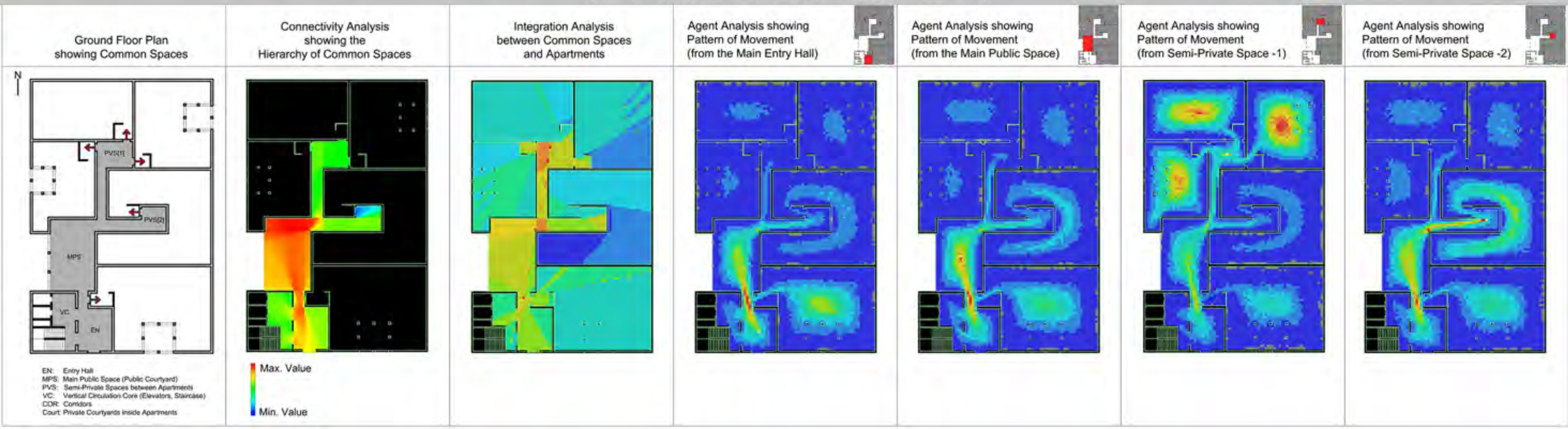


Case No. (3): Ground Floor

Syntactic Analysis (using Visibility Graph Analysis - VGA) for the Ground Floor

(Carried out by Author using 'DepthMapX 0.50 Software')

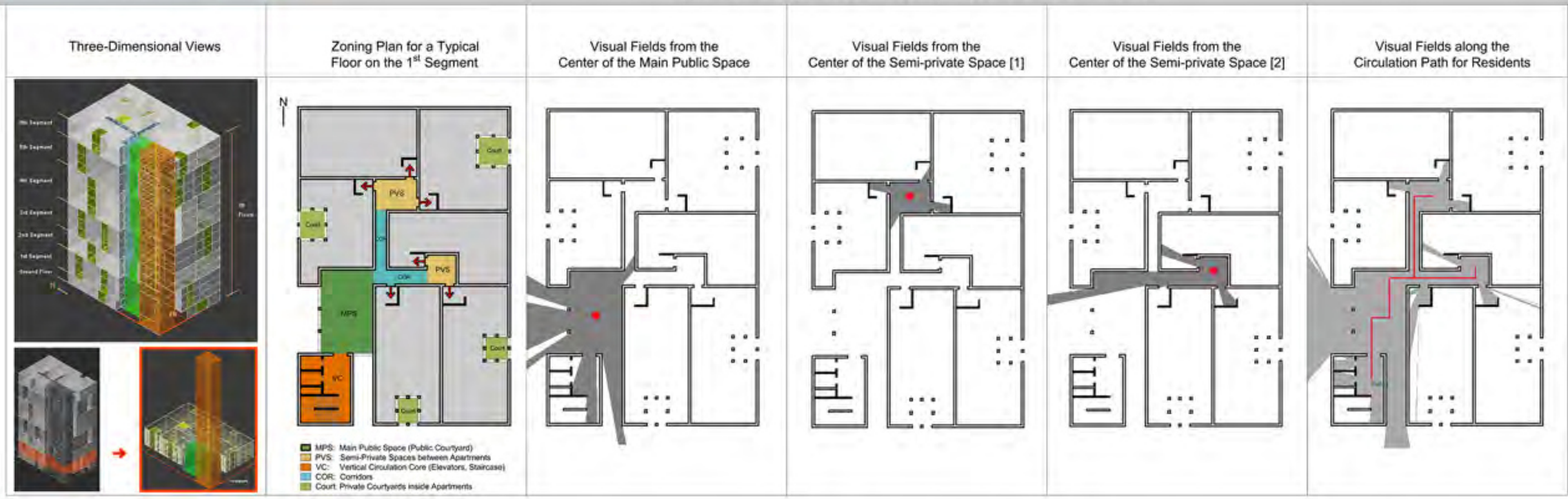
Ground Floor Plan showing Common Spaces	Connectivity Analysis showing the Hierarchy of Common Spaces	Integration Analysis between Common Spaces and Apartments	Agent Analysis showing Pattern of Movement (from the Main Entry Hall)	Agent Analysis showing Pattern of Movement (from the Main Public Space)	Agent Analysis showing Pattern of Movement (from Semi-Private Space -1)	Agent Analysis showing Pattern of Movement (from Semi-Private Space -2)



Case No. (3): 1st Segment

Visibility Study for a Typical Floor located on the 1st Segment

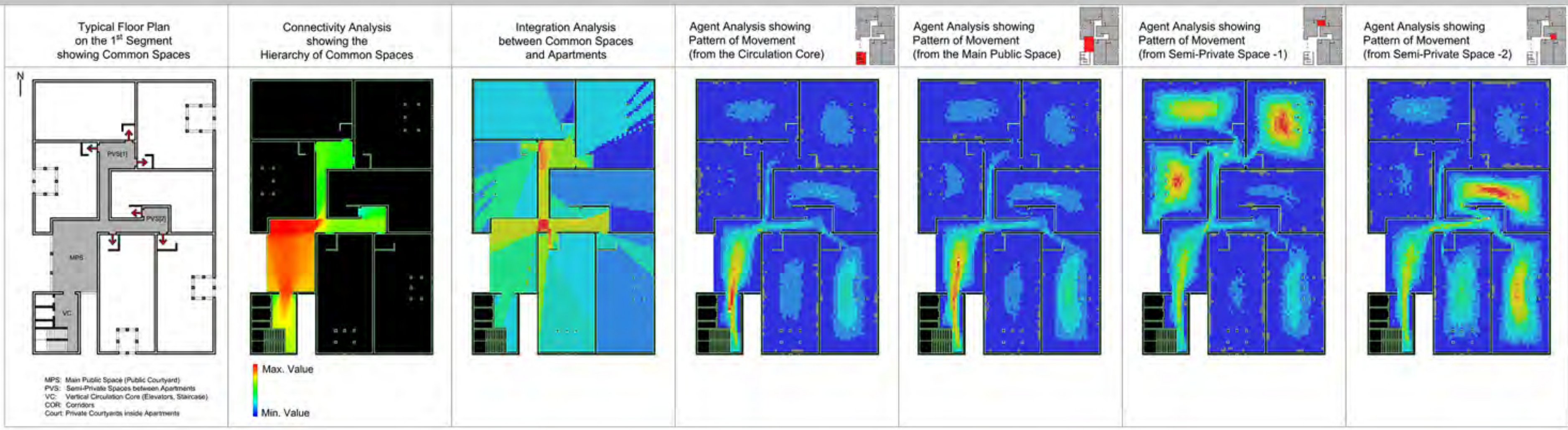
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



Case No. (3): 1st Segment

Syntactic Analysis (using Visibility Graph Analysis - VGA) for a Typical Floor located on the 1st Segment

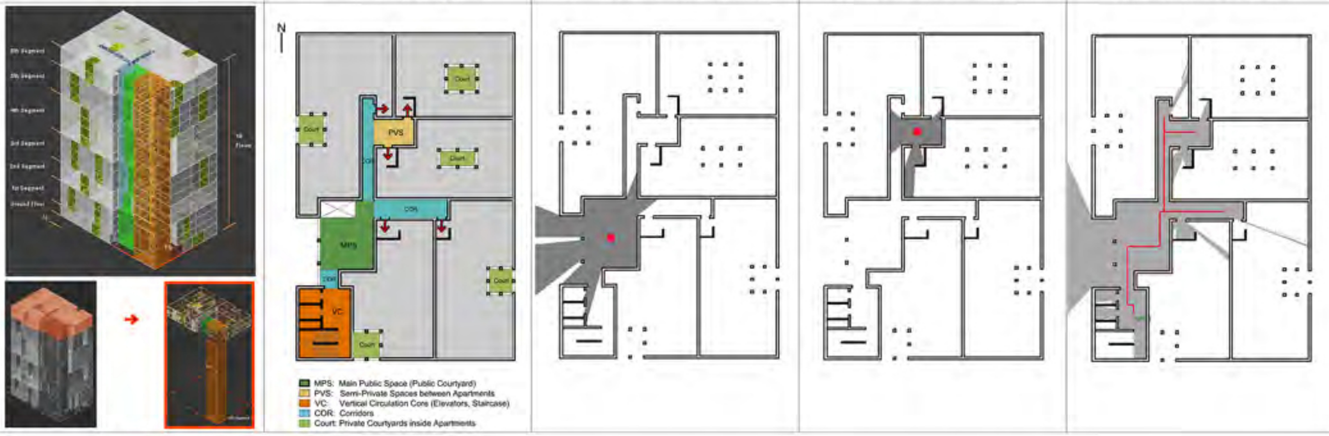
(Carried out by Author using 'DepthMapX 0.50 Software')



Case No. (3): 6th Segment

Visibility Study for a Typical Floor located on the 6th Segment
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')

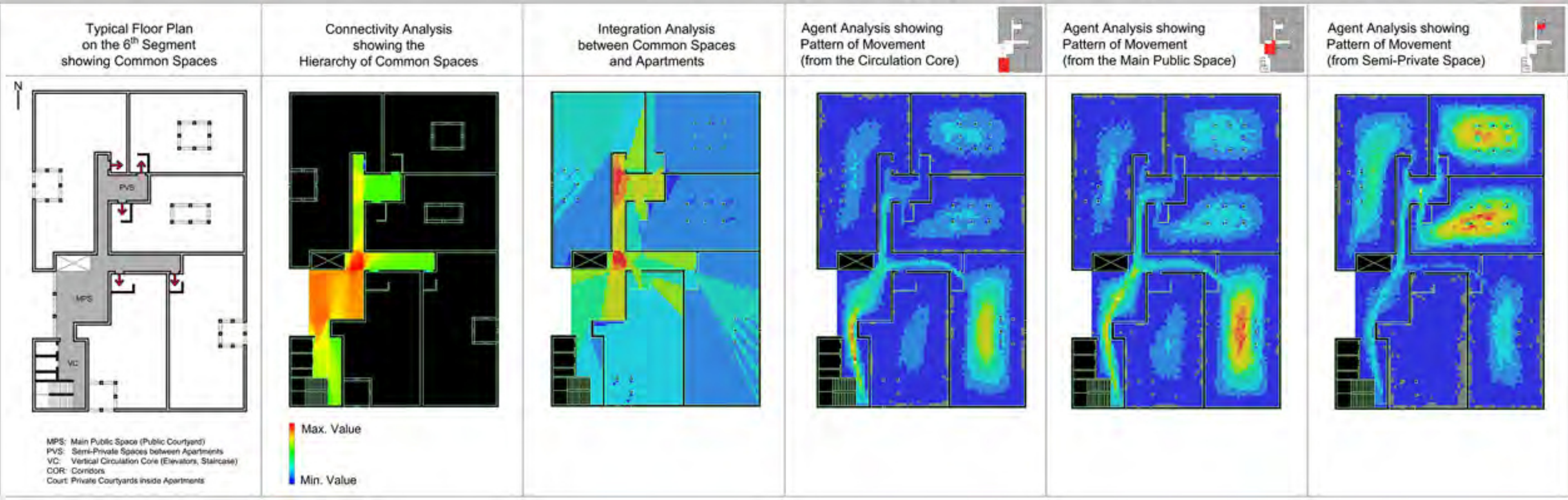
Three-Dimensional Views	Zoning Plan for a Typical Floor on the 6th Segment	Visual Fields from the Center of the Main Public Space	Visual Fields from the Center of the Semi-private Space	Visual Fields along the Circulation Path for Residents



Case No. (3): 6th Segment

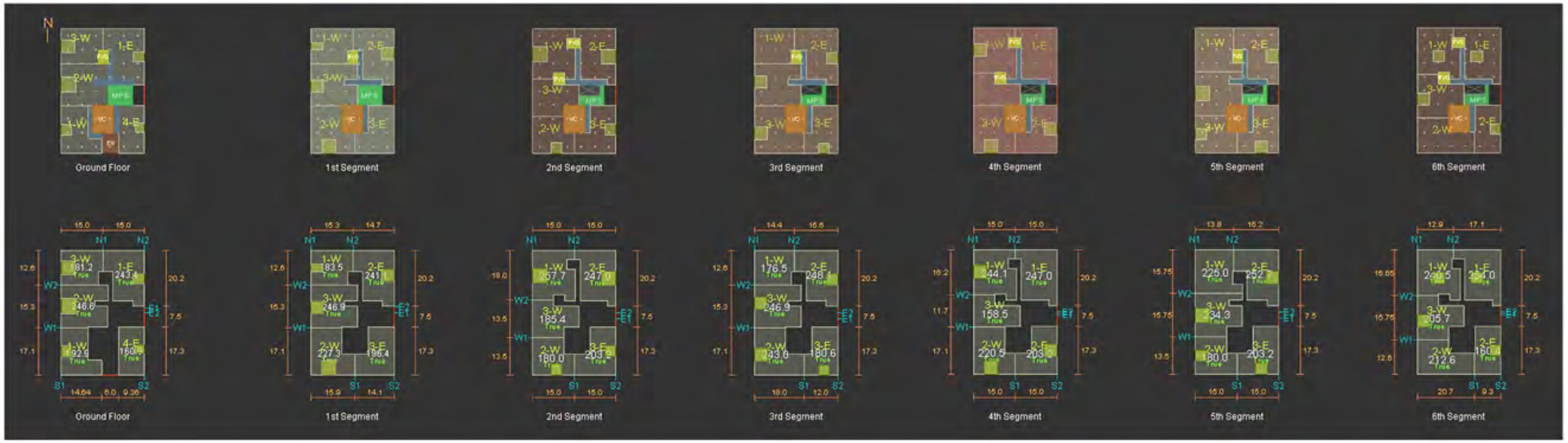
Syntactic Analysis (using Visibility Graph Analysis - VGA) for a Typical Floor located on the 6th Segment
(Carried out by Author using 'DepthMapX 0.50 Software')

Typical Floor Plan on the 6th Segment showing Common Spaces	Connectivity Analysis showing the Hierarchy of Common Spaces	Integration Analysis between Common Spaces and Apartments	Agent Analysis showing Pattern of Movement (from the Circulation Core)	Agent Analysis showing Pattern of Movement (from the Main Public Space)	Agent Analysis showing Pattern of Movement (from Semi-Private Space)

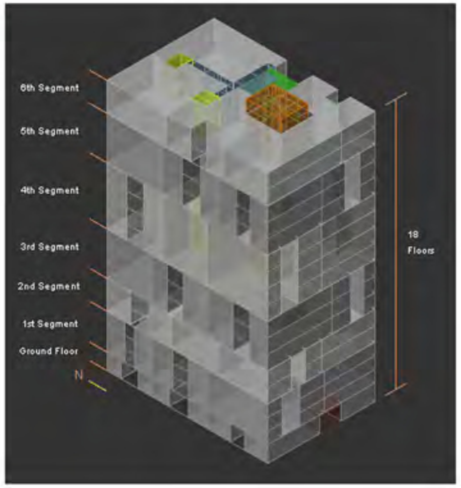


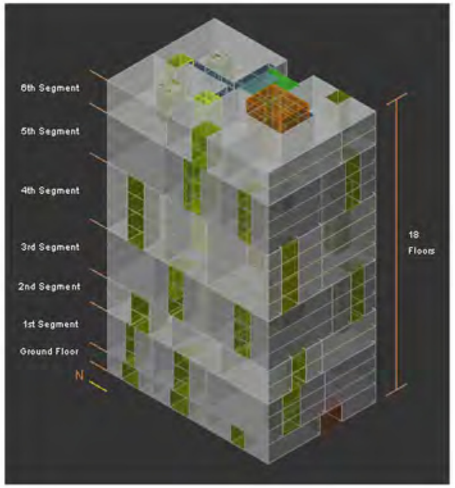
Case No. 4

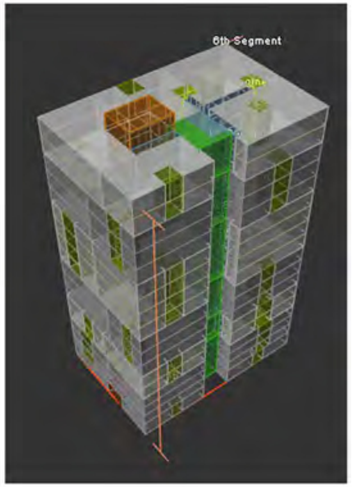
Floors Plans and Three-Dimensional Views



- 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





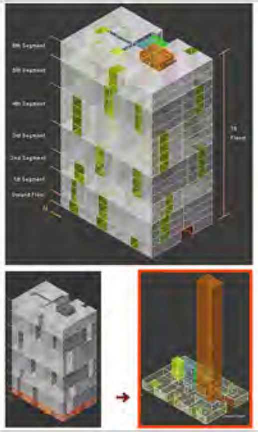


Case No. (4): Ground Floor

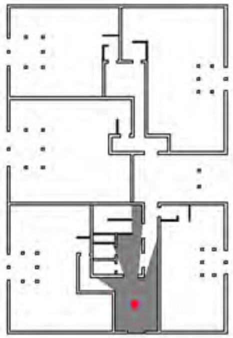
Visibility Study for the Ground Floor

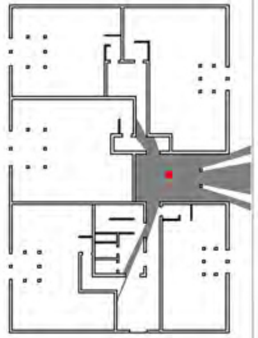
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')

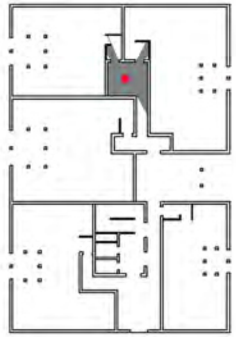
Three-Dimensional Views	Zoning Plan for the Ground Floor	Visual Fields from the Center of the Main Entry Hall	Visual Fields from the Center of the Main Public Space	Visual Fields from the Center of the Semi-private Space	Visual Fields along the Circulation Path for Residents

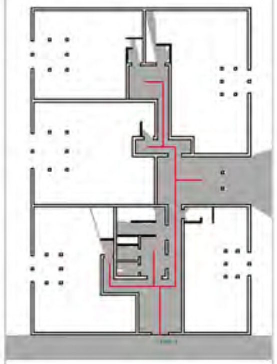


EN: Entry Hall
MPS: Main Public Space (Public Courtyard)
PVS: Semi-Private Spaces between Apartments
VC: Vertical Circulation Core (Elevators, Staircase)
COR: Corridors
Court: Private Courtyards inside Apartments







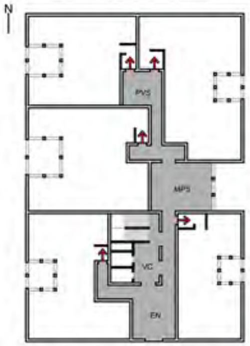


Case No. (4): Ground Floor

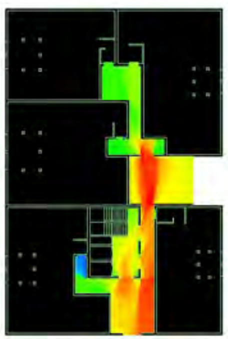
Syntactic Analysis (using Visibility Graph Analysis - VGA) for the Ground Floor

(Carried out by Author using 'DepthMapX 0.50 Software')

Ground Floor Plan showing Common Spaces	Connectivity Analysis showing the Hierarchy of Common Spaces	Integration Analysis between Common Spaces and Apartments	Agent Analysis showing Pattern of Movement (from the Main Entry Hall)	Agent Analysis showing Pattern of Movement (from the Main Public Space)	Agent Analysis showing Pattern of Movement (from Semi-Private Space)

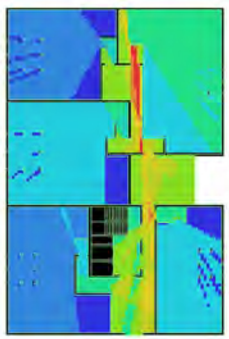


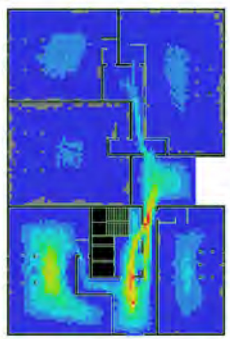
EN: Entry Hall
MPS: Main Public Space (Public Courtyard)
PVS: Semi-Private Spaces between Apartments
VC: Vertical Circulation Core (Elevators, Staircase)
COR: Corridors
Court: Private Courtyards inside Apartments

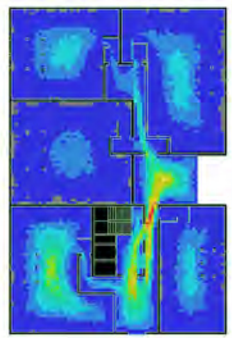


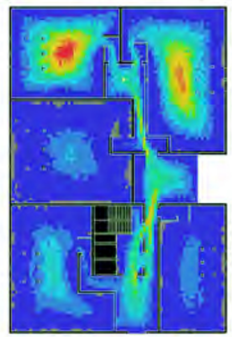
Max. Value

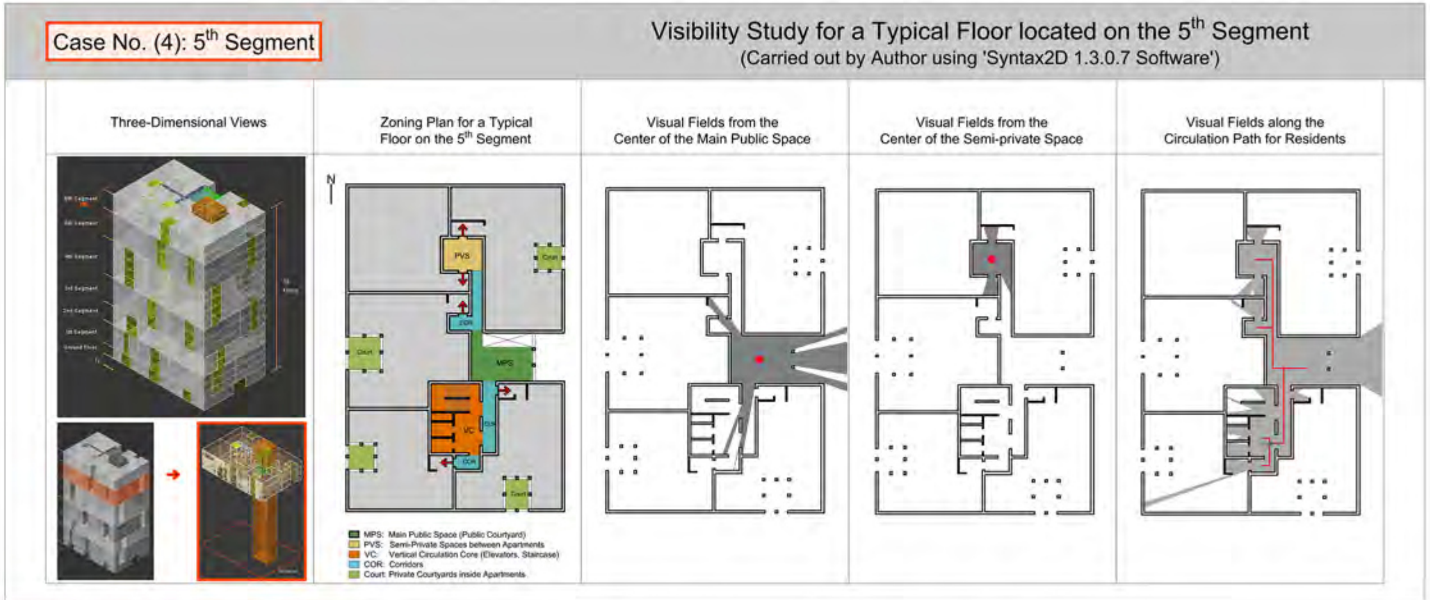
Min. Value



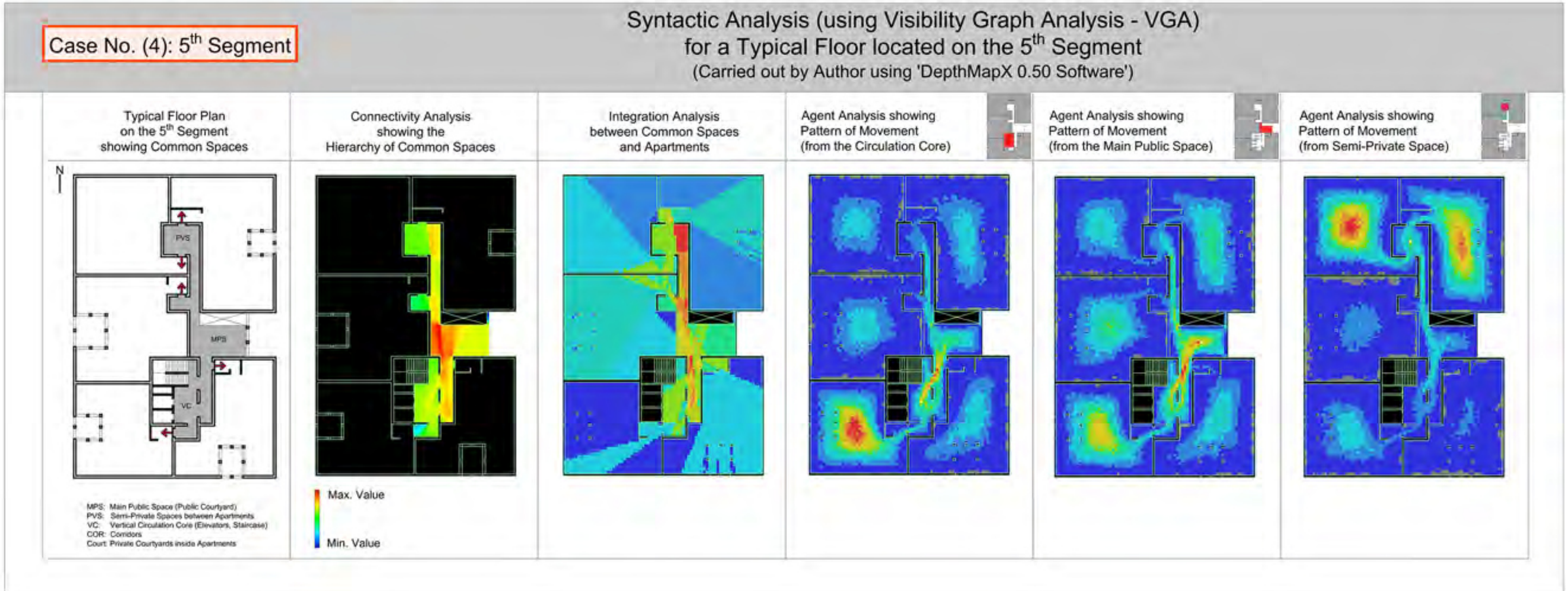




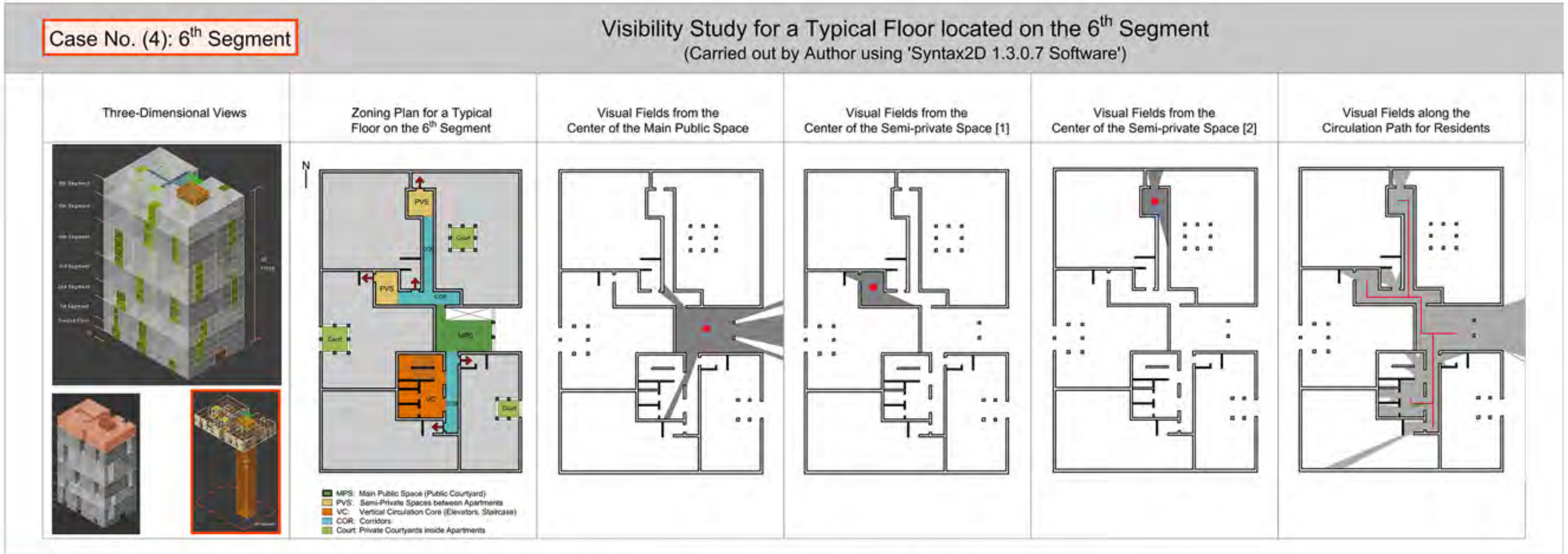




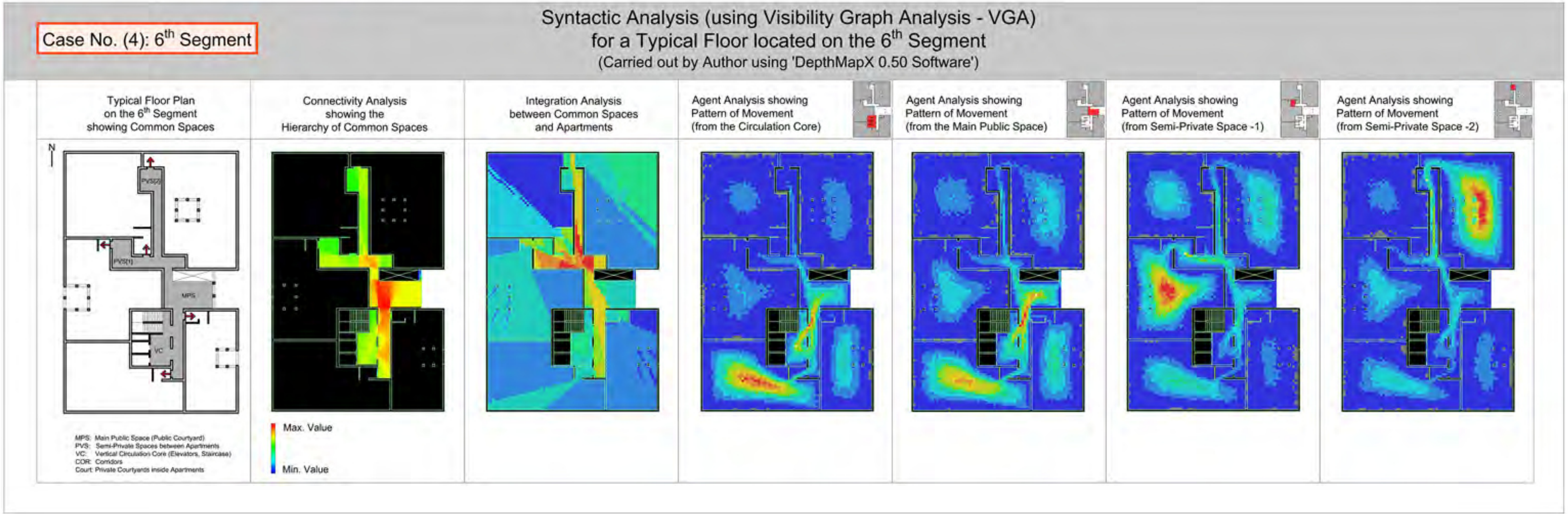
Case No. (4): 5th Segment
Visibility Study for a Typical Floor located on the 5th Segment
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')
Three-Dimensional Views
Zoning Plan for a Typical Floor on the 5th Segment
Visual Fields from the Center of the Main Public Space
Visual Fields from the Center of the Semi-private Space
Visual Fields along the Circulation Path for Residents
N
PVS
COR
MPS
VC
Court
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): 5th Segment
Syntactic Analysis (using Visibility Graph Analysis - VGA)
for a Typical Floor located on the 5th Segment
(Carried out by Author using 'DepthMapX 0.50 Software')
Typical Floor Plan on the 5th Segment showing Common Spaces
Connectivity Analysis showing the Hierarchy of Common Spaces
Integration Analysis between Common Spaces and Apartments
Agent Analysis showing Pattern of Movement (from the Circulation Core)
Agent Analysis showing Pattern of Movement (from the Main Public Space)
Agent Analysis showing Pattern of Movement (from Semi-Private Space)
N
PVS
MPS
VC
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
Max. Value
Min. Value



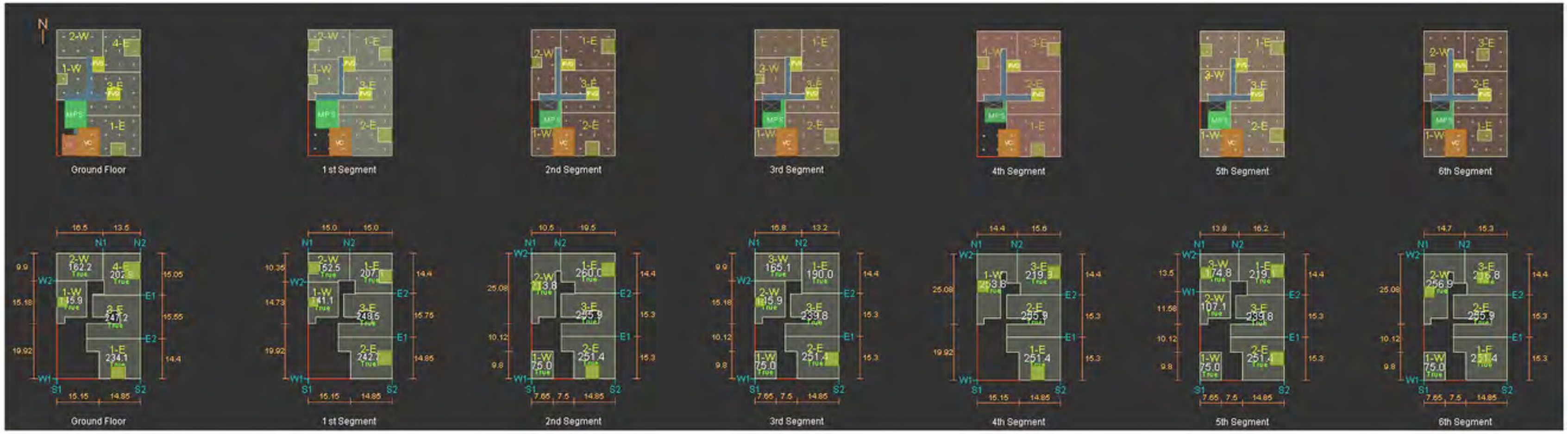
Case No. (4): 6th Segment
Visibility Study for a Typical Floor located on the 6th Segment
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')
Three-Dimensional Views
Zoning Plan for a Typical Floor on the 6th Segment
Visual Fields from the Center of the Main Public Space
Visual Fields from the Center of the Semi-private Space [1]
Visual Fields from the Center of the Semi-private Space [2]
Visual Fields along the Circulation Path for Residents
N
PVS
Court
COR
MPS
VC
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



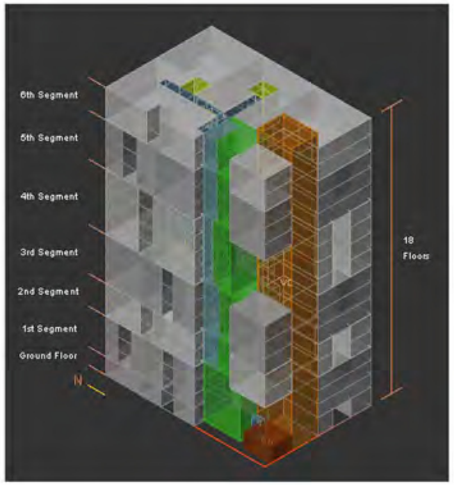
Case No. (4): 6th Segment
Syntactic Analysis (using Visibility Graph Analysis - VGA)
for a Typical Floor located on the 6th Segment
(Carried out by Author using 'DepthMapX 0.50 Software')
Typical Floor Plan on the 6th Segment showing Common Spaces
Connectivity Analysis showing the Hierarchy of Common Spaces
Integration Analysis between Common Spaces and Apartments
Agent Analysis showing Pattern of Movement (from the Circulation Core)
Agent Analysis showing Pattern of Movement (from the Main Public Space)
Agent Analysis showing Pattern of Movement (from Semi-Private Space -1)
Agent Analysis showing Pattern of Movement (from Semi-Private Space -2)
N
PVS(2)
PVS(1)
MPS
VC
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
Max. Value
Min. Value

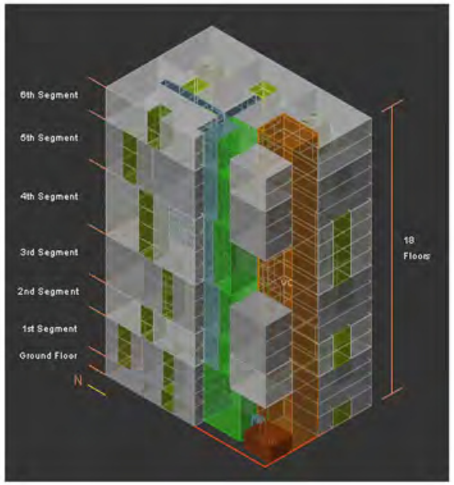
Case No. 5

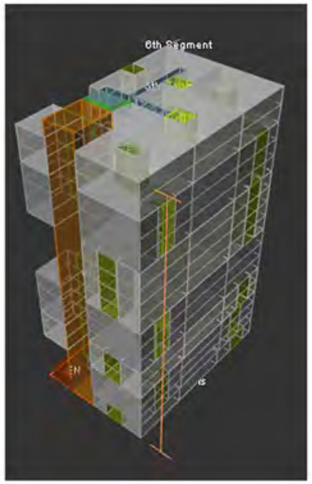
Floors Plans and Three-Dimensional Views

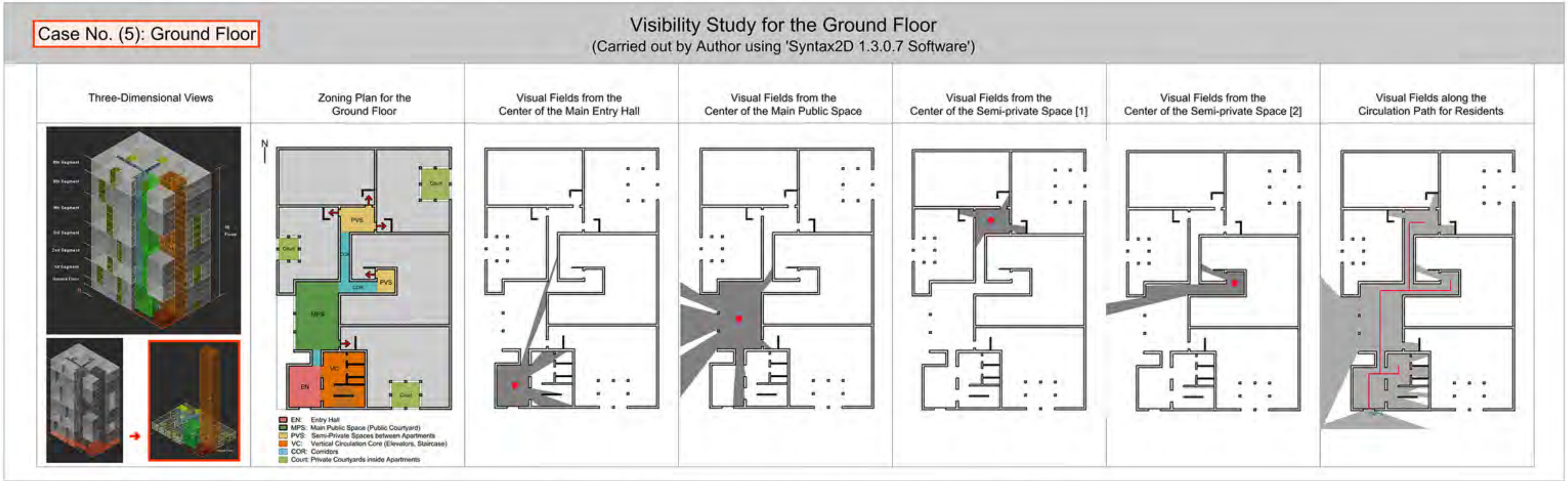


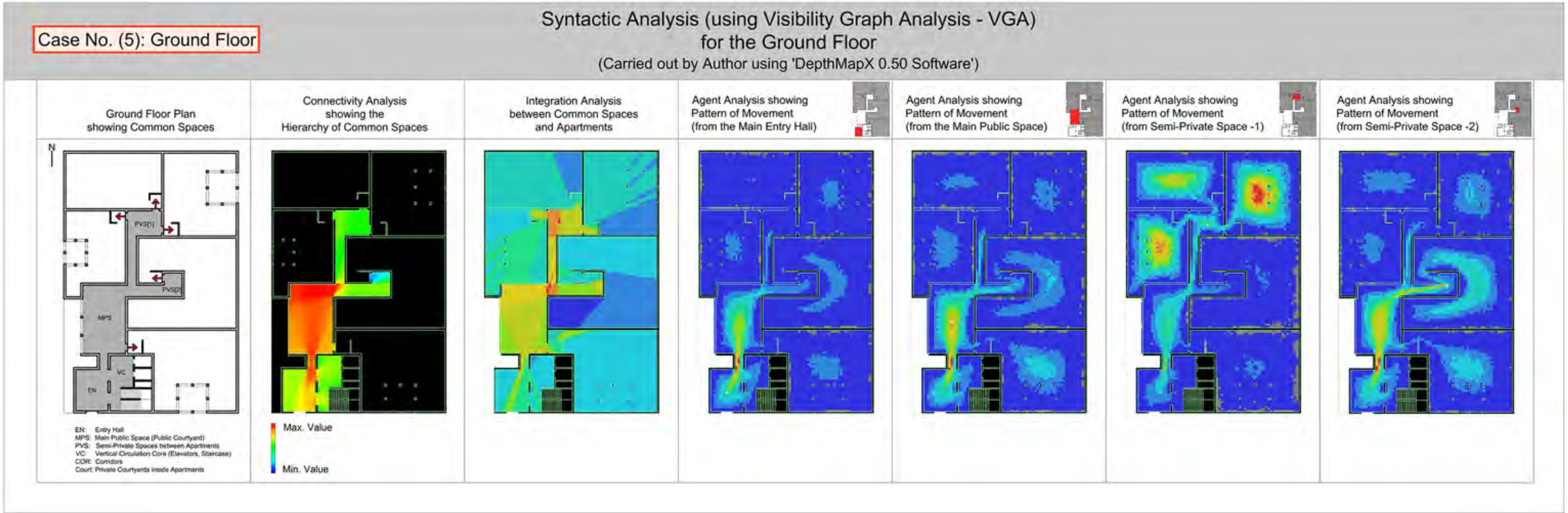
- EN: Entry Hall
- MPS: Main Public Space (Public Courtyard)
- PVS: Semi-Private Spaces between Apartments
- VC: Vertical Circulation Core (Elevators, Staircase)
- COR: Corridors
- Court: Private Courtyards inside Apartments








Case No. (5): Ground Floor
Visibility Study for the Ground Floor
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')
Three-Dimensional Views
Zoning Plan for the Ground Floor
Visual Fields from the Center of the Main Entry Hall
Visual Fields from the Center of the Main Public Space
Visual Fields from the Center of the Semi-private Space [1]
Visual Fields from the Center of the Semi-private Space [2]
Visual Fields along the Circulation Path for Residents
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

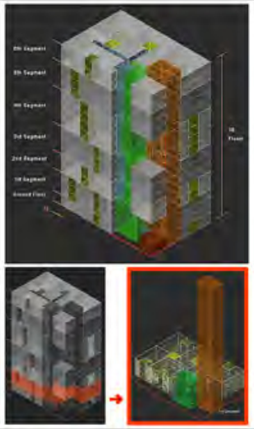

Case No. (5): Ground Floor
Syntactic Analysis (using Visibility Graph Analysis - VGA) for the Ground Floor
(Carried out by Author using 'DepthMapX 0.50 Software')
Ground Floor Plan showing Common Spaces
Connectivity Analysis showing the Hierarchy of Common Spaces
Integration Analysis between Common Spaces and Apartments
Agent Analysis showing Pattern of Movement (from the Main Entry Hall)
Agent Analysis showing Pattern of Movement (from the Main Public Space)
Agent Analysis showing Pattern of Movement (from Semi-Private Space -1)
Agent Analysis showing Pattern of Movement (from Semi-Private Space -2)
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
Max. Value
Min. Value

Case No. (5): 1st Segment

Visibility Study for a Typical Floor located on the 1st Segment

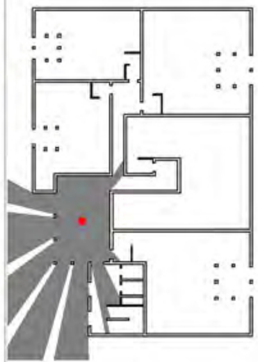
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')

Three-Dimensional Views

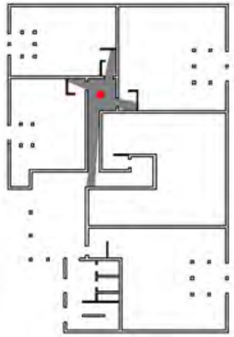


Zoning Plan for a Typical Floor on the 1st Segment

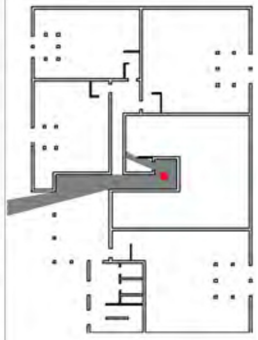
Visual Fields from the Center of the Main Public Space



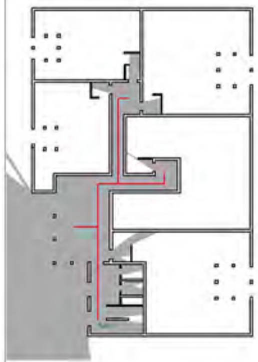
Visual Fields from the Center of the Semi-private Space [1]



Visual Fields from the Center of the Semi-private Space [2]



Visual Fields along the Circulation Path for Residents



Case No. (5): 1st Segment

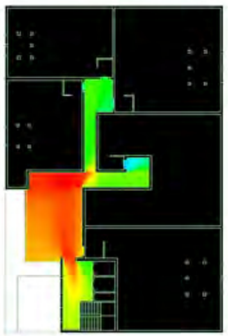
Syntactic Analysis (using Visibility Graph Analysis - VGA) for a Typical Floor located on the 1st Segment

(Carried out by Author using 'DepthMapX 0.50 Software')

Typical Floor Plan on the 1st Segment showing Common Spaces

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

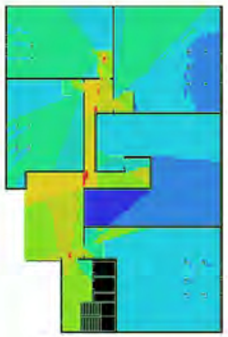
Connectivity Analysis showing the Hierarchy of Common Spaces



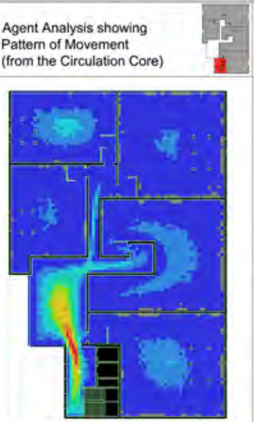
Max. Value

Min. Value

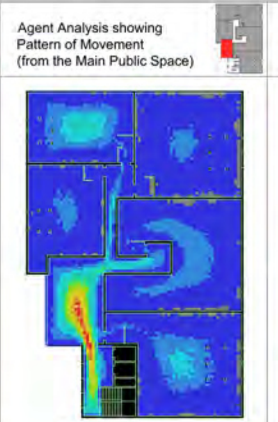
Integration Analysis between Common Spaces and Apartments



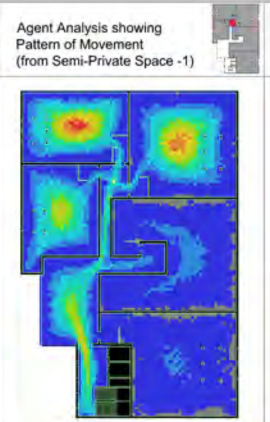
Agent Analysis showing Pattern of Movement (from the Circulation Core)



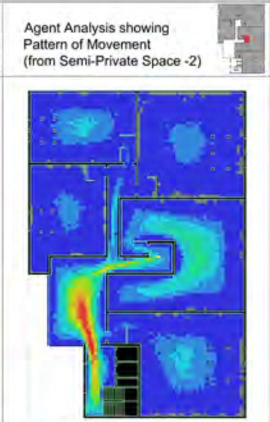
Agent Analysis showing Pattern of Movement (from the Main Public Space)



Agent Analysis showing Pattern of Movement (from Semi-Private Space -1)



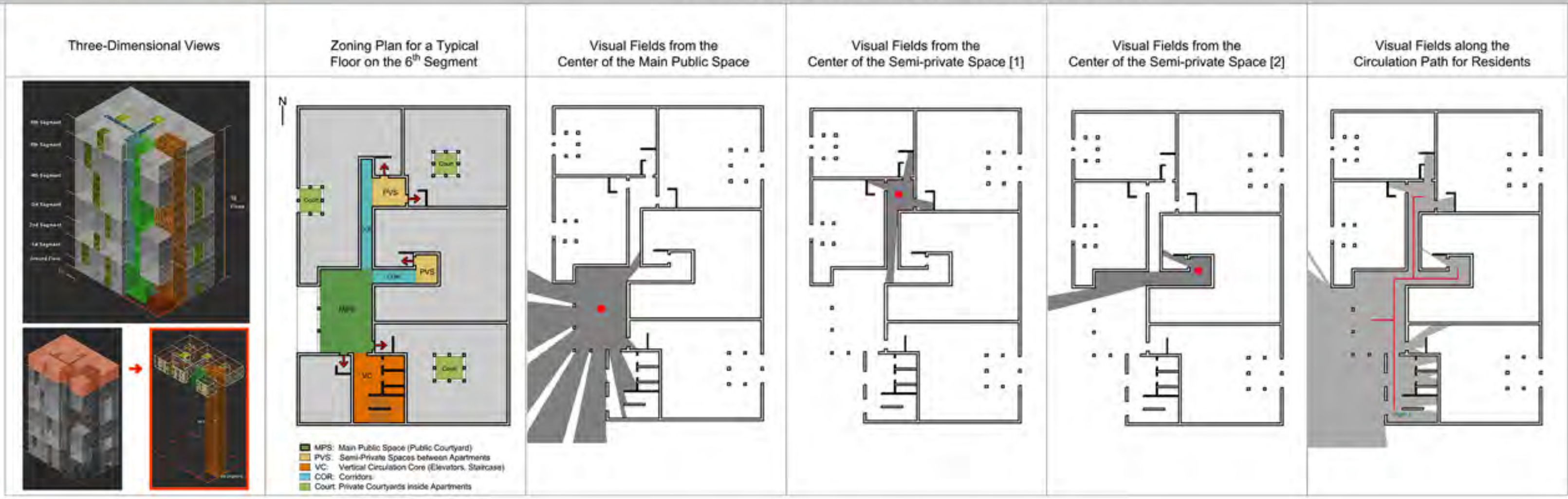
Agent Analysis showing Pattern of Movement (from Semi-Private Space -2)



Case No. (5): 6th Segment

Visibility Study for a Typical Floor located on the 6th Segment

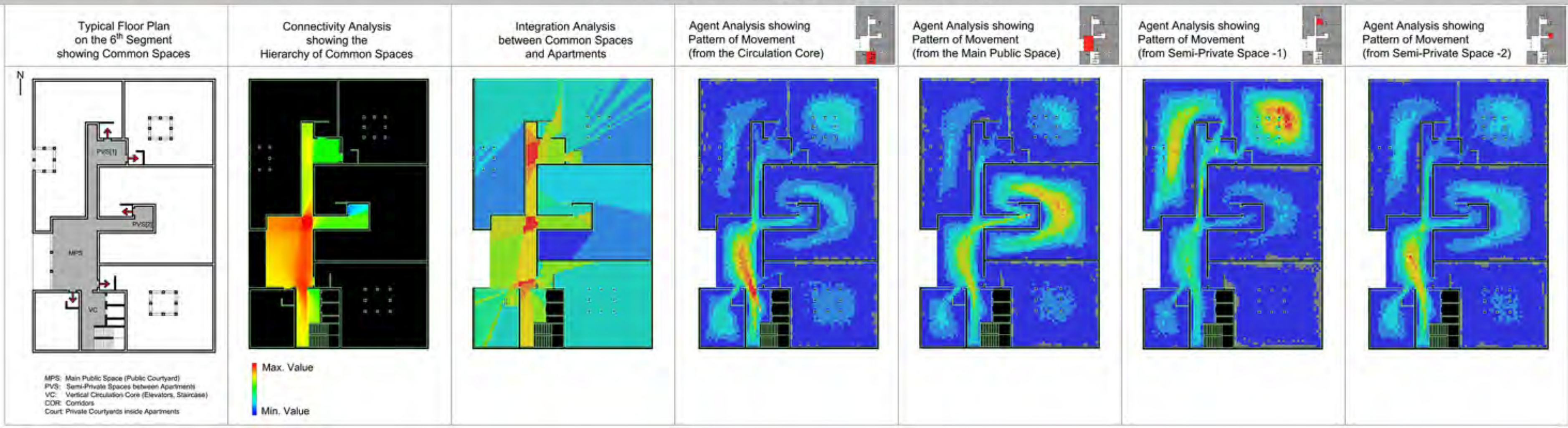
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



Case No. (5): 6th Segment

Syntactic Analysis (using Visibility Graph Analysis - VGA) for a Typical Floor located on the 6th Segment

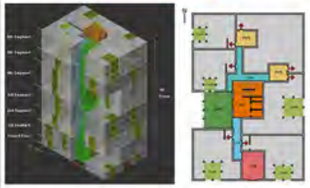
(Carried out by Author using 'DepthMapX 0.50 Software')



<u>Appendix (5-C-3)</u>

Results of Radiation Analysis for All Cases generated by the Researcher

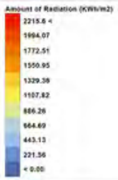
Case No. (1)



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/m² multiplied by the area of the face that the test points is representing.
- Time: 1 JAN 1:00 - 31 DEC 24:00

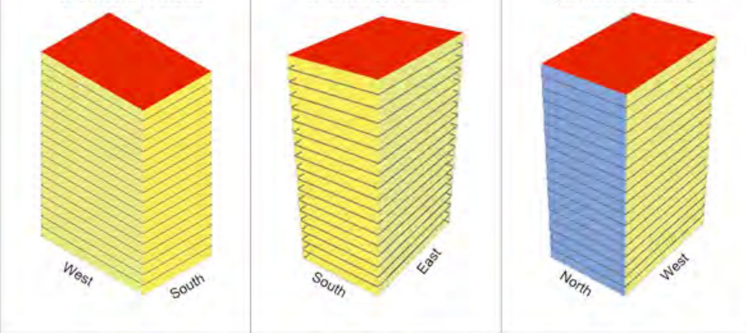
Key:



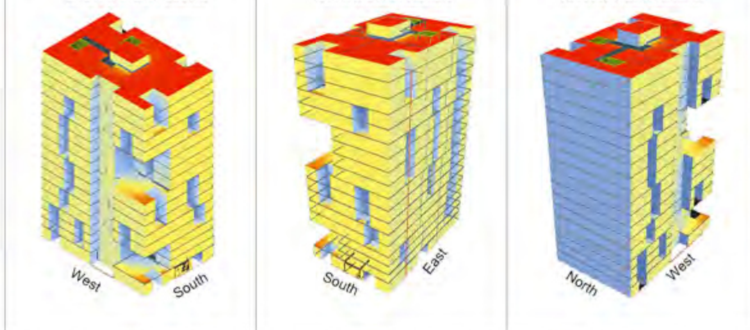
Radiation Analysis (Weather: Riyadh, KSA) Case No. (1)

(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



	18-Floor Building Mass with No Courtyards			The Proposed Design with Courtyards		
Total Radiation	11,736,821 KWh			11,401,993 KWh		
Amount of Radiation	0.0 to 800.0 KWh/m²	800.1 to 1500.0 KWh/m²	1500.1 to 2215.6 KWh/m²	0.0 to 800.0 KWh/m²	800.1 to 1500.0 KWh/m²	1500.1 to 2215.6 KWh/m²
% of Surface Area	26.1 %	58.0 %	15.9 %	82.8 %	14.4 %	2.8 %
Location of Surfaces	North Facade	East, West, and South Facades	Mainly on Roofs	North Facade, and Courtyards	East, West, and South Facades	Mainly on Roofs

Reduced: (568%)

Reduced: (403%)

Increased: +315%

Case No. (2)

Settings:

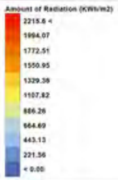
* All weather data are obtained from (http://Energyplus.net/weather), accessed on 24.11.2017

* 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

Key:

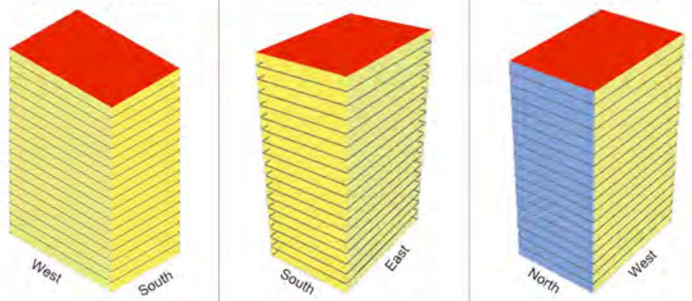


Radiation Analysis (Weather: Riyadh, KSA) Case No. (2)

(carried out by Author using Ladybug Plug-in, Grasshopper/Rhinoceros 5)

18-Floor Building Mass (30x45x70 meters) with No Courtyards

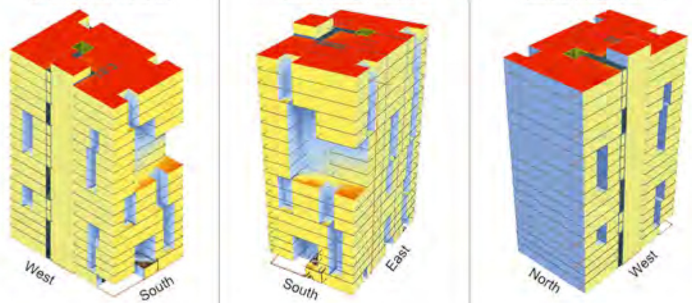
South & West Facades | South & East Facades | North & West Facades



Total Radiation	11,736,821 KWh		
Amount of Radiation	0.0 to 800.0 KWh/m^2	800.1 to 1500.0 KWh/m^2	1500.1 to 2215.6 KWh/m^2
% of Surface Area	26.1 %	58.0 %	15.9 %
Location of Surfaces	North Facade	East, West, and South Facades	Mainly on Roofs

The Proposed Design (30x45x70 meters) with Courtyards

South & West Facades | South & East Facades | North & West Facades



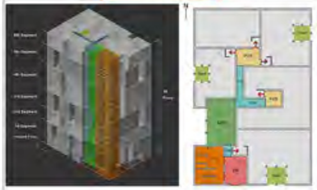
Total Radiation	11,443,531 KWh		
Amount of Radiation	0.0 to 800.0 KWh/m^2	800.1 to 1500.0 KWh/m^2	1500.1 to 2215.6 KWh/m^2
% of Surface Area	82.4 %	14.2 %	3.4 %
Location of Surfaces	North Facade, and Courtyards	East, West, and South Facades	Mainly on Roofs

Reduced: (470%)

Reduced: (410%)

Increased: +315%

Case No. (3)



Settings:

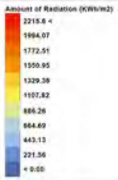
* All weather data are obtained from (http://Energyplus.net/weather), accessed on 24.11.2017

* 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/m² multiplied by the area of the face that the test points is representing.

* Time: 1 JAN 1:00 - 31 DEC 24:00

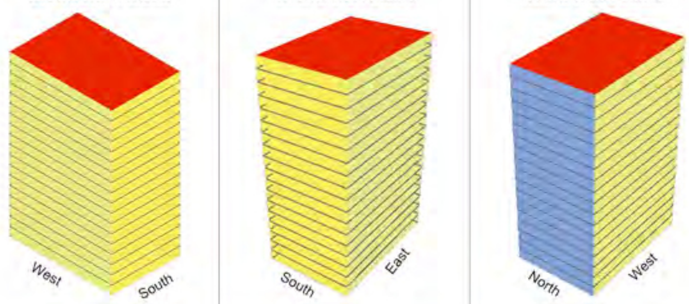
Key:



Radiation Analysis (Weather: Riyadh, KSA) Case No. (3)

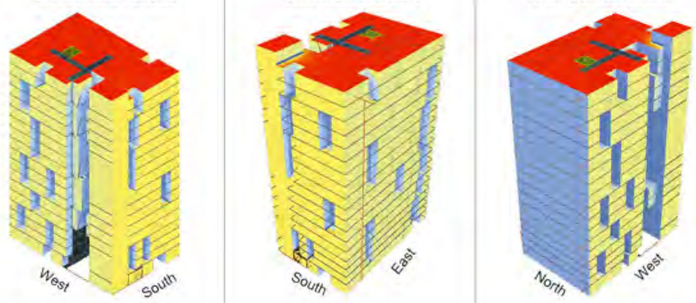
(carried out by Author using Ladybug Plug-in, Grasshopper/Rhinoceros 5)

18-Floor Building Mass (30x45x70 meters) with No Courtyards



Total Radiation	11,736,821 KWh		
Amount of Radiation	0.0 to 800.0 KWh/m²	800.1 to 1500.0 KWh/m²	1500.1 to 2215.6 KWh/m²
% of Surface Area	26.1 %	58.0 %	15.9 %
Location of Surfaces	North Facade	East, West, and South Facades	Mainly on Roofs

The Proposed Design (30x45x70 meters) with Courtyards



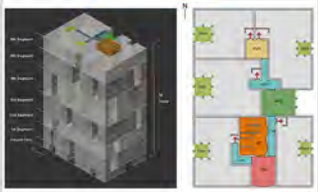
Total Radiation	11,454,201 KWh		
Amount of Radiation	0.0 to 800.0 KWh/m²	800.1 to 1500.0 KWh/m²	1500.1 to 2215.6 KWh/m²
% of Surface Area	83.3 %	14.0 %	2.7 %
Location of Surfaces	North Facade, and Courtyards	East, West, and South Facades	Mainly on Roofs

Reduced: (590%)

Reduced: (415%)

Increased: +320

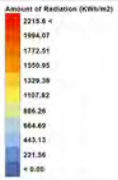
Case No. (4)



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/m² multiplied by the area of the face that the test points is representing.
- Time: 1 JAN 1:00 - 31 DEC 24:00

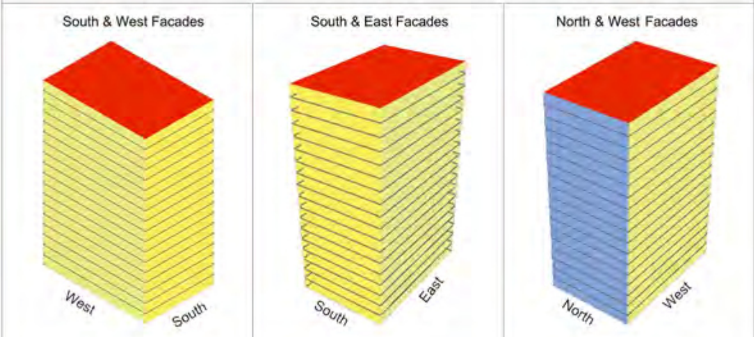
Key:



Radiation Analysis (Weather: Riyadh, KSA) Case No. (4)

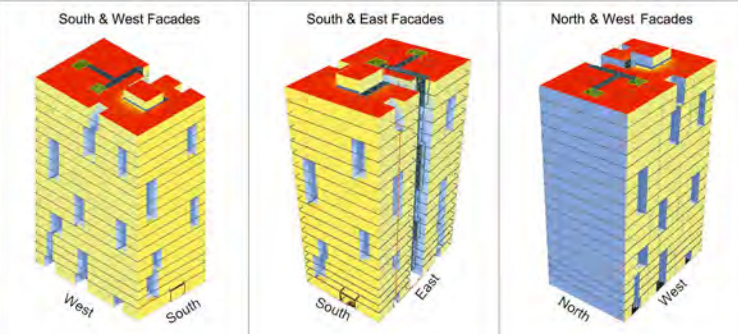
(carried out by Author using Ladybug Plug-in, Grasshopper/Rhinoceros 5)

18-Floor Building Mass (30x45x70 meters) with No Courtyards



Total Radiation	11,736,821 KWh		
Amount of Radiation	0.0 to 800.0 KWh/m²	800.1 to 1500.0 KWh/m²	1500.1 to 2215.6 KWh/m²
% of Surface Area	26.1 %	58.0 %	15.9 %
Location of Surfaces	North Facade	East, West, and South Facades	Mainly on Roofs

The Proposed Design (30x45x70 meters) with Courtyards



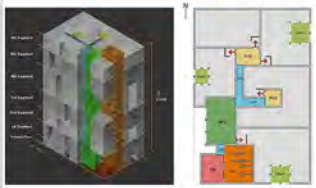
Total Radiation	11,474,006 KWh		
Amount of Radiation	0.0 to 800.0 KWh/m²	800.1 to 1500.0 KWh/m²	1500.1 to 2215.6 KWh/m²
% of Surface Area	82.3 %	14.8 %	2.9 %
Location of Surfaces	North Facade, and Courtyards	East, West, and South Facades	Mainly on Roofs

Reduced: (550%)

Reduced: (392%)

Increased: +315

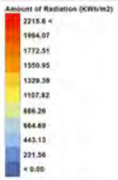
Case No. (5)



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/m² multiplied by the area of the face that the test points is representing.
* Time: 1 JAN 1:00 - 31 DEC 24:00

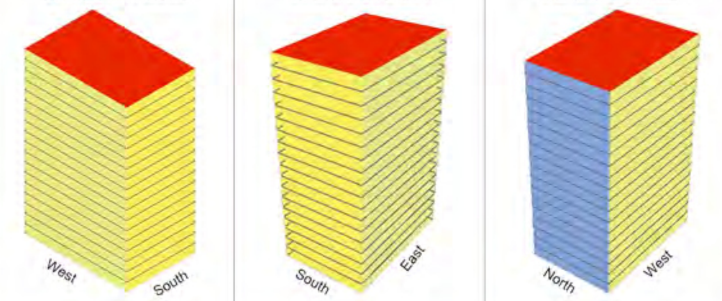
Key:



Radiation Analysis (Weather: Riyadh, KSA) Case No. (5)

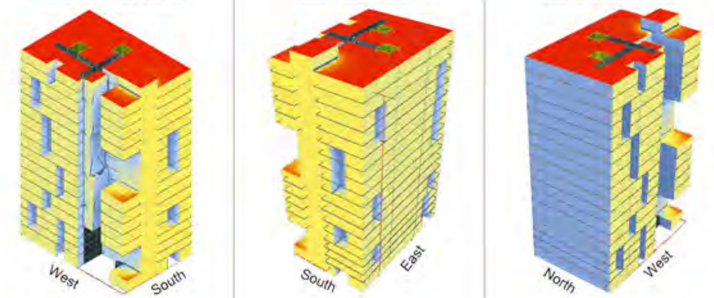
(carried out by Author using Ladybug Plug-in, Grasshopper/Rhinoceros 5)

18-Floor Building Mass (30x45x70 meters) with No Courtyards



Total Radiation	11,736,821 KWh		
Amount of Radiation	0.0 to 800.0 KWh/m²	800.1 to 1500.0 KWh/m²	1500.1 to 2215.6 KWh/m²
% of Surface Area	26.1 %	58.0 %	15.9 %
Location of Surfaces	North Facade	East, West, and South Facades	Mainly on Roofs

The Proposed Design (30x45x70 meters) with Courtyards



Total Radiation	11,324,268 KWh		
Amount of Radiation	0.0 to 800.0 KWh/m²	800.1 to 1500.0 KWh/m²	1500.1 to 2215.6 KWh/m²
% of Surface Area	83.2 %	14.1 %	2.7 %
Location of Surfaces	North Facade, and Courtyards	East, West, and South Facades	Mainly on Roofs

Reduced: (590%)

Reduced: (411%)

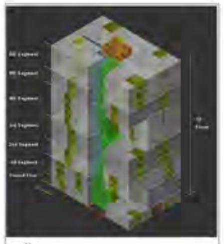
Increased: +320

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 (m2)	24300.0
Total Designed Area for the Building (m2)	22517.51
Total Number of Floors	18
Total Height of the Building (meter)	70.4
Total Area of Common Spaces on All Floors (m2)	4158.49 = 18.47 % of the Total Designed Area
Total Area of Residential Apartments on All Floors (m2)	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 (m2)	Total Designed Area for All Floors on Each Segment (m2)	% 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 %
TOTAL	18	94			22517.51	

Detailed Calculations for Residential Apartments

	Private Courtyards inside Apartments					Area of Apartments (including Courtyards)			
	Area on Each Floor (m2)	% 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 (m2)	% 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	74.73 %	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 = 10.82 % from the Total Area of Apartments	8.83 %			18359.02	81.53 %

Detailed Calculations for Common Spaces inside the Building

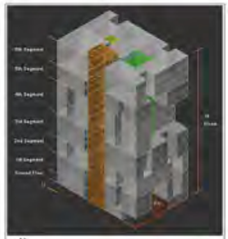
	Main Public Space (MPS)				Semi-Private Spaces (PVS)			
	Area on Each Floor (m2)	% from the Area of Each Floor	Area on All Floors of the Segment	% from the Total Area of the Building	Area on Each Floor (m2)	% from the Area of Each Floor	Area on All Floors of the Segment	% from the Total Area of the Building
Ground Floor	79.28	6.02%	79.28	0.35%	39.64	3.01 %	39.64	0.18 %
1st Segment	79.28	6.82 %	237.84	1.06 %	39.64	3.41 %	118.92	0.53 %
2nd Segment	30.09	2.28 %	60.18	0.27 %	39.61	3.01 %	79.22	0.35 %
3rd Segment	49.74	3.77 %	149.22	0.66 %	39.64	3.01 %	118.92	0.53 %
4th Segment	38.49	3.39 %	153.96	0.68 %	39.61	3.49 %	158.44	0.7 %
5th Segment	31.8	2.41 %	63.6	0.28 %	39.64	3.01 %	79.28	0.35 %
6th Segment	43.84	3.33 %	131.52	0.58 %	39.61	3.01 %	118.83	0.53 %
TOTAL			875.6	3.88 %			713.25	3.17 %

	Entry Hall (EN)			Corridors (COR)			
	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
Ground Floor	45.0	3.41 %	0.2 %	71.46	5.42 %	71.46	0.32%
1st Segment				49.46	4.26 %	148.38	0.66 %
2nd Segment				50.36	3.82 %	100.72	0.45 %
3rd Segment				49.46	3.75 %	148.38	0.66 %
4th Segment				50.36	4.44 %	201.44	0.89 %
5th Segment				49.46	3.75 %	98.92	0.44 %
6th Segment				50.36	3.82 %	151.08	0.67 %
TOTAL	45.0	3.41 %	0.2 %			920.38	4.09 %

	Vertical Core (VC)			
	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	73.5	5.58 %	73.5	0.33 %
1st Segment	73.5	6.33 %	220.5	0.98 %
2nd Segment	73.5	5.58 %	147.0	0.65 %
3rd Segment	73.5	5.58 %	220.5	0.98 %
4th Segment	73.5	6.48 %	294.0	1.31 %
5th Segment	73.5	5.58 %	147.0	0.65 %
6th Segment	73.5	5.58 %	220.5	0.98 %
TOTAL			1323.0	5.88 %

Case No. 2

Spatial Calculations



Ground Floor Plan

Overall Calculations for the Building

Total Allowable Area for the Building (m2): 24300.0

Total Designed Area for the Building (m2): 22922.68

Total Number of Floors: 18

Total Height of the Building (meter): 70.4

Total Area of Common Spaces on All Floors (m2): 4292.96 = 18.73 % of the Total Designed Area

Total Area of Residential Apartments on All Floors (m2): 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 (m2)	Total Designed Area for All Floors on Each Segment (m2)	% 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 %
TOTAL	18	94			22922.68	

Detailed Calculations for Residential Apartments

	Private Courtyards inside Apartments					Area of Apartments (including Courtyards)			
	Area on Each Floor (m2)	% 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 (m2)	% from the Area of Each Floor	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 %	3002.59	14.37 %
2nd Segment	101.3	8.8 %	8.34 %	202.6	0.97 %	1150.64	85.23 %	2301.28	11.01 %
3rd Segment	113.7	10.64 %	9.36 %	341.1	1.63 %	1068.36	79.14 %	3205.09	15.34 %
4th Segment	89.5	9.36 %	8.46 %	358.0	1.71 %	956.64	70.86 %	3826.57	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 %	3383.06	16.19 %
TOTAL				1599 = 8.58 % from the Total Area of Apartments	7.64 %			18629.72	81.27 %

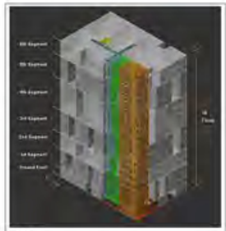
Detailed Calculations for Common Spaces inside the Building

	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
Ground Floor	91.8	7.56%	91.8	0.44%	45.89	3.78 %	45.89	0.22 %
1st Segment	91.8	8.0 %	275.4	1.32 %	45.89	4.0 %	137.67	0.66 %
2nd Segment	41.96	3.45 %	83.92	0.4 %	22.95	1.89 %	45.9	0.22 %
3rd Segment	61.8	5.09 %	185.4	0.89 %	45.89	3.78 %	137.67	0.66 %
4th Segment	68.4	6.47 %	273.6	1.31 %	22.95	2.17 %	91.8	0.44 %
5th Segment	68.4	5.96 %	136.8	0.65 %	45.89	4.0 %	91.78	0.44 %
6th Segment	59.22	4.87 %	177.66	0.85 %	22.95	1.89 %	68.85	0.33 %
TOTAL			1224.58	5.86 %			619.56	2.97 %

	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	3.7 %	0.22 %	85.5	7.04 %	85.5	0.41 %	73.5	6.05 %	73.5	0.35 %
1st Segment				70.55	6.15 %	211.65	1.01 %	73.5	6.41 %	220.5	1.06 %
2nd Segment				47.88	3.94 %	95.76	0.46 %	73.5	6.05 %	147.0	0.7 %
3rd Segment				70.55	5.81 %	211.65	1.01 %	73.5	6.05 %	220.5	1.06 %
4th Segment				47.88	4.53 %	191.52	0.92 %	73.5	6.95 %	294.0	1.41 %
5th Segment				70.55	6.15 %	141.1	0.68 %	73.5	6.41 %	147.0	0.7 %
6th Segment				47.88	3.94 %	143.64	0.69 %	73.5	6.05 %	220.5	1.06 %
TOTAL	45.0	3.7 %	0.22 %			1080.82	5.18 %			1323.0	6.34 %

Case No. 3

Spatial Calculations



Ground Floor Plan

Overall Calculations for the Building

Total Allowable Area for the Building (m2): 24300.0

Total Designed Area for the Building (m2): 23248.30

Total Number of Floors: 18

Total Height of the Building (meter): 70.4

Total Area of Common Spaces on All Floors (m2): 3906.37 = 16.80 % of the Total Designed Area

Total Area of Residential Apartments on All Floors (m2): 19341.93 = 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 (m2)	Total Designed Area for All Floors on Each Segment (m2)	% 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 %
TOTAL	18	100			23248.30	

Detailed Calculations for Residential Apartments

	Private Courtyards inside Apartments					Area of Apartments (including Courtyards)			
	Area on Each Floor (m2)	% 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 (m2)	% 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 %	1073.09	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 %
TOTAL				1366 = 7.06 % from the Total Area of Apartments	5.95 %			19341.93	83.20 %

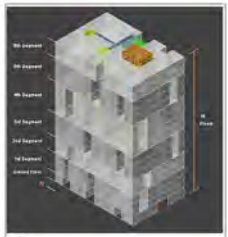
Detailed Calculations for Common Spaces inside the Building

	Main Public Space (MPS)				Semi-Private Spaces (PVS)				Entry Hall (EN)		
	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 (m2)	% from the Area of the Floor	% 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 %
1st Segment	80.96	6.65 %	242.88	1.06 %	40.5	3.33 %	121.5	0.53 %			
2nd Segment	34.93	2.64 %	69.86	0.3 %	20.25	1.53 %	40.5	0.18 %			
3rd Segment	53.59	4.05 %	160.77	0.7 %	40.5	3.06 %	121.5	0.53 %			
4th Segment	44.34	3.73 %	177.36	0.77 %	20.25	1.7 %	81.0	0.35 %			
5th Segment	37.51	2.84 %	112.53	0.49 %	40.5	3.06 %	121.5	0.53 %			
6th Segment	44.34	3.35 %	88.68	0.39 %	20.25	1.53 %	40.5	0.18 %			
TOTAL			933.04	4.06 %			567.0	2.48 %	45.0	3.4 %	0.2 %

	Corridors (COR)				Vertical Core (VC)			
	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	57.57	4.35 %	57.57	0.25 %	73.5	5.56 %	73.5	0.32 %
1st Segment	54.12	4.45 %	162.36	0.71 %	73.5	6.04 %	220.5	0.96 %
2nd Segment	61.71	4.67 %	123.42	0.54 %	73.5	5.56 %	147.0	0.64 %
3rd Segment	54.12	4.09 %	162.36	0.71 %	73.5	5.56 %	220.5	0.96 %
4th Segment	61.71	5.19 %	246.84	1.08 %	73.5	6.18 %	294.0	1.28 %
5th Segment	54.12	4.09 %	162.36	0.71 %	73.5	5.56 %	220.5	0.96 %
6th Segment	61.71	4.67 %	123.42	0.54 %	73.5	5.56 %	147.0	0.64 %
TOTAL			1038.33	4.54 %			1323.0	5.76 %

Case No. 4

Spatial Calculations



Ground Floor Plan

Overall Calculations for the Building

Total Allowable Area for the Building (m2): 24300.0

Total Designed Area for the Building (m2): 23733.0

Total Number of Floors: 18

Total Height of the Building (meter): 70.4

Total Area of Common Spaces on All Floors (m2): 4266.04 = 17.98 % of the Total Designed Area

Total Area of Residential Apartments on All Floors (m2): 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 (m2)	Total Designed Area for All Floors on Each Segment (m2)	% 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 %
TOTAL	18	92			23733.0	

Detailed Calculations for Residential Apartments

	Private Courtyards inside Apartments					Area of Apartments (including Courtyards)			
	Area on Each Floor (m2)	% 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 (m2)	% 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 %
TOTAL				1324 = 6.8 % from the Total Area of Apartments	5.58 %			19466.96	82.02 %

Detailed Calculations for Common Spaces inside the Building

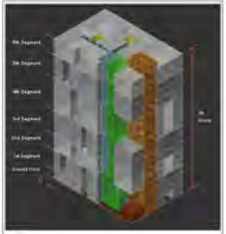
	Main Public Space (MPS)				Semi-Private Spaces (PVS)			
	Area on Each Floor (m2)	% from the Area of Each Floor	Area on All Floors of the Segment	% from the Total Area of the Building	Area on Each Floor (m2)	% from the Area of Each Floor	Area on All Floors of the Segment	% from the Total Area of the Building
Ground Floor	67.5	5.12 %	67.5	0.28 %	16.87	1.28 %	16.87	0.07 %
1st Segment	67.5	5.12 %	202.5	0.85 %	16.87	1.28 %	50.61	0.21 %
2nd Segment	39.38	2.99 %	78.76	0.33 %	33.78	2.56 %	67.56	0.28 %
3rd Segment	40.58	3.08 %	121.74	0.51 %	16.87	1.28 %	50.61	0.21 %
4th Segment	41.55	3.15 %	166.2	0.7 %	33.78	2.56 %	135.12	0.57 %
5th Segment	41.55	3.15 %	124.65	0.53 %	16.87	1.28 %	50.61	0.21 %
6th Segment	41.55	3.15 %	83.1	0.35 %	33.78	2.56 %	67.56	0.28 %
TOTAL			844.45	3.55 %			438.94	1.83 %

	Entry Hall (EN)		
	Area (m2)	% from the Area of the Floor	% from the Total Area of the Building
Ground Floor	45.0	3.41 %	0.19 %
1st Segment			
2nd Segment			
3rd Segment			
4th Segment			
5th Segment			
6th Segment			
TOTAL	45.0	3.41 %	0.19 %

	Corridors (COR)				Vertical Core (VC)			
	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	90.63	6.87 %	90.63	0.38 %	73.5	5.57 %	73.5	0.31 %
1st Segment	65.47	4.97 %	196.41	0.83 %	73.5	5.57 %	220.5	0.93 %
2nd Segment	70.54	5.35 %	141.08	0.59 %	73.5	5.57 %	147.0	0.62 %
3rd Segment	65.47	4.97 %	196.41	0.83 %	73.5	5.57 %	220.5	0.93 %
4th Segment	70.54	5.35 %	282.16	1.19 %	73.5	5.57 %	294.0	1.24 %
5th Segment	65.47	4.97 %	196.41	0.83 %	73.5	5.57 %	220.5	0.93 %
6th Segment	70.54	5.35 %	141.08	0.59 %	73.5	5.57 %	147.0	0.62 %
TOTAL			1244.18	5.24 %			1323.0	5.58 %

Case No. 5

Spatial Calculations



Ground Floor Plan

Overall Calculations for the Building

Total Allowable Area for the Building (m2)	24300.0
Total Designed Area for the Building (m2)	22855.21
Total Number of Floors	18
Total Height of the Building (meter)	70.4
Total Area of Common Spaces on All Floors (m2)	4334.22 = 18.96 % of the Total Designed Area
Total Area of Residential Apartments on All Floors (m2)	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 (m2)	Total Designed Area for All Floors on Each Segment (m2)	% 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 %
TOTAL	18	93			22855.21	

Detailed Calculations for Residential Apartments

	Private Courtyards inside Apartments					Area of Apartments (including Courtyards)			
	Area on Each Floor (m2)	% 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 (m2)	% 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 %
TOTAL				1082 = 5.84 % from the Total Area of Apartments	5.15 %			18520.99	81.04 %

Detailed Calculations for Common Spaces inside the Building

	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
Ground Floor	80.96	6.65 %	80.96	0.38 %	40.5	3.33 %	40.5	0.19 %
1st Segment	80.96	7.28 %	242.88	1.15 %	40.5	3.64 %	121.5	0.58 %
2nd Segment	56.35	4.63 %	112.7	0.54 %	41.15	3.38 %	82.3	0.39 %
3rd Segment	53.59	4.4 %	160.77	0.76 %	40.5	3.33 %	121.5	0.58 %
4th Segment	44.34	4.09 %	177.36	0.84 %	41.15	3.8 %	164.6	0.78 %
5th Segment	58.0	4.77 %	174.0	0.83 %	40.5	3.33 %	121.5	0.58 %
6th Segment	58.0	4.77 %	116.0	0.55 %	41.15	3.38 %	82.3	0.39 %
TOTAL			1064.67	5.05 %			734.2	3.49 %

	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	3.7 %	0.21 %	63.44	5.21 %	63.44	0.3 %	73.5	6.04 %	73.5	0.35 %
1st Segment				59.99	5.4 %	179.97	0.85 %	73.5	6.61 %	220.5	1.05 %
2nd Segment				70.5	5.79 %	141.0	0.67 %	73.5	6.04 %	147.0	0.7 %
3rd Segment				59.99	4.93 %	179.97	0.85 %	73.5	6.04 %	220.5	1.05 %
4th Segment				70.5	6.5 %	282.0	1.34 %	73.5	6.78 %	294.0	1.4 %
5th Segment				59.99	4.93 %	179.97	0.85 %	73.5	6.04 %	220.5	1.05 %
6th Segment				70.5	5.79 %	141.0	0.67 %	73.5	6.04 %	147.0	0.7 %
TOTAL	45.0	3.7 %	0.21 %			1167.35	5.53 %			1323.0	6.3 %

Appendix (5-C-5)

Questionnaire Form for the Evaluation of the Computational Tool, and Ethical Approval Form

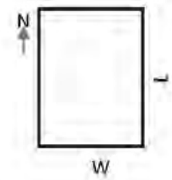
Guide for Designing High-rise Residential Buildings using a Computational Tool

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^2.



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:** ☐ 2nd Year ☐ 3rd Year

☐ **Architect:** Years of experience: ....

1.2. Do you have previous experience in Grasshopper? ☐ Yes ☐ No

<u>Questions to be answered after the implementation:</u>

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 <u>positive</u> aspects of the tool:

1. ....

2. ....

3. ....

2.3. List the most <u>negative</u> 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:** ....

EC1711.346

WELSH SCHOOL OF ARCHITECTURE
ETHICS APPROVAL FORM FOR STAFF AND PHD/MPHIL PROJECTS

WSA

Tick one box:	☐ STAFF ■ 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:	13th 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 (http://www.cardiff.ac.uk/archi/ethics_committee.php)				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)[1]	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? (http://www.cf.ac.uk/osheu/index.html)	x		

Research Governance	YES	NO	N/A
Does your study include the use of a drug? You need to contact Research Governance before submission (resgov@cf.ac.uk)		x	
Does the study involve the collection or use of human tissue? You need to contact the Human Tissue Act team before submission (hta@cf.ac.uk)		x	

[1] 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*).	x
• 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

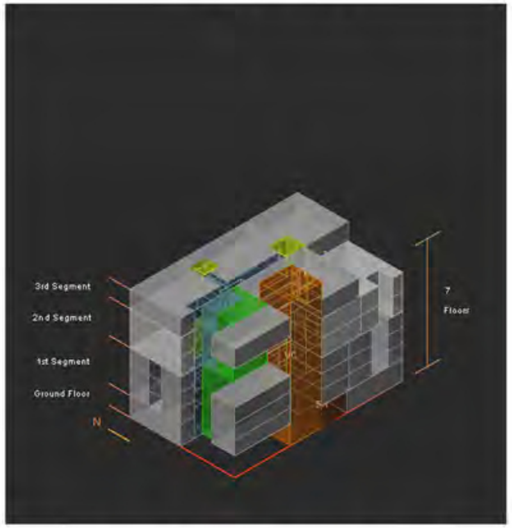
Signature **Name** GABRIELA ZAPATA-LANCASTER **Date** 16/11/17

Chair, School Research Ethics Committee

Appendix (5-C-6)

Three-Dimensional Views for All Experiments generated by Participants

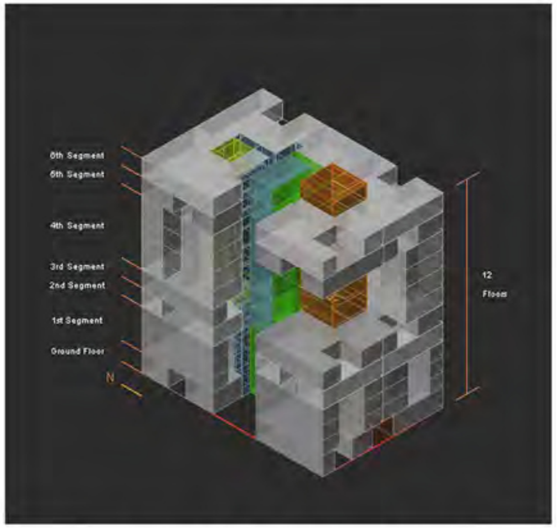
Exp. # A



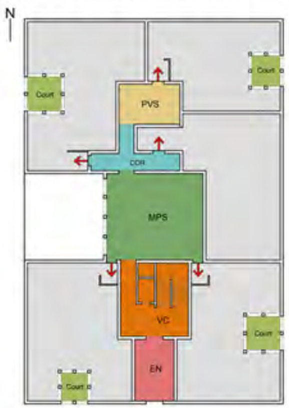
Zoning Plan for the Ground Floor

- 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

Exp. # B

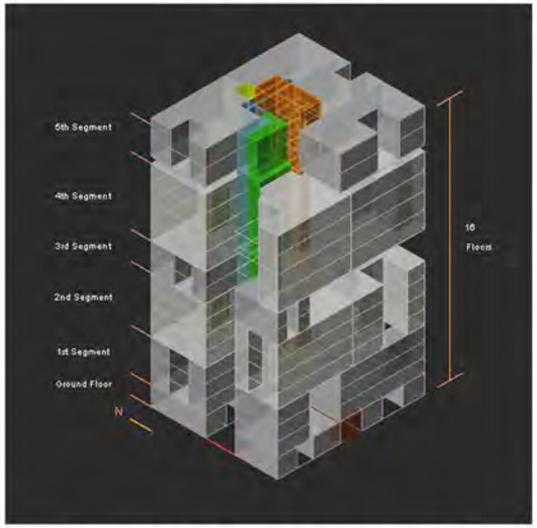


Zoning Plan for the Ground Floor



- 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

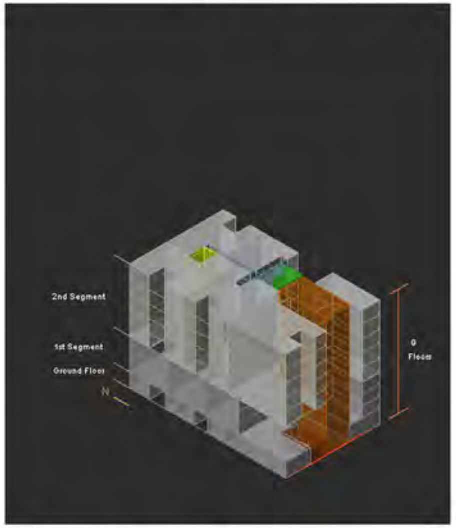
Exp. # C



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

Exp. # D



Zoning Plan for the Ground Floor

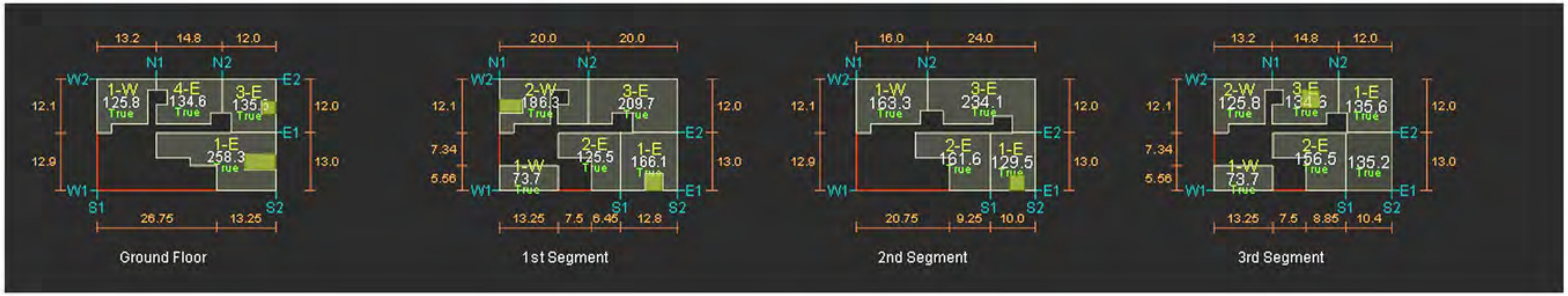
- EN: Entry Hall
- MPS: Main Public Space (Public Courtyard)
- PVS: Semi-Private Spaces between Apartments
- VC: Vertical Circulation Core (Elevators, Staircase)
- COR: Corridors
- Court: Private Courtyards inside Apartments

Appendix (5-C-7)

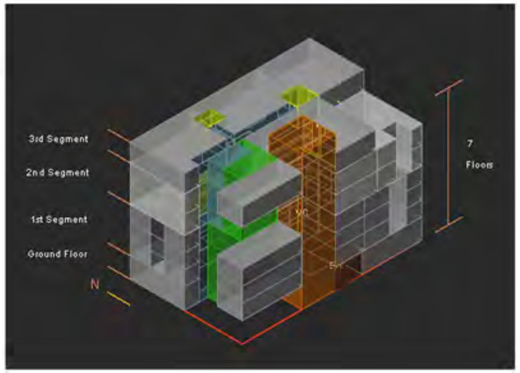
A Detailed Spatial Analysis for All Experiments generated by the Participants

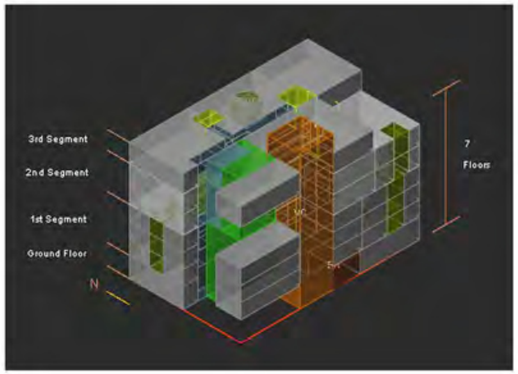
Exp. No. (A)

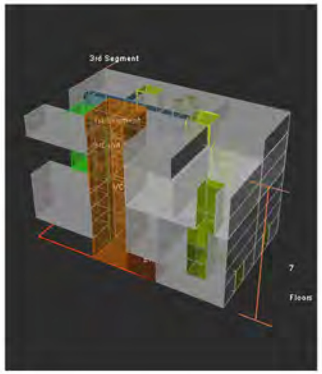
Floors Plans and Three-Dimensional Views



- 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



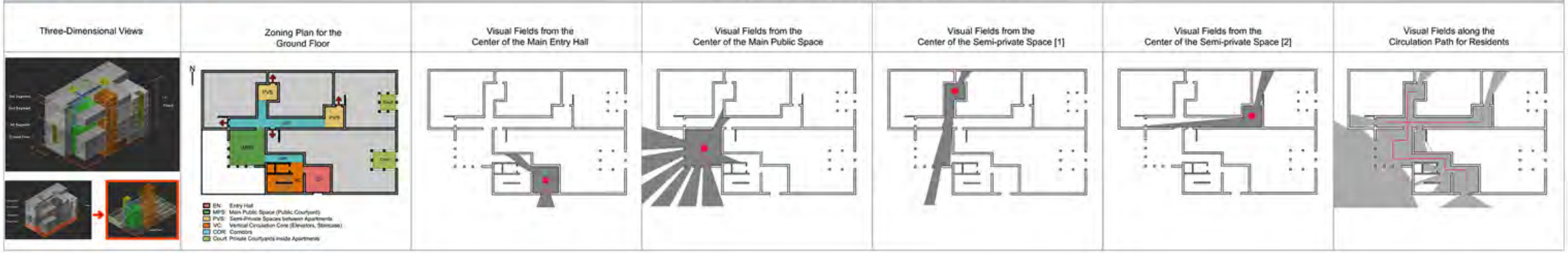




Exp. No. (A): Ground Floor

Visibility Study for the Ground Floor

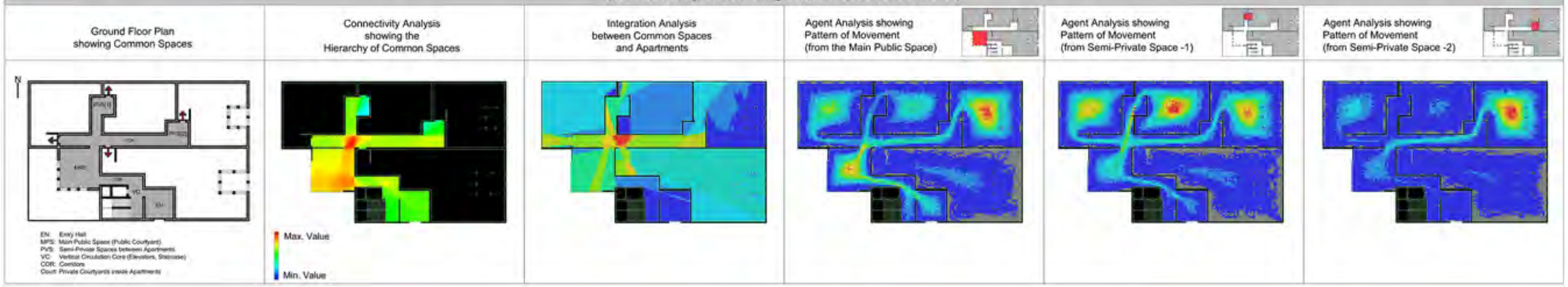
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



Exp. No. (A): Ground Floor

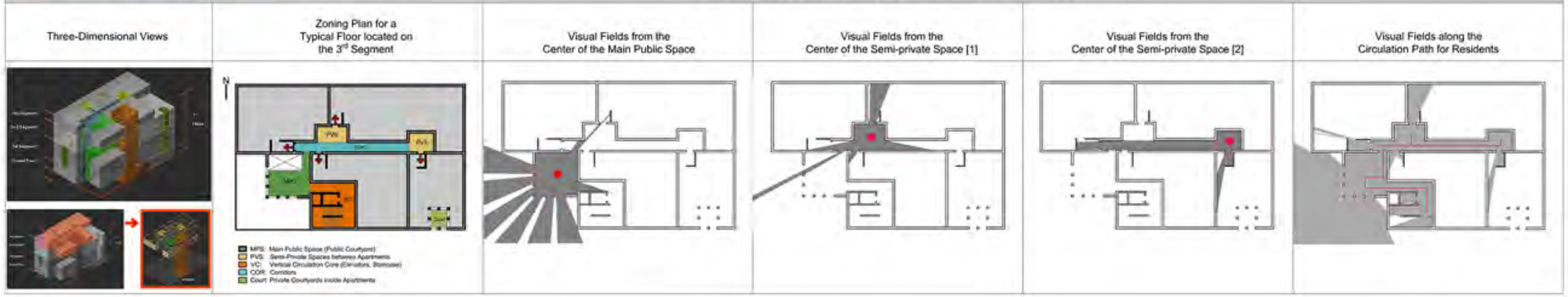
Syntactic Analysis (using Visibility Graph Analysis - VGA) for the Ground Floor

(Carried out by Author using 'DepthMapX 0.50 Software')



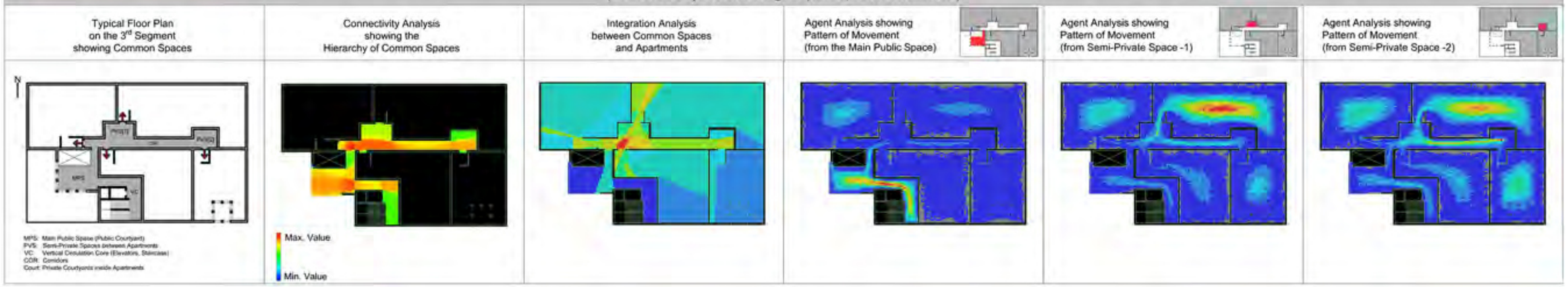
Exp. No. (A): 3rd Segment

Visibility Study for a Typical Floor located on the 3rd Segment
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')



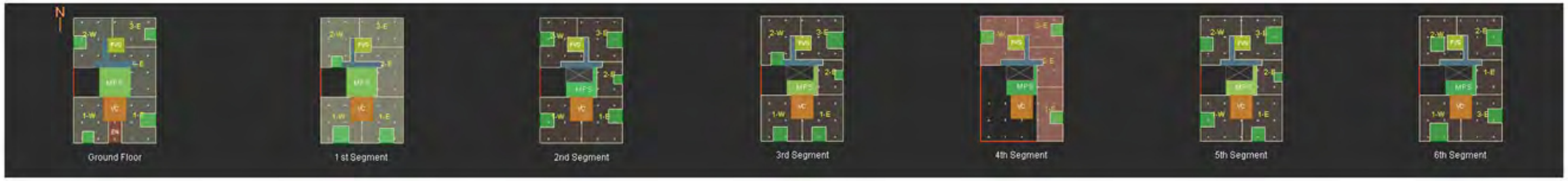
Exp. No. (A): 3rd Segment

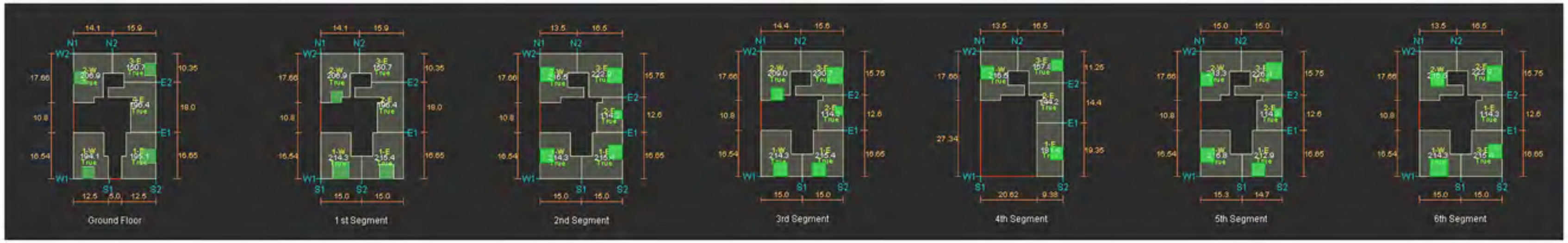
Syntactic Analysis (using Visibility Graph Analysis - VGA) for a Typical Floor located on the 3rd Segment
(Carried out by Author using 'DepthMapX 0.50 Software')



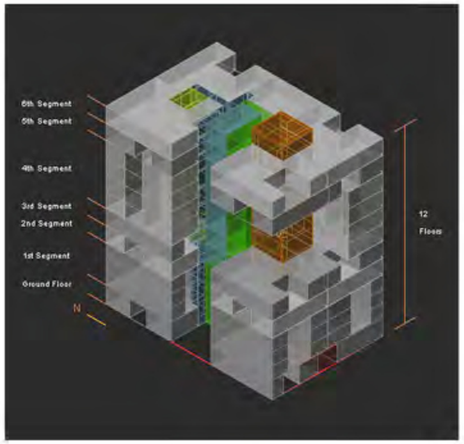
Exp. No. (B)

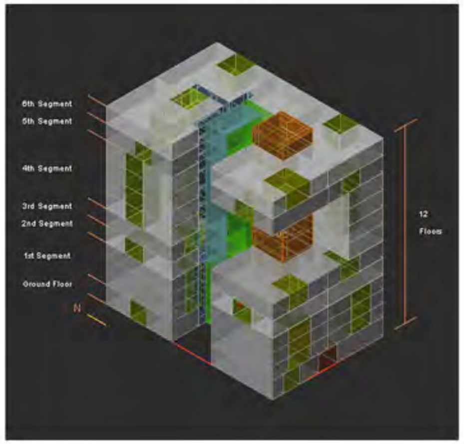
Floors Plans and Three-Dimensional Views

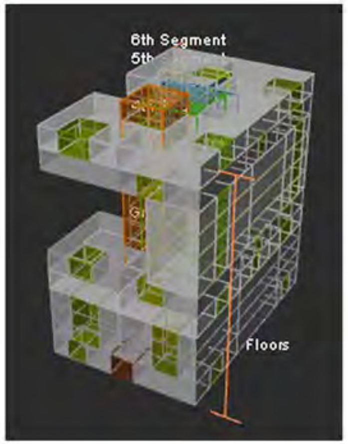




- EN: Entry Hall
- MPS: Main Public Space (Public Courtyard)
- PVS: Semi-Private Spaces between Apartments
- VC: Vertical Circulation Core (Elevators, Staircase)
- COR: Corridors
- Court: Private Courtyards inside Apartments





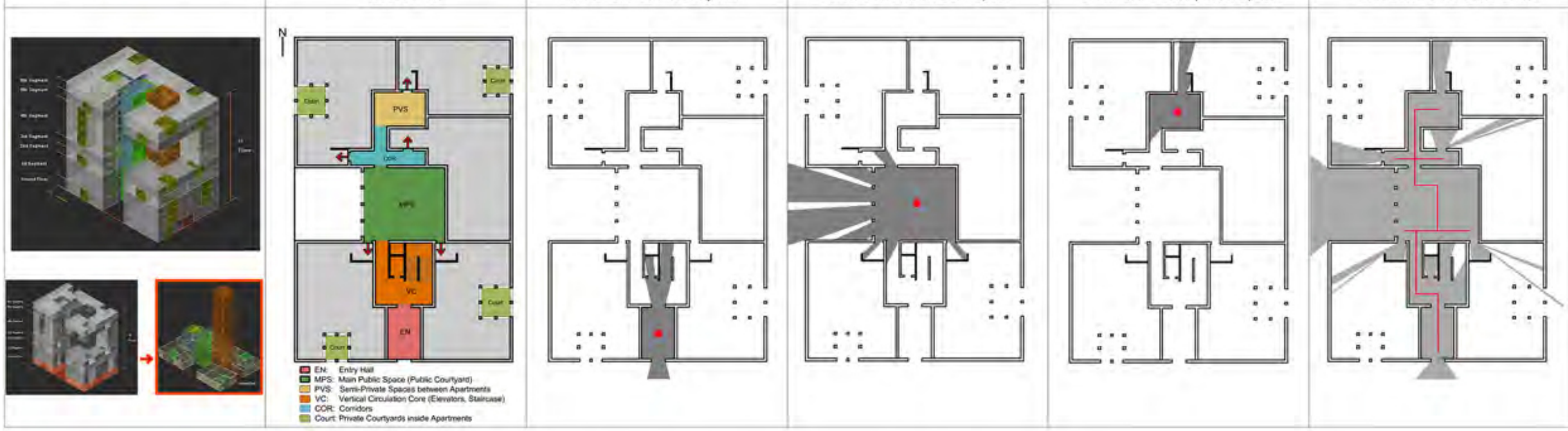


Exp. No. (B): Ground Floor

Visibility Study for the Ground Floor

(Carried out by Author using 'Syntax2D 1.3.0.7 Software')

Three-Dimensional Views	Zoning Plan for the Ground Floor	Visual Fields from the Center of the Main Entry Hall	Visual Fields from the Center of the Main Public Space	Visual Fields from the Center of the Semi-private Space	Visual Fields along the Circulation Path for Residents

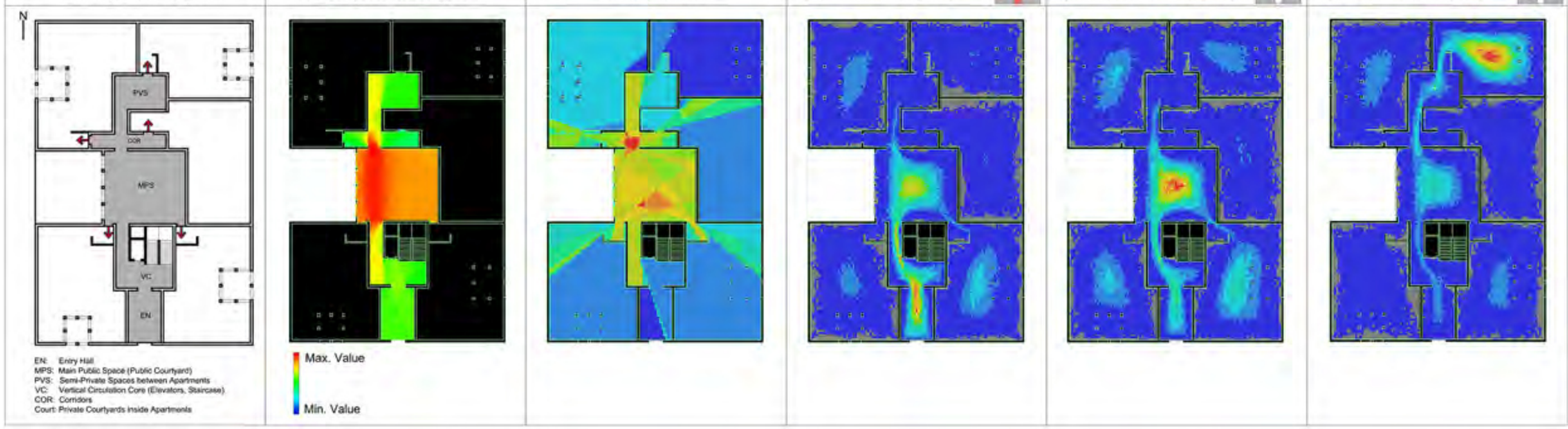


Exp. No. (B): Ground Floor

Syntactic Analysis (using Visibility Graph Analysis - VGA) for the Ground Floor

(Carried out by Author using 'DepthMapX 0.50 Software')

Ground Floor Plan showing Common Spaces	Connectivity Analysis showing the Hierarchy of Common Spaces	Integration Analysis between Common Spaces and Apartments	Agent Analysis showing Pattern of Movement (from the Main Entry Hall)	Agent Analysis showing Pattern of Movement (from the Main Public Space)	Agent Analysis showing Pattern of Movement (from Semi-Private Space)

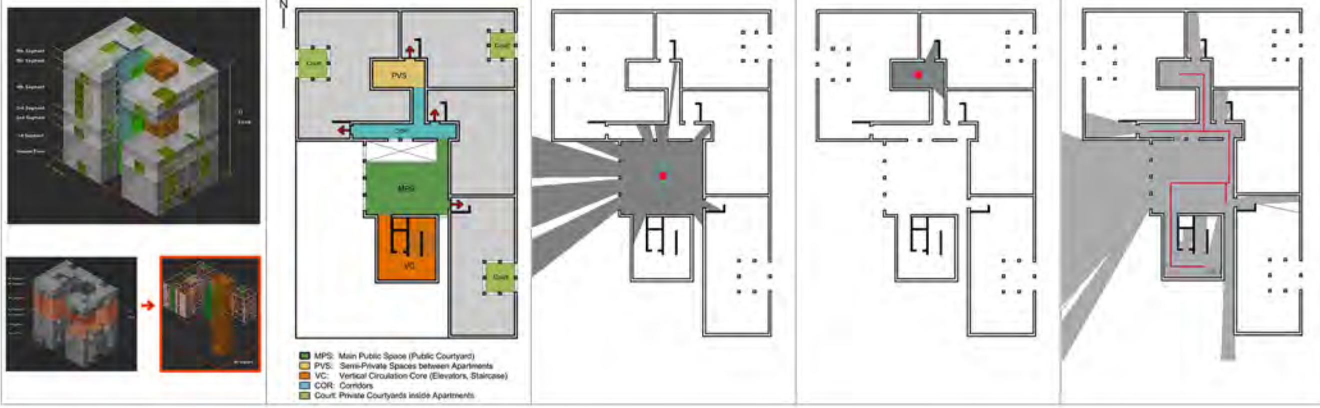


Exp. No. (B): 4th Segment

Visibility Study for a Typical Floor located on the 4th Segment

(Carried out by Author using 'Syntax2D 1.3.0.7 Software')

Three-Dimensional Views	Zoning Plan for a Typical Floor located on the 4th Segment	Visual Fields from the Center of the Main Public Space	Visual Fields from the Center of the Semi-private Space	Visual Fields along the Circulation Path for Residents

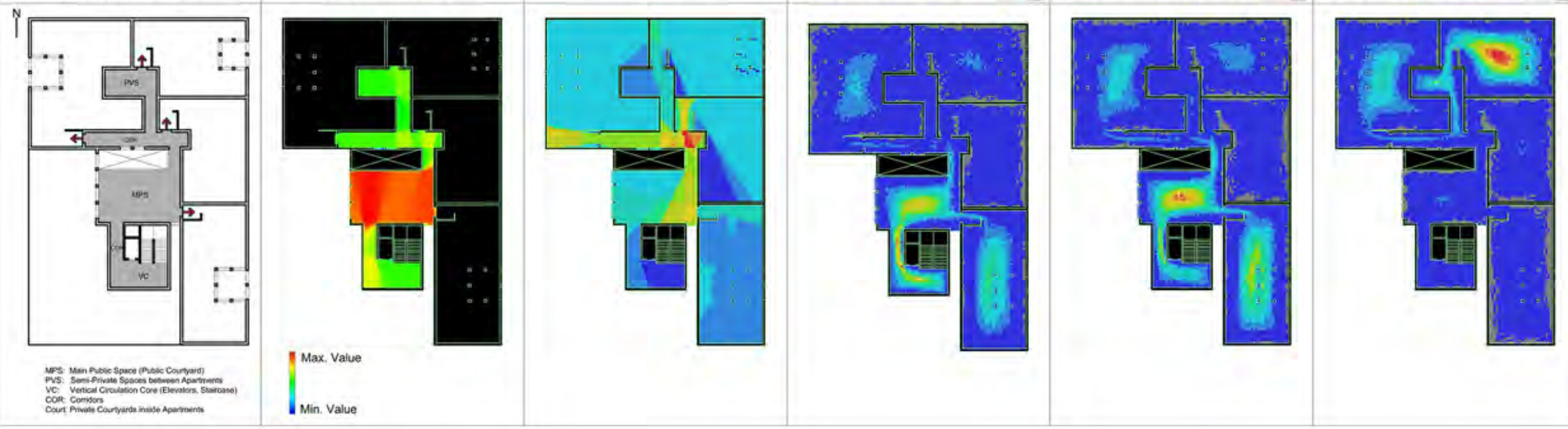


Exp. No. (B): 4th Segment

Syntactic Analysis (using Visibility Graph Analysis - VGA) for a Typical Floor located on the 4th Segment

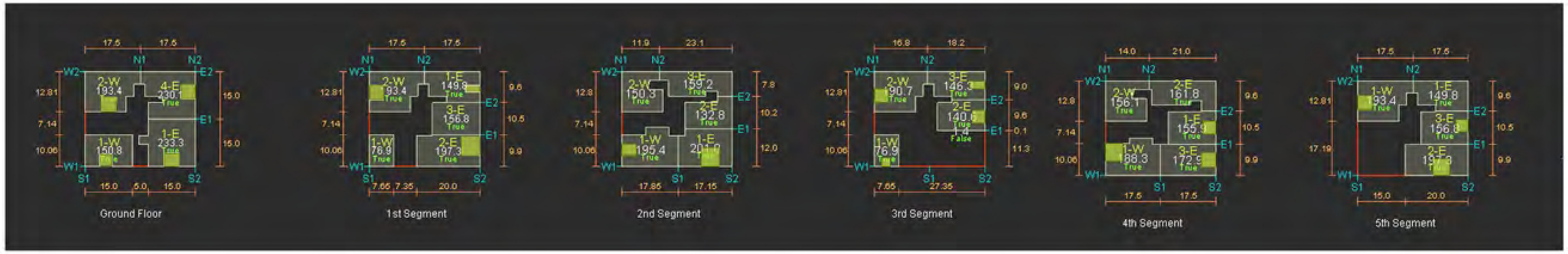
(Carried out by Author using 'DepthMapX 0.50 Software')

Typical Floor Plan on the 4th Segment showing Common Spaces	Connectivity Analysis showing the Hierarchy of Common Spaces	Integration Analysis between Common Spaces and Apartments	Agent Analysis showing Pattern of Movement (from the Circulation Core)	Agent Analysis showing Pattern of Movement (from the Main Public Space)	Agent Analysis showing Pattern of Movement (from Semi-Private Space)

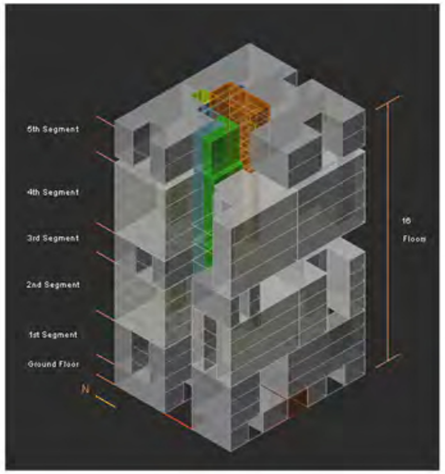


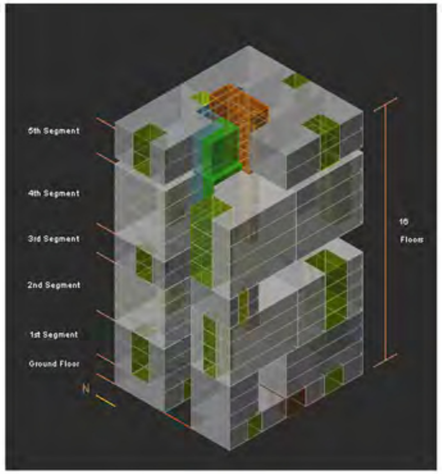
Exp. No. (C)

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

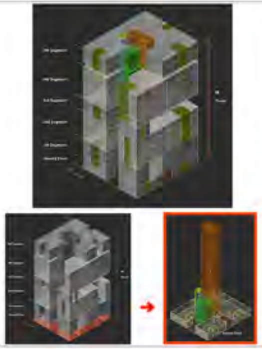
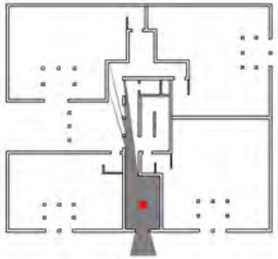
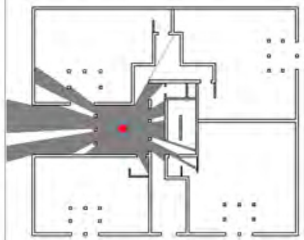
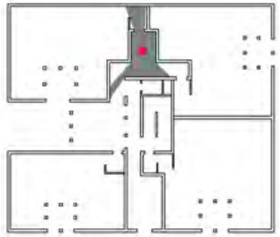
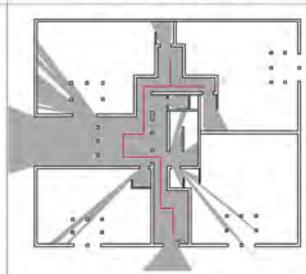




Exp. No. (C): Ground Floor

Visibility Study for the Ground Floor

(Carried out by Author using 'Syntax2D 1.3.0.7 Software')

Three-Dimensional Views	Zoning Plan for the Ground Floor	Visual Fields from the Center of the Main Entry Hall	Visual Fields from the Center of the Main Public Space	Visual Fields from the Center of the Semi-private Space	Visual Fields along the Circulation Path for Residents
					

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MPS: Main Public Space (Public Courtyard)
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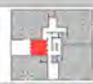
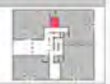
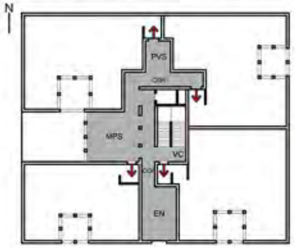
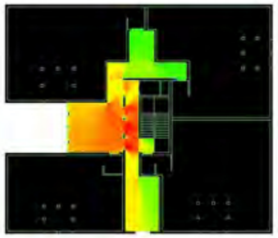
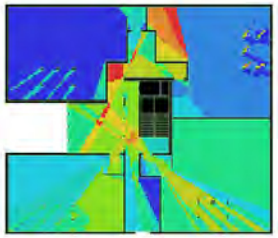
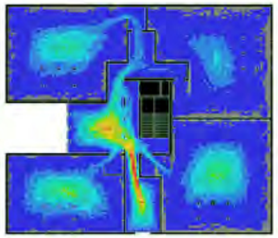
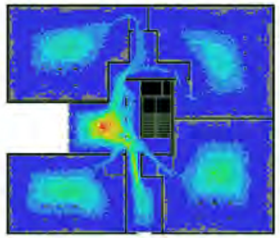
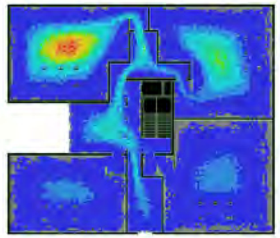
VC: Vertical Circulation Core (Elevators, Staircase)
COR: Corridors
Court: Private Courtyards inside Apartments

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')

Ground Floor Plan showing Common Spaces	Connectivity Analysis showing the Hierarchy of Common Spaces	Integration Analysis between Common Spaces and Apartments	Agent Analysis showing Pattern of Movement (from the Main Entry Hall) 	Agent Analysis showing Pattern of Movement (from the Main Public Space) 	Agent Analysis showing Pattern of Movement (from Semi-Private Space) 
					

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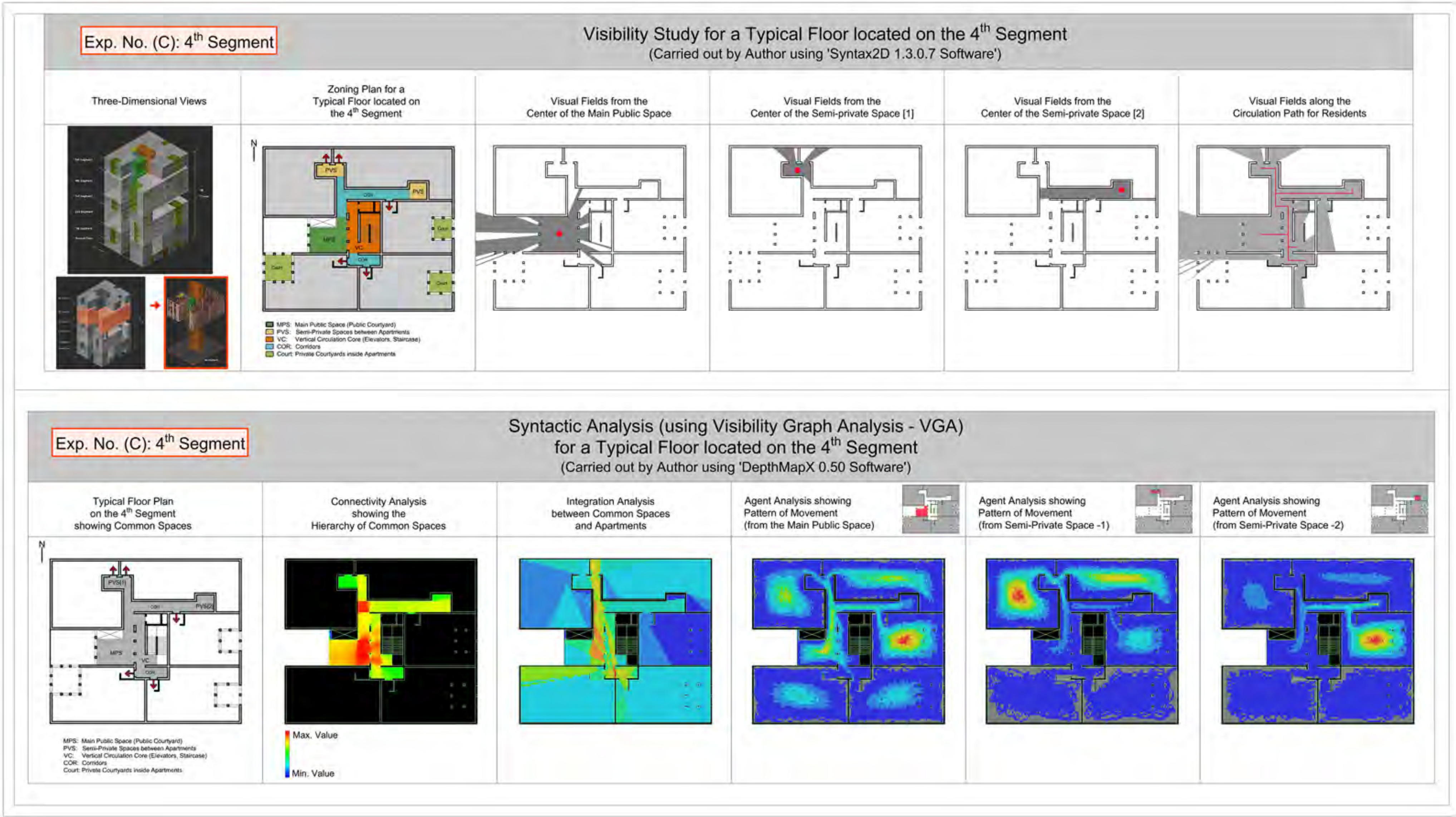
Court: Private Courtyards inside Apartments

Max. Value

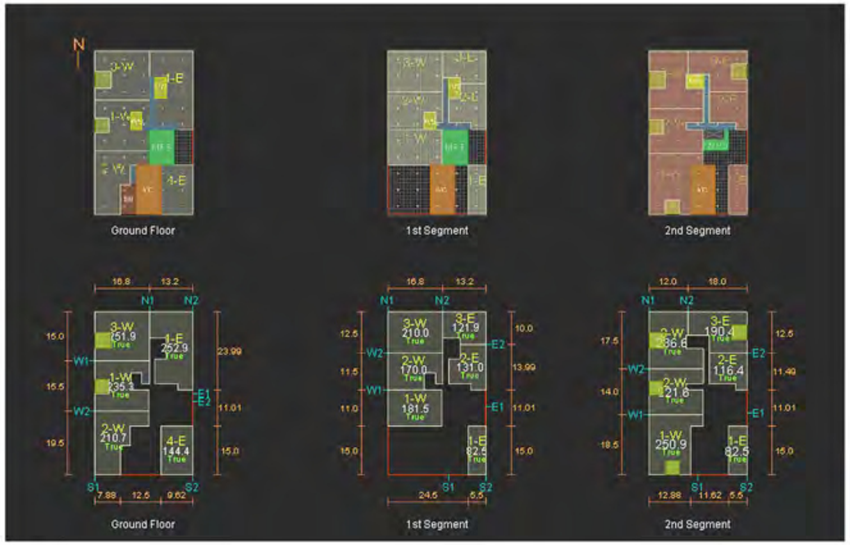
Min. Value



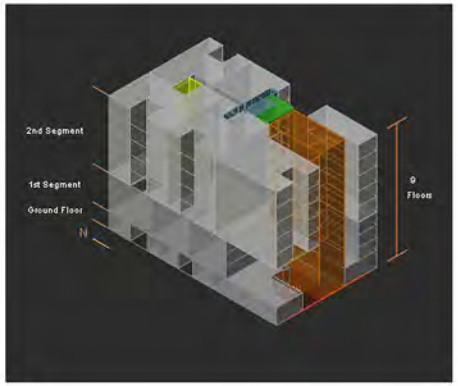
Exp. No. (C): 4th Segment
Visibility Study for a Typical Floor located on the 4th Segment
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')
Three-Dimensional Views
Zoning Plan for a Typical Floor located on the 4th Segment
Visual Fields from the Center of the Main Public Space
Visual Fields from the Center of the Semi-private Space [1]
Visual Fields from the Center of the Semi-private Space [2]
Visual Fields along the Circulation Path for Residents
N
PVS
COR
VC
MPS
Court
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): 4th Segment
Syntactic Analysis (using Visibility Graph Analysis - VGA) for a Typical Floor located on the 4th Segment
(Carried out by Author using 'DepthMapX 0.50 Software')
Typical Floor Plan on the 4th Segment showing Common Spaces
Connectivity Analysis showing the Hierarchy of Common Spaces
Integration Analysis between Common Spaces and Apartments
Agent Analysis showing Pattern of Movement (from the Main Public Space)
Agent Analysis showing Pattern of Movement (from Semi-Private Space -1)
Agent Analysis showing Pattern of Movement (from Semi-Private Space -2)
N
PVS(1)
PVS(2)
COR
MPS
VC
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
Max. Value
Min. Value

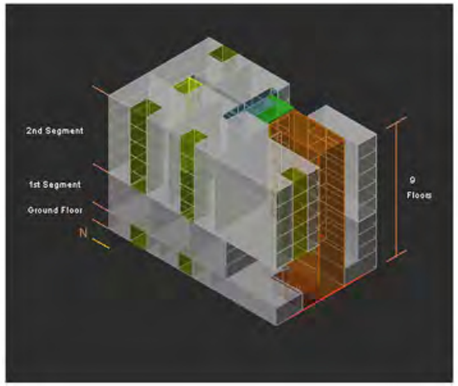
Exp. No. (D)

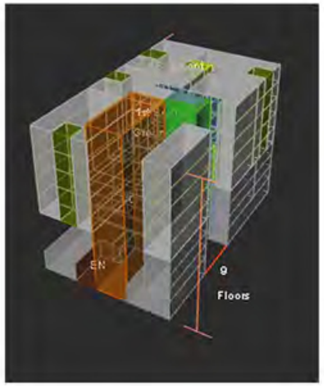
Floors Plans and Three-Dimensional Views

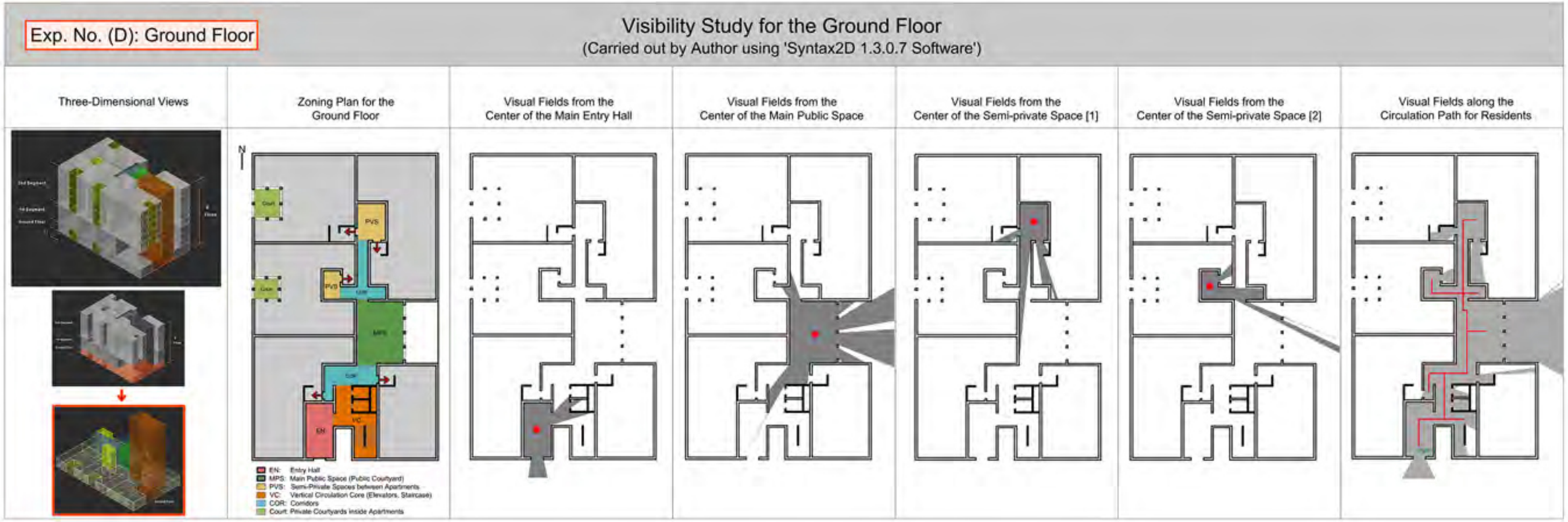


- EN: Entry Hall
- MPS: Main Public Space (Public Courtyard)
- PVS: Semi-Private Spaces between Apartments
- VC: Vertical Circulation Core (Elevators, Staircase)
- COR: Corridors
- Court: Private Courtyards inside Apartments

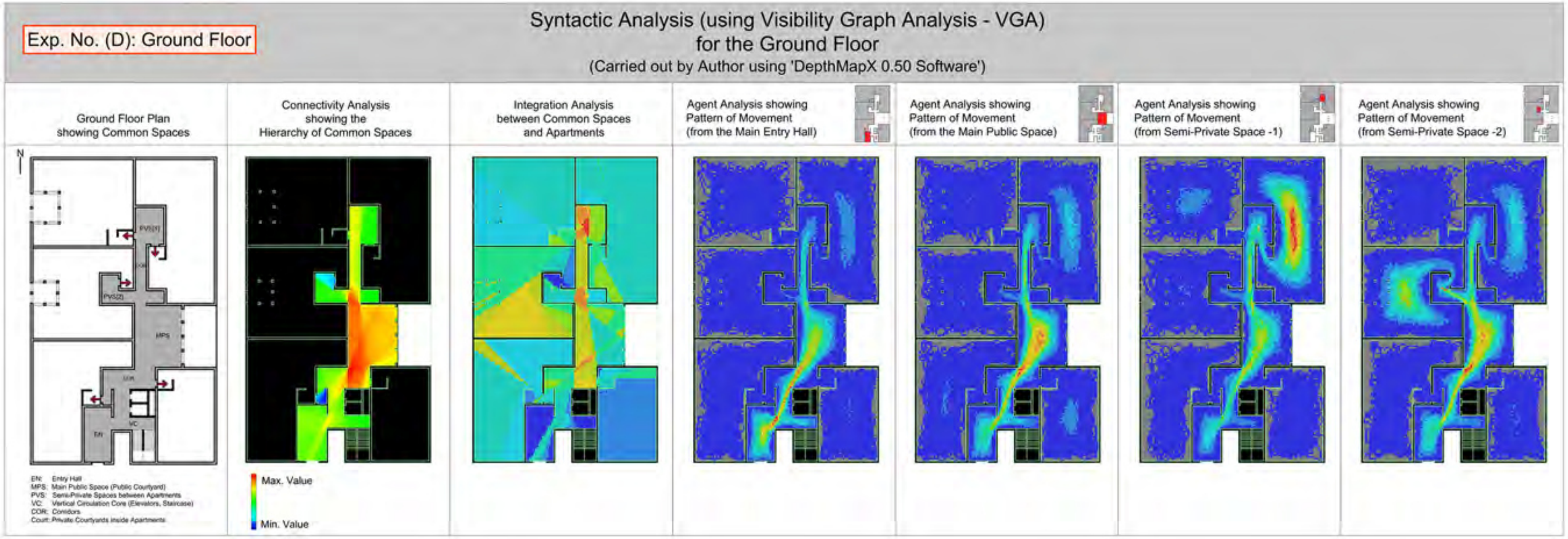




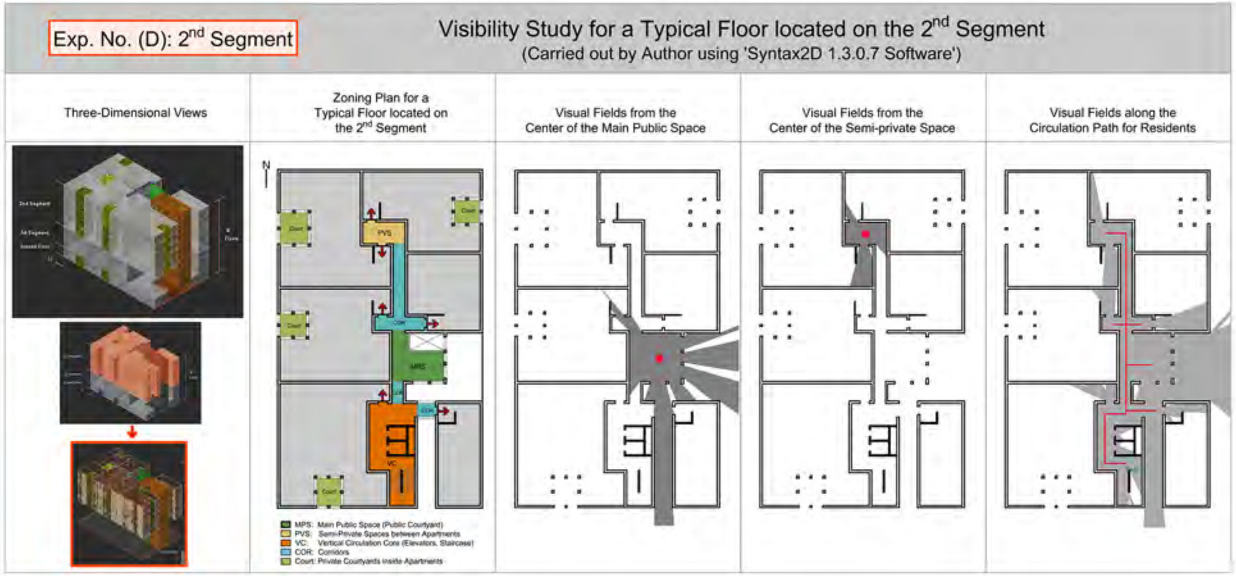




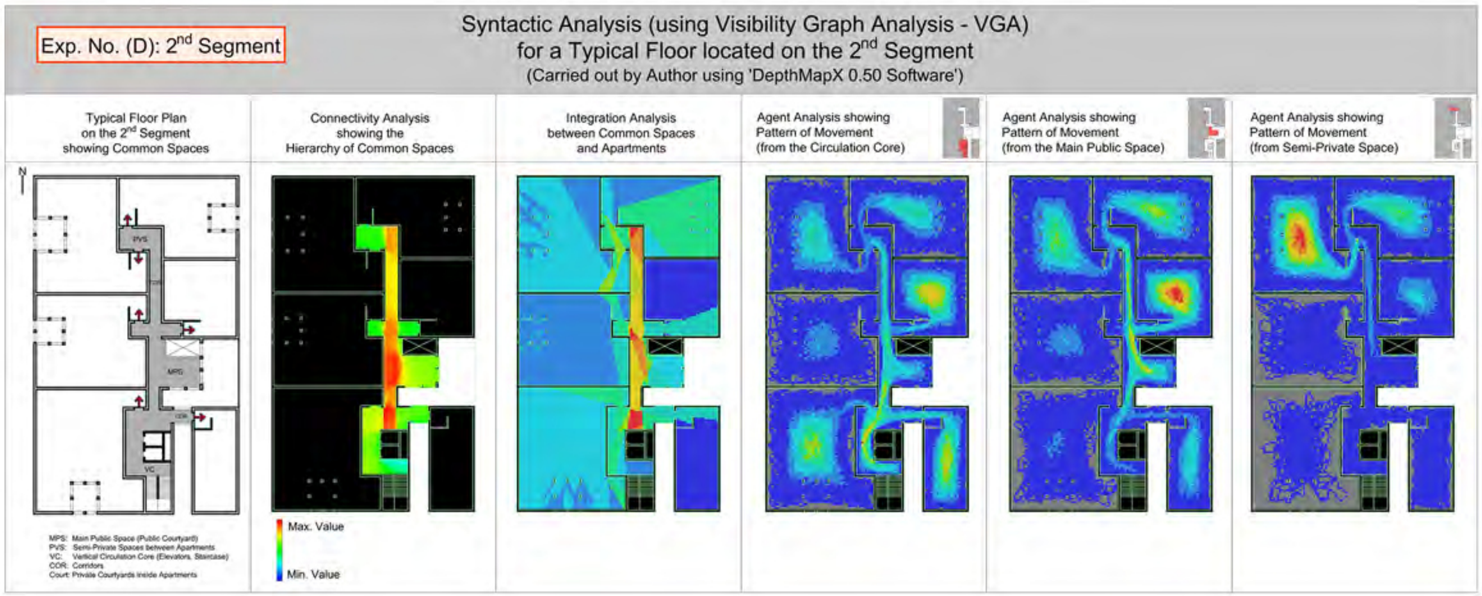
Exp. No. (D): Ground Floor
Visibility Study for the Ground Floor
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')
Three-Dimensional Views
Zoning Plan for the Ground Floor
Visual Fields from the Center of the Main Entry Hall
Visual Fields from the Center of the Main Public Space
Visual Fields from the Center of the Semi-private Space [1]
Visual Fields from the Center of the Semi-private Space [2]
Visual Fields along the Circulation Path for Residents
N
PVS
MPS
EN
VC
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. (D): Ground Floor
Syntactic Analysis (using Visibility Graph Analysis - VGA)
for the Ground Floor
(Carried out by Author using 'DepthMapX 0.50 Software')
Ground Floor Plan showing Common Spaces
Connectivity Analysis showing the Hierarchy of Common Spaces
Integration Analysis between Common Spaces and Apartments
Agent Analysis showing Pattern of Movement (from the Main Entry Hall)
Agent Analysis showing Pattern of Movement (from the Main Public Space)
Agent Analysis showing Pattern of Movement (from Semi-Private Space -1)
Agent Analysis showing Pattern of Movement (from Semi-Private Space -2)
N
MPS
VC
EN
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
Max. Value
Min. Value



Exp. No. (D): 2nd Segment
Visibility Study for a Typical Floor located on the 2nd Segment
(Carried out by Author using 'Syntax2D 1.3.0.7 Software')
Three-Dimensional Views
Zoning Plan for a Typical Floor located on the 2nd Segment
Visual Fields from the Center of the Main Public Space
Visual Fields from the Center of the Semi-private Space
Visual Fields along the Circulation Path for Residents
N
PVS
COR
MPS
VC
Court
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. (D): 2nd Segment
Syntactic Analysis (using Visibility Graph Analysis - VGA)
for a Typical Floor located on the 2nd Segment
(Carried out by Author using 'DepthMapX 0.50 Software')
Typical Floor Plan on the 2nd Segment showing Common Spaces
Connectivity Analysis showing the Hierarchy of Common Spaces
Integration Analysis between Common Spaces and Apartments
Agent Analysis showing Pattern of Movement (from the Circulation Core)
Agent Analysis showing Pattern of Movement (from the Main Public Space)
Agent Analysis showing Pattern of Movement (from Semi-Private Space)
N
PVS
MPS
COR
VC
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
Max. Value
Min. Value

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 (m2): 7000.0

Total Designed Area for the Building (m2): 6067.26

Total Number of Floors: 7

Total Height of the Building (meter): 26.4

Total Area of Common Spaces on All Floors (m2): 990.47 = 16.32 % of the Total Designed Area

Total Area of Residential Apartments on All Floors (m2): 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 (m2)	Total Designed Area for All Floors on Each Segment (m2)	% 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. %
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 %
TOTAL	7	51			6067.26	

Detailed Calculations for Residential Apartments

	Private Courtyards inside Apartments					Area of Apartments (including Courtyards)			
	Area on Each Floor (m2)	% 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 (m2)	% 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 %
5th Segment			%	0.0	0.0 %			0.0	0.0 %
6th Segment			%	0.0	0.0 %			0.0	0.0 %
TOTAL				181 = 3.57 % from the Total Area of Apartments	2.98 %			5076.79	83.68 %

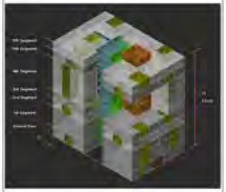
Detailed Calculations for Common Spaces inside the Building

	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
Ground Floor	58.72	6.61 %	58.72	0.97 %	35.25	3.97 %	35.25	0.58 %
1st Segment	58.72	6.61 %	176.16	2.9 %	35.25	3.97 %	105.75	1.74 %
2nd Segment	38.41	4.72 %	76.82	1.27 %	31.62	3.88 %	63.24	1.04 %
3rd Segment	39.12	4.41 %	39.12	0.64 %	35.25	3.97 %	35.25	0.58 %
4th Segment	0.0	%	0.0	0.0 %	0	%	0.0	0.0 %
5th Segment	0.0	%	0.0	0.0 %	0	%	0.0	0.0 %
6th Segment	0.0	%	0.0	0.0 %	0	%	0.0	0.0 %
TOTAL			350.82	5.78 %			239.49	3.94 %

	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	33.36	3.76 %	0.55 %	51.7	5.82 %	51.7	0.85 %	54.45	6.13 %	54.45	0.9 %
1st Segment				51.7	5.82 %	155.1	2.56 %	54.45	6.13 %	163.35	2.69 %
2nd Segment				54.45	6.69 %	108.9	1.79 %	54.45	6.69 %	108.9	1.79 %
3rd Segment				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 %
5th Segment				0	%	0.0	0.0 %	0.0	%	0.0	0.0 %
6th Segment				0	%	0.0	0.0 %	0.0	%	0.0	0.0 %
TOTAL	33.36	3.76 %	0.55 %			367.4	6.05 %			381.15	6.28 %

Exp. No. (B)

Spatial Calculations



Ground Floor Plan

Overall Calculations for the Building

Total Allowable Area for the Building (m2)	16200.0
Total Designed Area for the Building (m2)	13620.44
Total Number of Floors	12
Total Height of the Building (meter)	46.4
Total Area of Common Spaces on All Floors (m2)	2952.51 = 21.68 % of the Total Designed Area
Total Area of Residential Apartments on All Floors (m2)	10667.93 = 78.32 % 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 (m2)	Total Designed Area for All Floors on Each Segment (m2)	% from the Total Designed Area of the Building
Ground Floor	1	7	7	1248.7	1248.7	9.17 %
1st Segment	3	15	5	1248.7	3746.2	27.5 %
2nd Segment	1	5.	5	1248.7	1248.7	9.17 %
3rd Segment	1	5.	5	1248.7	1248.7	9.1 %
4th Segment	4	16	4	907.61	3630.4	26.6 %
5th Segment	1	5.	5	1248.7	1248.7	9.17 %
6th Segment	1	5.	5	1248.7	1248.7	9.17 %
TOTAL	12	58			13620.44	100 %

Detailed Calculations for Residential Apartments

	Private Courtyards inside Apartments					Area of Apartments (including Courtyards)			
	Area on Each Floor (m2)	% 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 (m2)	% from the Area of Each Floor	Area on All Floors of the Segment	% from the Total Designed Area of the Building
Ground Floor	82.8	8.78 %	6.63 %	82.8	0.61 %	943.24	69.87 %	943.24	6.93 %
1st Segment	79.2	8.05 %	6.34 %	237.6	1.74 %	983.73	72.87 %	2951.19	21.67 %
2nd Segment	119.5	12.15 %	9.57 %	119.5	0.88 %	983.42	72.85 %	983.42	7.22 %
3rd Segment	118.7	12.07 %	9.51 %	118.7	0.87 %	983.73	72.87 %	983.73	7.22 %
4th Segment	63.1	8.89 %	6.95 %	252.4	1.85 %	709.8	52.58 %	2839.2	20.85 %
5th Segment	120.6	12.26%	9.66 %	120.6	0.89 %	983.73	72.87%	983.73	7.22 %
6th Segment	124.9	12.7 %	10.0 %	124.9	0.92 %	983.42	72.85 %	983.42	7.22 %
TOTAL				1056 = 9.9 % from the Total Area of Apartments	7.76 %			10667.93	78.32 %

Detailed Calculations for Common Spaces inside the Building

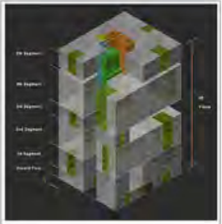
	Main Public Space (MPS)				Semi-Private Spaces (PVS)			
	Area on Each Floor (m2)	% from the Area of Each Floor	Area on All Floors of the Segment	% from the Total Area of the Building	Area on Each Floor (m2)	% from the Area of Each Floor	Area on All Floors of the Segment	% from the Total Area of the Building
Ground Floor	121.5	9.73 %	121.5	0.89 %	30.36	2.43 %	30.36	0.22 %
1st Segment	121.5	9.73 %	364.5	2.68 %	30.36	2.43 %	91.08	0.67 %
2nd Segment	68.85	5.51 %	68.85	0.51 %	30.36	2.43 %	30.36	0.22 %
3rd Segment	68.85	5.51 %	68.85	0.51 %	30.36	2.43 %	30.36	0.22 %
4th Segment	68.85	7.59 %	275.4	2.02 %	30.36	3.35 %	121.44	0.89 %
5th Segment	68.85	5.51 %	68.85	0.51 %	30.36	2.43 %	30.36	0.22 %
6th Segment	68.85	5.51 %	68.85	0.51 %	30.36	2.43 %	30.36	0.22 %
TOTAL			1036.8	7.63 %			364.32	2.66 %
		Double Volume	151.17	1.06 %				

	Entry Hall (EN)		
	Area (m2)	% from the Area of the Floor	% from the Total Area of the Building
Ground Floor	40.5	3.24 %	0.3 %
1st Segment			
2nd Segment			
3rd Segment			
4th Segment			
5th Segment			
6th Segment			
TOTAL	40.5	3.24 %	0.3 %

	Corridors (COR)				Vertical Core (VC)			
	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	45.63	3.65 %	45.63	0.34%	67.52	5.41%	67.52	0.5 %
1st Segment	45.63	3.65 %	136.89	1.01 %	67.52	5.41 %	202.56	1.49 %
2nd Segment	45.95	3.68 %	45.95	0.34 %	67.52	5.41%	67.52	0.5 %
3rd Segment	45.63	3.65 %	45.63	0.34 %	67.52	5.41 %	67.52	0.5 %
4th Segment	45.95	5.06 %	183.8	1.35 %	67.52	7.44%	270.08	1.98 %
5th Segment	45.63	3.65 %	45.63	0.34 %	67.52	5.41 %	67.52	0.5 %
6th Segment	45.95	3.68 %	45.95	0.34 %	67.52	5.41 %	67.52	0.5 %
TOTAL			549.48	4.06 %			810.24	5.97 %

Exp. No. (C)

Spatial Calculations



Ground Floor Plan

Overall Calculations for the Building

Total Allowable Area for the Building (m2): 16800.0

Total Designed Area for the Building (m2): 14704.01

Total Number of Floors: 16

Total Height of the Building (meter): 58.2

Total Area of Common Spaces on All Floors (m2): 2372.79 = 16.14 % of the Total Designed Area

Total Area of Residential Apartments on All Floors (m2): 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 (m2)	Total Designed Area for All Floors on Each Segment (m2)	% 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 %
TOTAL	16	94			14704.01	100 %

Detailed Calculations for Residential Apartments

	Private Courtyards inside Apartments					Area of Apartments (including Courtyards)			
	Area on Each Floor (m2)	% 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 (m2)	% 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 %
TOTAL				985 = 7.99 % from the Total Area of Apartments	6.7 %			12331.22	83.86 %

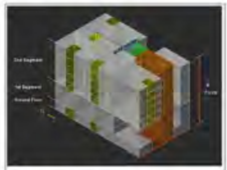
Detailed Calculations for Common Spaces inside the Building

	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
Ground Floor	52.48	5.27%	52.48	0.36%	13.13	1.32 %	13.13	0.09 %
1st Segment	52.48	5.7 %	157.44	1.07%	13.13	1.42 %	39.39	0.27 %
2nd Segment	21.76	2.19%	87.04	0.59%	26.27	2.64 %	105.08	0.71 %
3rd Segment	26.94	3.93 %	53.88	0.37%	13.13	1.91 %	26.26	0.18 %
4th Segment	24.26	2.44 %	97.04	0.66 %	26.27	2.64 %	105.08	0.71 %
5th Segment	19.79	2.46 %	39.58	0.27 %	13.13	1.63 %	26.26	0.18 %
6th Segment	27.84	2.8 %	0.0	0.0 %	0	0.0 %	0.0	0.0 %
TOTAL			487.46	3.32 %			315.2	2.14 %
			Double Volume	0.79 %				

	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	35.0	3.52 %	0.24 %	34.67	3.48 %	34.67	0.24%	52.5	5.27%	52.5	0.36 %
1st Segment				29.17	3.17 %	87.51	0.6 %	52.5	5.7 %	157.5	1.07 %
2nd Segment				42.25	4.24 %	169.0	1.15 %	52.5	5.27%	210.0	1.43 %
3rd Segment				29.17	4.25 %	58.34	0.4 %	52.5	7.65 %	105.0	0.71 %
4th Segment				42.25	4.24 %	169.0	1.15 %	52.5	5.27%	210.0	1.43 %
5th Segment				29.17	3.63 %	58.34	0.4 %	52.5	6.53 %	105.0	0.71 %
6th Segment				0	0.0 %	0.0	0.0 %	52.5	5.27%	0.0	0.0 %
TOTAL	35.0	3.52 %	0.24 %			576.86	3.94 %			840.0	5.71 %

Exp. No. (D)

Spatial Calculations



Ground Floor Plan

Overall Calculations for the Building

Total Allowable Area for the Building (m2)	13500.0
Total Designed Area for the Building (m2)	11605.15
Total Number of Floors	9
Total Height of the Building (meter)	34.4
Total Area of Common Spaces on All Floors (m2)	2327.52 = 20.06 % of the Total Designed Area
Total Area of Residential Apartments on All Floors (m2)	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 (m2)	Total Designed Area for All Floors on Each Segment (m2)	% from the Total Designed Area of the Building
Ground Floor	1	8	8	1439.4	1439.4	13.0 %
1st Segment	3	30	1	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 %
TOTAL	9	68			11076.35	
				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 (m2)	% 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 (m2)	% 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 %
4th Segment	0	0	null %	0.0	0.0 %	0	0	0.0	0.0 %
5th Segment	0	0	null %	0.0	0.0 %	0	0	0.0	0.0 %
6th Segment	0	0	null %	0.0	0.0 %	0	0	0.0	0.0 %
TOTAL				466	4.01 %			9277.63	79.94 %
				= 5.02 % from the Total Area of Apartments					

Detailed Calculations for Common Spaces inside the Building

	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
Ground Floor	88.08	6.12 %	88.08	0.8 %	40.53	2.82 %	40.53	0.37 %
1st Segment	88.08	8.22 %	264.24	2.39 %	40.53	3.78 %	121.59	1.1 %
2nd Segment	32.98	2.57 %	164.9	1.49 %	22.04	1.72 %	110.2	0.99 %
3rd Segment	0.0	0.0	0.0	0.0 %	0	null %	0.0	0.0 %
4th Segment	0.0	0.0	0.0	0.0 %	0	null %	0.0	0.0 %
5th Segment	0.0	0.0	0.0	0.0 %	0	null %	0.0	0.0 %
6th Segment	0.0	0.0	0.0	0.0 %	0	null %	0.0	0.0 %
TOTAL			517.22	4.68 %			272.32	2.46 %
			% of Double Volume =	-0.97 %				

	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	3.13 %	0.41 %	58.15	4.04 %	58.15	0.52 %	112.5	7.82 %	112.5	1.02 %
1st Segment				46.51	4.34 %	139.53	1.26 %	112.5	10.49%	337.5	3.05 %
2nd Segment				56.56	4.4 %	282.8	2.55 %	112.5	8.76 %	562.5	5.08 %
3rd Segment				0	null %	0.0	0.0 %	0.0	0.0	0.0	0.0 %
4th Segment				0	null %	0.0	0.0 %	0.0	0.0	0.0	0.0 %
5th Segment				0	null %	0.0	0.0 %	0.0	0.0	0.0	0.0 %
6th Segment				0	null %	0.0	0.0 %	0.0	0.0	0.0	0.0 %
TOTAL	45.0	3.13 %	0.41 %			480.48	4.33 %			1012.5	9.15 %