BRITISH COUNCIL | Newton Fund | INSTITUTIONAL LINKS

International Conference for

Sustainable Design of the Built Environment SDBE 2017

Proceedings

Editors

Heba Elsharkawy
Sahar Zahiri
Jack Clough

SDBE Sustainable Development of the Built Environment | UEL University of East London | Ain Shams University | University of Strathclyde Glasgow

Scientific Committee

Prof. Hassan Abdalla, University of East London
Dr. Wael Abdelhameed, University of Bahrain
Prof. Ahmed Abdin, Cairo University
Prof. Khalifa Al-Jabri,
Sultan Qaboos University
Dr. Chaham Alalouch,
Sultan Qaboos University
Prof. Ayman Ashour, Ain Shams University
Prof. Suzette Aziz, Arab Academy for Science, Technology & Maritime Transport
Dr. Isin Can, İzmir Institute of Technology
Mr. Alan Chandler, University of East London
Dr. Stuart Connop, University of East London
Dr. Mihaela Anca Ciupala, University of East London
Mr. Jack Clough, University of East London
Dr. Ranjith Dayaratne, University of Bahrain
Prof. Khaled Dewidar, British University in Egypt
Dr. Bahar Durmaz Drinkwater, İzmir University of Economics
Prof. Ibtihal El-Bastawissi, Beirut Arab University
Prof. Germin Elgohary, Ain Shams University
Prof. Omar El-Husseiny, Ain Shams University
Dr. Heba Elsharkawy, University of East London
Dr. Ayman Hamza, Ain Shams University
Dr. David Grierson, University of Strathclyde
Prof. Rajat Gupta, Oxford Brookes University
Prof. Mostafa Ismail, Ain Shams University
Prof. Philip Jones, Cardiff University
Dr. Mohammad Arif Kamal, Aligarh Muslim University
Dr. Anastasia Karandinou, University of East London
Prof. Marwa Khalifa, Ain Shams University
Dr. Simon Lannon, Cardiff University
Prof. Ayman Mahmoud, Cairo University
Prof. Jitka Mohelníková, Brno University of Technology
Prof. Yasser Mansour, Ain Shams University
Prof. Darryl Newport, University of East London
Dr. Ashraf Nessim, Ain Shams University
Dr. Farzad Pour Rahimian, University of Strathclyde
Prof. Ahmed Rashed, British University in Egypt
Dr. Peter Rutherford, University of Nottingham
Prof. Ashraf Salama, University of Strathclyde
Ms. Maria Segantini, University of East London
Prof. Zeinab Shafik, Cairo University
Prof. Steve Sharples, University of Liverpool
Prof. Lobna Sherif, Arab Academy for Science, Technology & Maritime Transport
Prof. Nagwa Sherif, American University in Cairo
Dr. Sahar Zahiri, University of East London

Keynote speakers

Prof. Brian Ford, Emeritus Professor, University of Nottingham
Prof. Rajat Gupta, School of Architecture, Oxford Brookes University
Mr. Mark Jenkinson, , City of London Director, Siemens
Prof. Philip Jones, Welsh School of Architecture, Cardiff University
Mr. Bruno Moser, Head of Urban Design, Foster and Partners
Prof. Fergus Nicol, London Metropolitan University
Prof. Steve Sharples, School of Architecture, University of Liverpool
Mr. Charles Walker, Director Zaha Hadid Architects

Editors

Dr. Heba Elsharkawy
Dr. Sahar Zahiri
Mr. Jack Clough

Vernacular Neighbourhoods as Models for Socially-Sustainable Vertical Cities: A Computational Approach

Amer Al-Jokhadar[1] and Wassim Jabi[2]

[1] Ph.D. Researcher, Welsh School of Architecture, Cardiff University, UK. Correspondence Email: Al-JokhadarA@cardiff.ac.uk

[2] Reader, Welsh School of Architecture, Cardiff University, UK. Email: JabiW@cardiff.ac.uk

Abstract: The Middle East and North Africa (MENA) region has one of the world's most rapidly expanding urban population. This issue has dramatic impacts on the built environment and increases the need for constructing sustainable vertical buildings. However, most recent developments in the study area have focused on utilising technology and have ignored the potential of incorporating social needs and cultural values. Information gained from a post-occupancy evaluation for contemporary apartment buildings in MENA region show that there are several problems affected 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 and the standarization of floors destructed the privacy of the family and the identity of each unit. In contrast, vernacular neighbourhoods in the study area represent a successful example of a socially cohesive and healthy environment. For instance, the hierarchical configuration of public spaces and private courtyards allow for a high degree of social interaction between families, and at the same time maintain their privacy. This research aims to benefit from potentials of such horizontal clusters for generating socially-sustainable tall residential buildings that trace the cultural values of the society. Spatial analysis of various traditional neighbourhoods was adopted as a rigorous method for understanding the layout complexity and discovering logical topologies that have social or experiential significance. Using principles of shape grammar, results extracted from the analytical process, associated with specific requirements for vertical buildings, were used to identify sets of parametric rules that combine geometrical properties of spaces with aspects that enhance the social life of residents. Samples of potentially sustainable social solutions, generated by a computational tool, are presented.

Keywords: Tall Residential Buildings, Social Sustainability, Courtyards, Spatial Reasoning, Parametric Grammars

Introduction

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% (215 million) of urban inhabitants (Serageldin et al., 2015). This number, which is expected to reach the double by 2050, increases the demand for affordable high-rise living and working spaces (Hudgins, 2009; Yeang, 2012; Modi, 2014). A high-rise building is a massive built up spaces on a small footprint. Ken Yeang (2012) claims that this huge volume could be defined as a '*vertical city*', which requires architects to take into account the different pillars of sustainability during the design process to improve the quality of life and to achieve the needs of users. However, the broad attention of sustainable developments is concerned with environmental and economic dimensions rather than the social aspect (Cuthill, 2010). For instance, designs of contemporary high-rise buildings do not reflect a realisation of social spaces, local traditions or appropriate living patterns as a high priority.

A study, conducted by Professor Ade Kearns (2012) and his colleagues (2012) in Glasgow, examines the social outputs of living in high-rise buildings compared to other types of dwellings. They concluded that the current designs of such developments have negative impacts on residents. These issues could be summarised in six categories: (1) fear and insecurity; (2) lower sense of community and familiarity with neighbours; (3) lower

levels of social support due to isolation; (4) lack of identity for each unit due to the standardization of floor plates; (5) mental/physical health effects due to the overcrowded spaces; and (6) impacts on families and children as parents keep their children indoors due to safety concerns and difficulties of supervision at a distance.

In contrast to the contemporary model of vertical buildings, vernacular neighbourhoods in many cities in MENA region (e.g., Cairo, Tunis, Aleppo, Medina, Algeria, Fez, and Marrakech) could be considered as a homogeneous fabric and a socially sustainable townscape (Bianca, 2000; Al-Masri, 2010). For instance, public squares, which have been designed by residents themselves as a response to their needs, norms, behavioural and cultural values, allow for a high degree of social interaction between people, and reflect their sense of community (Al-Jokhadar and Jabi, 2016). Moreover, the hierarchal movement pattern increases degrees of privacy, and at the same time maintains a balance between isolation and interaction (Crouch and Johnson, 2001).

Learning from previous experiences is a suitable way to design with sensitivity as it provides continuity to the existing context, and the cultural roots of the society (Ragette 2003). This research builds on the benefits of the vernacular model of residential quarters to generate vertical developments that could enhance the social life inside these buildings and the well-being qualities, such as privacy and security, for residents.

Social Sustainability

Social sustainability is about reflecting the identity of the place, and the different needs of users, on the spatial design of the physical environment (Berkeley-Group and UK-GBC, 2012). Schwarz and Krabbendam (2013) identified four qualities for socially sustainable designs: (1) sharing and interaction; (2) reflecting local culture; (3) connecting people and their living environment with nature; and (4) focusing on proportion and human scale/comfort.

One of the most difficult issues for designers is how to address these qualities in the design of spatial layouts. Each social quality has different indicators and measurements that could be translated into design specifications (Modi, 2014; Oldfield, 2012; Dempsey *et al.*, 2011; Cuthill, 2010). For instance, the social interaction could be enhanced through the provision of gathering spaces and courtyards inside the building. These common areas are also important features for providing secure playgrounds for children. Reflection of a local culture could be achieved through maintaining the visual privacy of families from neighbours. Therefore, it is recommended to arrange the layout of each floor in a hierarchal system of movement from the public (such as common gathering areas) to semi-private (such as corridors) to private areas (such as apartments). Moreover, entrances of residential units should be arranged in a staggered pattern. Finally, human comfort could be achieved with the availability of green areas, a suitable number of apartments on each floor, and appropriate width of corridors based on the number of people live on the floor.

Observations from the Current High-rise Residential Buildings in MENA Region

Exploring the current situation of residential buildings in MENA region, and recording the different needs of users are important issues for designing a socially sustainable development. A phenomenological survey has been conducted by the authors in the summer of 2016 to develop a holistic picture of the everyday life of residents. The study included a questionnaire distributed to 211 families from 17 countries within the study area. It focused on five aspects: (1) information about the house and the household structure; (2)

spatial descriptions; (3) social merits; (4) environmental qualities; and (5) information about neighbours and the housing context.

Outcomes from the field survey showed that residents expressed their concerns regarding five aspects, which have impacts on the social quality of spaces: (1) security; (2) social interaction; (3) crowding; (4) visual privacy; and (5) accessibility and hierarchy of spaces (see Table 1). Results showed that 71% of the sample who live in apartment buildings considered that their current houses do not afford secure outdoor spaces for children. Furthermore, results indicated that residents have a problem with social interaction with neighbours, as spaces in front of their apartments are limited to narrow circulation paths. To adapt to 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 or the courtyard inside their building respectively. Regarding other social problems in the study area, 62% of respondents reported that they live in houses that have crowded living areas. Moreover, entrances in most current buildings are located directly opposite to each other, which destruct the privacy of the family members. As a suggestion, 87% of 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, it is not exposed to the daily life, so it seems to be lifeless.

Table 1. Social Problems in Apartment Buildings in MENA Region (Authors)

Social Indicators	Social Problems in Apartment Buildings in MENA Region	Percentage of Respondents
1. Security	- Current houses do not afford secure outdoor spaces for children	71 %
2. Social interaction	- There are limited spaces for social interaction with neighbours. To accommodate this problem, residents chat with neighbours:	
	o At the entrance of the building.	86 %
	o At the entrance of their apartment.	45 %
	o At the outside garden.	12 %
	o At the courtyard inside their building.	13 %
3. Crowding	- Residents live in buildings that are crowded regarding number of apartment on each floor	62 %
4. Visual privacy	- Entrances are located directly opposite to each other, which destruct the privacy of the family members.	86 %
	- Residents cannot use terraces/balconies due to the lack of privacy.	31 %
5. Accessibility and hierarchy of spaces	- There are many paths and circulation spaces between apartments.	54 %
	- Entrances of apartments open directly on the main core of the building	75 %

Exploring the Spatial Design of Residential Buildings in MENA Region

Social qualities of residential buildings could be explained through spatial configurations. This section aims to explore the spatial design of contemporary developments to address reasons of social problems presented in the previous section. Moreover, a spatial investigation for layouts of traditional neighbourhoods extends our understanding of the local culture and the different potentials of such precedents.

'Spatial reasoning' as a rigorous method for understanding the layout complexity, and exploring features that have social or experiential significance, has been adopted. Jerome

Bruner, in his studies about the psychology of knowing, defined 'reasoning' as 'going beyond the information given' (Bruner, 1973). For instance, tracing the visual fields from a certain location in a building allows a clear evaluation of spatial elements that affect the privacy of its occupants. To understand this complexity, two approaches have been adopted:

(1) Typological analysis, which involves categorizing components of designs that have shared characteristics according to predefined criteria (such as location, area, geometric properties, and patterns of arrangement).

(2) Syntactical analysis, which explores topological and social relations implicit in the architectural setting (Hillier and Hanson, 1984). Results extracted from this analysis are presented mathematically (control and integration values), which are useful for interpreting the social life and the overall configuration of selected cases (e.g., high integration values indicate that spaces are busy, more accessible, and less private). Two 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) (Wineman et al., 2007). Secondly, *DepthmapX*, which is a 'Visibility Graph Analysis (VGA)' tool to understand the spatial configuration of the environment (Turner, 2001). 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.

Readings from Traditional Neighbourhoods and Contemporary Apartment Buildings

A detailed typological analysis and a syntactical evaluation for four clusters of traditional houses and five apartment buildings, located in MENA region, have been conducted to assess the social quality of these arrangements. The layout of traditional neighbourhoods in the study area is usually characterised by organic spatial configurations with more than one focal centre, and a hierarchal system of open spaces. However, this irregularity of layouts produces a homogeneous urban fabric and balanced townscapes that are determined by specific social and cultural principles (Bianca, 2000). In contrast, the layout of contemporary residential buildings has one focal point, which is the main vertical core. In most cases, this space is considered the main gathering area for all apartments, which is attached directly to the entrance of residential units. The following illustrates results of analysis according to social indicators concerned by residents.

Social Interaction and Human Comfort

The dense structure and the physical cohesion layout are prominent features of traditional clusters. However, open spaces, which constitute an approximately half area of the cluster (39% to 54%), offer a valuable element in such harsh environments and could reduce external heat gain or loss (Ragette, 2003; Moossavi, 2014). The spatial analysis shows that open public spaces form 21% to 38% of the cluster's area (see Table 2). Moreover, the percent of private courtyards relative to the total ground floor area of residential units represents 18% to 28%. These open areas invite the gathering of residents at various times of the day and on different levels. Also, such spaces allow social interaction at a family level in private courtyards; social interaction among women and children in cul-de-sacs and semi-private alleyways; and mixed interaction in public spaces (Eben Saleh, 1997).

On the other hand, semi-public and semi-private spaces in front of apartments in contemporary buildings are limited to circulation paths and constitute less than 10% of the floor area (see Figure 1). Moreover, open spaces (such as balconies, terraces or courtyards)

represent only 3% from the total area of residential units, which, therefore, affected degrees of social interaction among neighbours, and levels of human comfort inside the house.

Figure 1. Common gathering spaces and open areas in (a) a traditional residential quarter; (b) contemporary apartment buildings (Authors)

Table 2. Percentages of open areas, public spaces and courtyards in traditional neighbourhoods (Authors)

Case No. and Location	Total Area of the Cluster (m^2)	Open Areas		Public Spaces		Private Courtyards	
		Area (m^2)	%	Area (m^2)	%	Area (m^2)	%
CLUS-1 (Egypt)	1185	616	52 %	454	38 %	162	22 %
CLUS-2 (Iraq)	1642	885	54 %	622	38 %	263	26 %
CLUS-3 (Iraq)	1929	755	39 %	499	26 %	256	18 %
CLUS-4 (Syria)	4525	1856	42 %	929	21 %	759	28 %

Accessibility, Hierarchy of Spaces, Safety, and Security

The access from public areas to residential units in traditional quarters is usually controlled and broken into hierarchical sections. Each group of courtyard houses is clustered around a small public space (a cul-de-sac), which varies in its width between 2.50 and 5.95 meters. These spaces are connected with main public spaces (width = 3.15 to 11.25 meters) through narrow-secondary alleys and pedestrian walkways (width = 2.25 to 3.50 meters) (see Figure 2). Syntactical analysis of such clusters shows that public spaces and courtyards have the highest connectivity values (as represented in Figure 2 with red/orange colours). This system prevents conflicts with the public realm, makes residents able to manage their desired rate of social contact, allows for children a secure place to meet and play with nearby neighbours, and at the same time maintains a balance between isolation and interaction (Mortada, 2003; Eben Saleh, 1997).

In contrast to the vernacular model, investigations at the scale of contemporary buildings show that there is a sudden transition from the vertical circulation core to the entrance of apartments, and from the entry point to the living area inside the house. Such issues have negative impacts on security and privacy of residents.

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, which are arranged in a staggered pattern that protects family members from outside strangers (see Figure 3). Moreover, entrances are connected with a small semi-private space instead of a main public area. In the case of linear passageways, entrances are usually lead to a corner of a house, where there are no private activities. In contrast to these patterns, entrances in most current developments are located opposite to each other with no visual barriers in front of doors.

Figure 2. 'Agent Analysis', showing patterns of movement and the frequent use of spaces released from the main public space, and 'Connectivity Analysis', showing number of points that are connected visually to other spaces produced by 'DepthmapX 0.50' software: (a) in traditional residential quarters; (b) in contemporary apartment buildings (Authors)

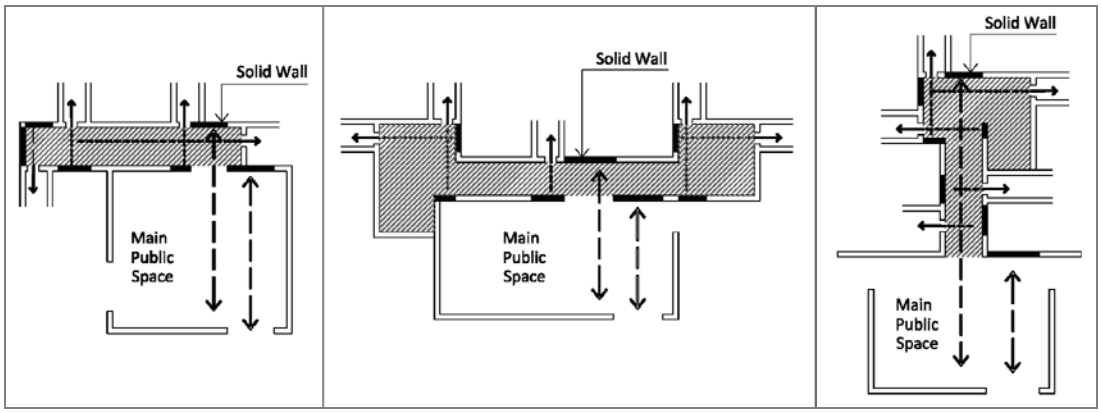

Figure 3. Strategies for achieving visual privacy in traditional neighbourhoods (Authors)

Strategies for Designing a Socially-Sustainable Vertical Building

A successful design means that it has an 'identity', which relates to the design of all components in harmony with context, climate, needs, and requirements of the modern and future time (Mehrpoya *et al.,* 2015). Yet, a socially-sustainable high-rise building needs a sensitive approach that deals with social interaction and accessibility inside the building while maintaining the privacy of residents (Kennedy *et al.,* 2015).

One approach to deal with these issues is to incorporate the local tradition and its unique responses to spatial arrangement, place, and climate, in the design of contemporary buildings (Lim, 2004, as cited in (AlHaroun, 2015). This methodology generates a

'contemporary vernacular' architecture that has symbolic identities. Information gained from the analytical process showed that traditional clusters have many potentials that are useful for achieving a socially-sustainable environment. Ken Yeang, for example, bases his works on the adaptation of regional architecture 'a critical regionalism approach', through understanding traditional values, as well as the importance of progress, without the direct use of traditional forms and materials (Pomeroy, 2013). This way of thinking, which leads design 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 they declare the inevitability of change in the age of globalisation (Ragette, 2003).

Based on that, results extracted from traditional neighbourhoods are used to establish a database that identifies spatial elements and specific relationships. This database, associated with spatial requirements of high-rise buildings, is used to generate alternatives for vertical developments. On a basic level, the overall social qualities of such horizontal quarters could have the potential of being transferred into vertical arrangements by dividing it into segments, as a representation of neighborhoods in a traditional fabric. This solution could highly promote the concept of hierarchy and clustering that create a mutual responsibility for common spaces in each segment for encouraging interaction between neighbors.

Shape grammar, as a rule-based system for generating layouts, is used. This system, developed by George Stiny and James Gips in 1970s, has a bottom-up approach, which starts with generating an initial shape (Stiny and Mitchell, 1978). 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; (3) formulating rules to be applied on forms; and (4) combining/articulating shapes through applying rules recursively, to define a language of design (Eilouti and Al-Jokhadar, 2007).

Establishing a Parametric Socio-Spatial Grammar

A residential cluster could be divided into two main zones: (a) common spaces, which represent the public zone that include gathering areas and corridors; and (b) residential units, which are the private zone for residents. Based on the typological analysis presented in the previous section, a socially-sustainable residential environment needs to include a hierarchal system of common spaces, which consists of: (a) a main public space (MPS); (b) semi-private spaces between residential units (PVS); and (c) pedestrian pathways (COR) that connect those two types. The total area of these spaces represents 21% to 38% from the area of the cluster. To increase the environmental benefits of such gatherings 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, semi-private spaces in front of apartments could be covered and considered as transitional/gathering areas.

To maintain a balance between isolation and interaction inside the residential unit, it is recommended to include a private courtyard for each house. There are different typologies for the location of such an introverted open space (see Figure 4). In high-rise residential buildings, the selection of appropriate typology is determined by two factors: (a) the location of the residential unit in relation to other units on the same floor; and (b) 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 (see Figure 5).

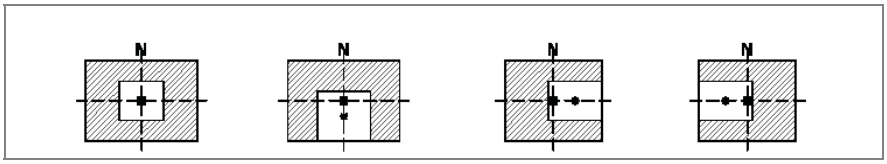

Figure 4. Typologies for the location of courtyards inside traditional houses (Authors)

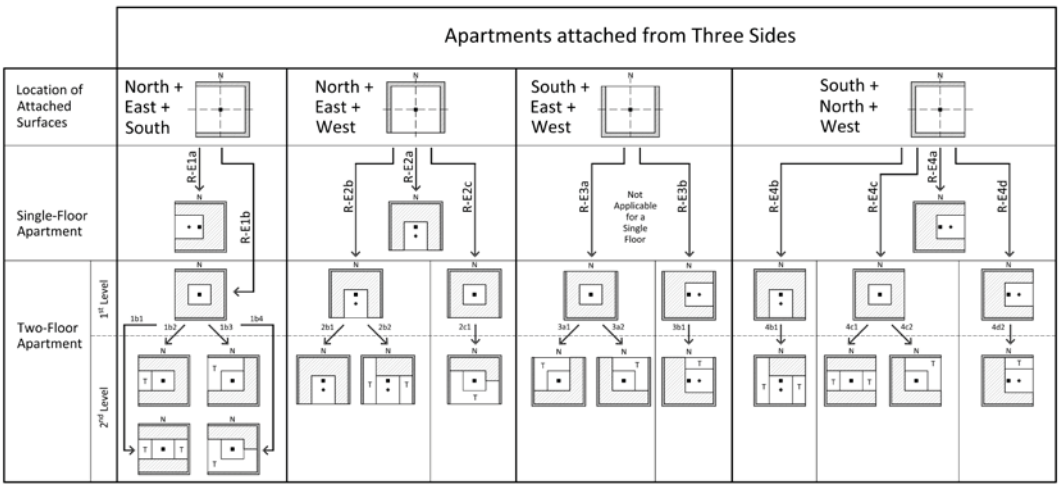

Figure 5. Sample of rules showing typologies of apartments and location of courtyards based on number of attached surfaces with other apartments on the same floor (Authors)

As creativity, flexibility, and adaptability are important issues that need to be addressed in the design process, a parametric design approach is incorporated in the construction of the grammar. Two characteristics are associated with such 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 (Jabi, 2013). For this study, the following parameters are defined: (a) geometric configuration of common spaces and courtyards; (b) the percent of public and semi-private spaces relative to the total area of the building; and (c) orientation of common spaces and private courtyards. Accordingly, social qualities of spaces could be affected positively or negatively (see Figure 6). 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.

Generating a High-rise Residential Building using a Computational Tool

The constructed grammar has been translated into a computational interface using 2D/3D CAD modeling software “Rhinoceros 3D”, with its plugin “Grasshopper”, to generate solutions with a high degree of accuracy in a short time of execution. Grasshopper is a visual scripting tool that helps the design to process. It allows input data to be passed from one component to another via connecting wires. 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. The tool suggests a list of 10 procedural tasks that guide the designer

through an interactive interface to define parameters and conditions (see Table 3). For each space, designers have the ability to define geometric properties, and alternatives for the location of each design element, through selecting numbers, as input data, from 'number sliders'.

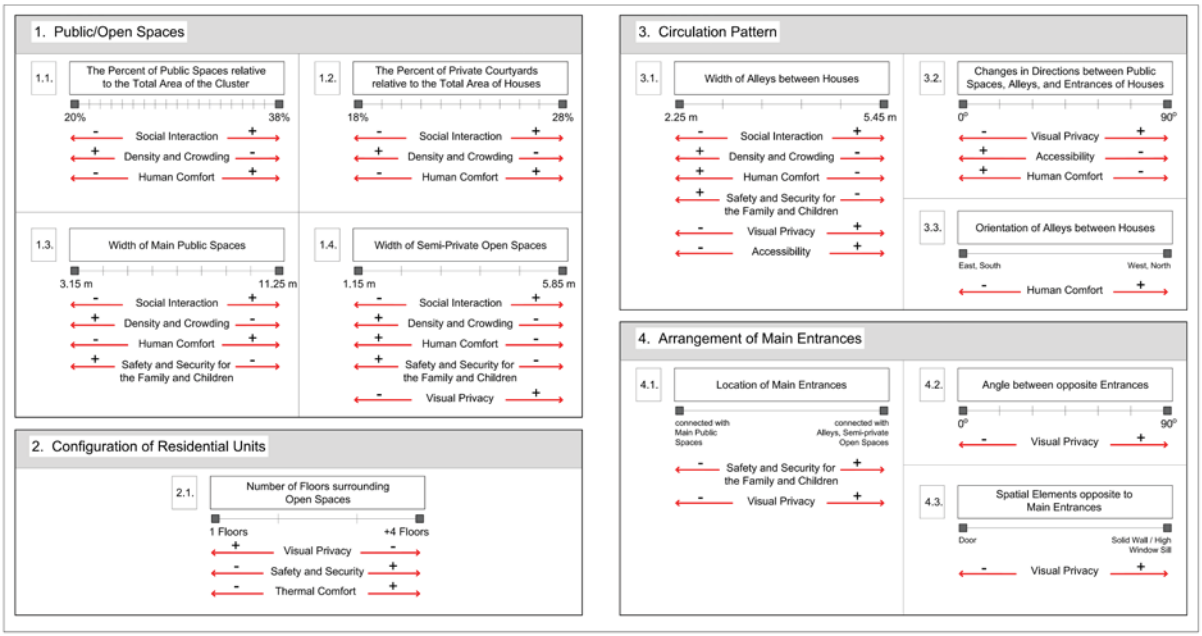

Figure 6. Parameters for main elements of design and how can affect qualities of social sustainability (Authors)

Table 3. Parameters and conditions for each task in the computational tool for generating a high-rise residential building (Authors)

Tasks and Stages of Design	Inputs (Parameters and Conditions)
1. Generating the allowable built-up area for the building	Width, length
2. Generating a vertical core (VC)	Width, length, height above roof level, location
3. Generating the main entry hall (EN)	Width, length, location
4. Generating the main public space (MPS) on the ground floor	Width, length, location
5. Generating a grid of structural columns	Size, distances between columns (x-axis, y-axis)
6. Generating corridors on ground floor (connecting EN, VC, MPS)	Width, location
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 MPS on each segment, typologies for the connection of MPS with the outside
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
9. Generating the layout of residential apartments	Maximum and minimum area of apartments on each segment, width and length of apartments
10. Generating courtyards for each apartment	Width, location

During the implementation of each task, two-dimensional plans for all segments and three-dimensional views of the design are presented. Moreover, the interface provides the user with overall calculations for the building, which include: total number of floors, total height of the building, total allowable built-up area, total area of common spaces, total area of residential units, number of apartments, detailed areas for each space, and percentage of area for each design feature from the total area of the building.

The tool has been tested to generate different solutions for high-rise buildings through modifying width, length, and location of each space. Figures (7) and (8) illustrate design alternatives for a 19-floor building and a 13-floor building, respectively, by changing number of floors on each segment of the design.

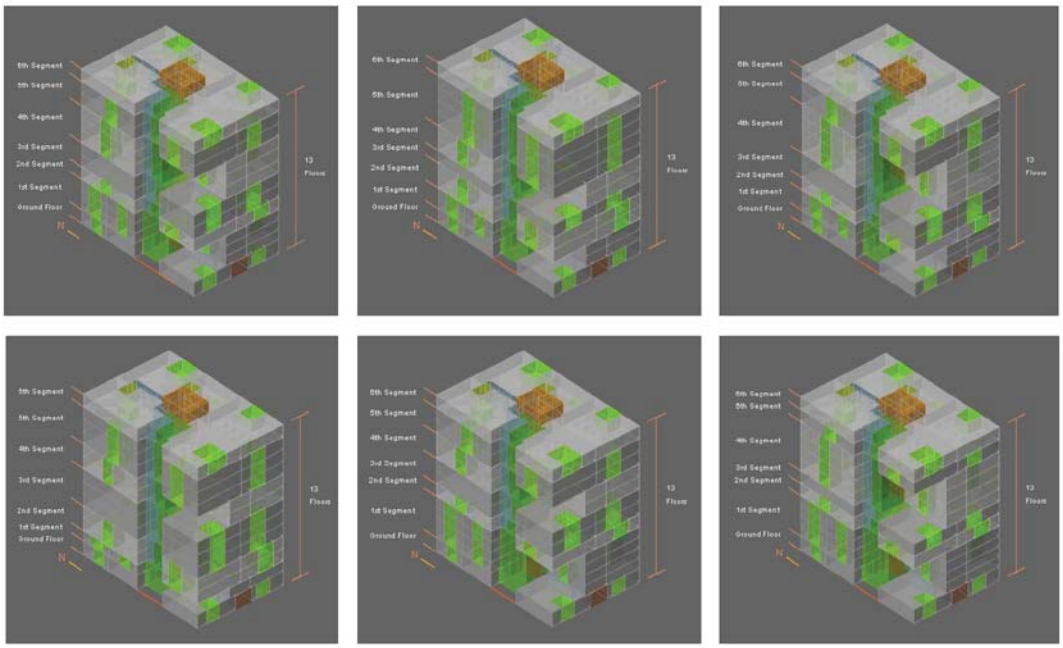

Figure 7. Six different alternatives for a 13-floor residential building generated by the developed parametric grammar, through changing number of floors on each segment of the building (Authors)

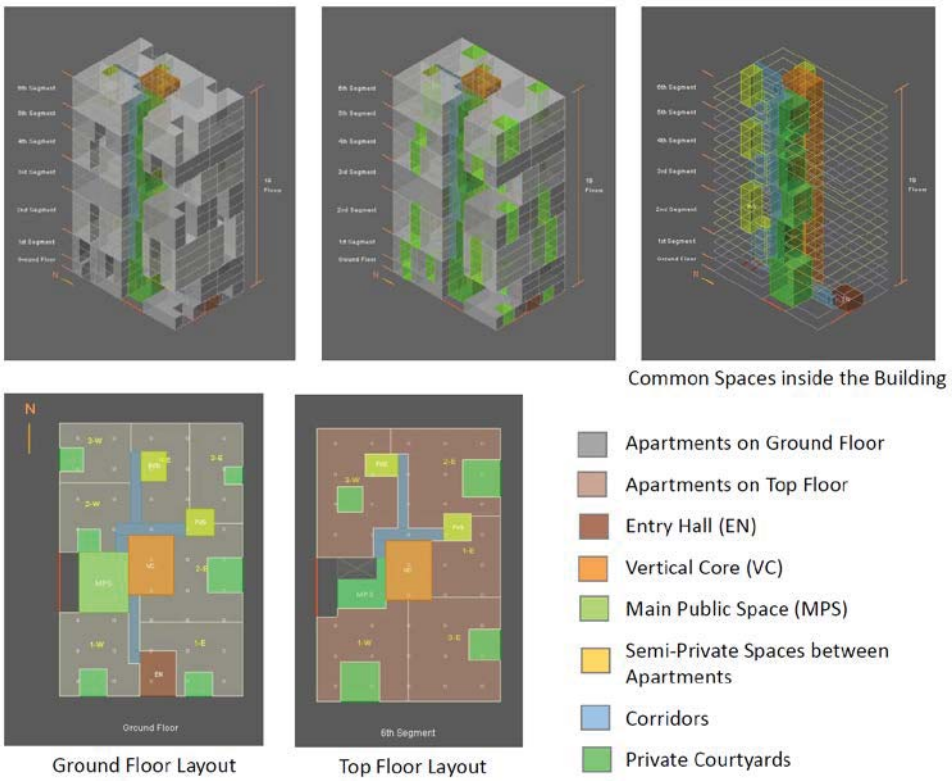

Figure 8. A 19-floor residential building generated by the developed parametric grammar, showing the hierarchy of common spaces and private courtyards (Authors)

Reflections and Conclusion

Achieving social sustainability in residential developments requires a holistic approach for clarifying spatial qualities that affect the social life inside the building. Information gained from the analytical reasoning process for traditional neighbourhoods in MENA region could help designers in problem interpretation and the projection of extracted results into new alternatives. These factors create a type-based database that can be used to improve the social qualities of future developments. For instance, studying the location of each space, and measuring distances between functions, are useful for analysing accessibility and movement. Moreover, defining relationships between spaces offer information about their hierarchy, the degree of social interaction that takes place within them, and their ability to maintain the privacy of their occupants.

The proposed 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 to the generation process.

The spatial analysis for alternatives produced by the developed interface shows that common spaces inside the building represent 18% of the total area of the building. Moreover, private courtyards represent 11% from the area of residential units. Therefore, several rewards, for both residents and developers, could be achieved using the developed model. Regarding social benefits, the hierarchal system of spaces and the availability of gathering areas inside the building offer an attractive place for social relations and could increase the frequency of contact with neighbours. Moreover, these public courtyards alleviate the sense of overcrowding, and at the same time act as a buffer zone in front of the private domain of residential units, which could be used as playgrounds for children under the watchful eyes of their parents.

Regarding environmental benefits, courtyards inside the building are suitable areas for planting trees and shrubs, as they are open to the sun and the natural air. Therefore, this could offer thermal comfort for users, and reduce heat gain and energy consumption. In addition, different economic rewards, especially for developers, could be achieved. Public spaces inside the building and courtyards inside apartments are part of the rentable area and aid the selling of the apartment. Thus, there is a revenue with no loss area. Furthermore, there is an omission of corridor spaces, which constitute less than 5% of the total area of the building. Finally, there is a reduction in the number of fire doors, as the courtyard is part of the escape route, and the apartment is open to a well-ventilated access.

Acknowledgment

The authors would like to acknowledge the University of Petra, Jordan for funding the study. This research is supported by a Leverhulme Trust Research Project Grant (Grant No. RPG-2016-016).

References

Al-Jokhadar, A. and Jabi, W. (2016). 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. Proceedings of the CTBUH 2016 International Conference; China*. Chicago: Council on Tall Buildings and Urban Habitat, pp. 633–641.

Al-Kodmany, M.K.A.-D. (1999). Residential visual privacy: Traditional and modern architecture and urban design. *Journal of Urban Design,* 4, pp. 283–311.

Al-Masri, W. (2010). The Courtyard House in Kuwait Today: Design Approaches and Case Studies. In: Rabbat, N. (ed.) *The Courtyard House: From Cultural Reference to Universal Relevance*. Surrey, England: Ashgate Publishing Limited, in association with the Aga Khan Program for Islamic Architecture, pp. 203–222.

AlHaroun, Y. (2015). *Contemporary Attitudes to Vernacular Elements in Kuwait's Domestic Architecture: A Mixed Method Study*. University of Sheffield, UK.

Berkeley-Group and UK-GBC (2012). *Practical How-to Guide : How to Use a Social Sustainability Framework*. London.

Bianca, S. (2000). *Urban Form in the Arab World: Past and Present*. New York: Thames and Hudson Inc.

Bruner, J.S. (1973). *Beyond the Information Given: Studies in the Psychology of Knowing*. Jeremy, M. A. (ed.). New York: W W Norton & Co Inc.

Crouch, D. and Johnson, J. (2001). *Traditions in Architecture: Africa, America, Asia and Oceania*. Oxford: Oxford University Press.

Cuthill, M. (2010). Strengthening the 'social' in sustainable development: Developing a conceptual framework for social sustainability in a rapid urban growth region in Australia. *Sustainable Development,* 18, pp. 362–373.

Dempsey, N., Bramley, G., Power, S. and Brown, C. (2011). The Social Dimension of Sustainable Development: Defining Urban Social Sustainability. *Sustainable Development,* 19, pp. 289–300.

Eben Saleh, M.A. (1997). Privacy and communal socialization: The role of space in the security of traditional and contemporary neighborhoods in Saudi Arabia. *Habitat International,* 21, pp. 167–184.

Eilouti, B.H. and Al-Jokhadar, A.M. (2007). A Generative System for Mamluk Madrasa Form-Making. *Nexus Network Journal,* 9, pp. 7–30.

Hillier, B. and Hanson, J. (1984). *The Social Logic of Space*. Cambridge: Cambridge University Press.

Hudgins, M. (2009). *High-Tech Engineering Helps Skyscraper Developers Reach Record Heights*. National Real Estate Investor.

Jabi, W. (2013). *Parametric Design for Architecture*. London: Laurence King Publishing Ltd.

Kearns, A., Whitley, E., Mason, P. and Bond, L. (2012). 'Living the high life'? Residential, social and psychosocial outcomes for high-rise occupants in a deprived context. *Housing Studies,* 27, pp. 97–126.

Kennedy, R., Buys, L. and Miller, E. (2015). Residents' Experiences of Privacy and Comfort in Multi-Storey Apartment Dwellings in Subtropical Brisbane. *Sustainability,* 7, pp. 7741–7761.

Mehrpoya, H., Khuonbazi, V. and Ahouei, S. (2015). A comparison of 'identity' in vernacular (traditional) and contemporary (modern) houses. *WALIA Journal,* 31, pp. 69–75.

Modi, S. (2014). Improving the Social Sustainability of High-rises. *CTBUH Journal.* Council on Tall Buildings and Urban Habitat), pp. 24–30.

Moossavi, S.M. (2014). Passive Building Design for Hot-Arid Climate in Traditional Iranian Architecture Climate of Iran. *Green Architecture and Arts Magazine,* pp. 1–20.

Mortada, H. (2003). *Traditional Islamic Principles of Built Environment*. Oxon: RoutledgeCurzon, Tailor and Francis Group.

Mustafa, F.A. (2010). Using space syntax analysis in detecting privacy: a comparative study of traditional and modern house layouts in Erbil city, Iraq. *Asian Social Science,* 6, pp. 157–166.

Oldfield, P.F. (2012). *Tall Buildings and Sustainability*. University of Nottingham.

Oxman, R. and Gu, N. (2015). Theories and Models of Parametric Design Thinking. In: *eCAADe 33*.

Pomeroy, J. (2013). Internal Environment and Planning. In: Parker, D. and Wood, A. (eds.) *The Tall Buildings Reference Book*. Oxon: Routledge, pp. 123–132.

Ragette, F. (2003). *Traditional Domestic Architecture of the Arab Region*. Sharjah, UAE: American University of Sharjah.

Schwarz, M. and Krabbendam, D. (2013). *Sustainist Design Guide: How Sharing, Localism, Connectedness and Proportionality Are Creating a New Agenda for Social Design*. Amsterdam: BISPublishers.

Serageldin, M., Larsen, M. and Summers, B. (2015). *World Migration Report 2015*.

Stiny, G. and Mitchell, W.J. (1978). The Palladian grammar. *Environment and Planning B,* 5, pp. 5–18.

Turner, A. (2001). Depthmap: a program to perform visibility graph analysis. In: *Proceedings of the 3rd International Symposium on Space Syntax*. Atlanta, pp. 7–11.

Wineman, J., Turner, J., Parra, S., Jung, S.K. and Sense, N. (2007). Syntax2d: an open source software platform for space syntax analysis. In: KUBAT, A. (ed.) *Proceedings of the 6th International Space Syntax Symposium*. Istanbul Technical University, Istanbul, Turkey, pp. 23–26.

Woodcraft, S. (2012). Social Sustainability and New Communities: Moving from Concept to Practice in the UK. *Procedia - Social and Behavioral Sciences,* 68, pp. 29–42.

Yeang, K. (2012). *A Vertical Theory of Urban Design*. Available at: http://www.buildingfutures.org.uk.

ISBN: *978-1-9997971-0-2*
Project website: *www.newton-sdbe.uk*
Twitter: *@Newton_SDBE*