Investigating the Social Impacts of High-Density Neighbourhoods Through Spatial Analysis

Sahar Soltani[1][(✉)], Ning Gu[1] , Jorge Ochoa Paniagua[1] ,
Alpana Sivam[1] , and Tim McGinley[2]

[1] University of South Australia, Adelaide, SA 5000, Australia
sahar.soltani@mymail.unisa.edu.au
[2] Technical University of Denmark, Lyngby, Denmark

Abstract. Studies argue that higher density areas incur social problems such as lack of safety [1], while other studies provide evidence for the positive impact of high-density urban areas, for instance opportunities for social interactions and equal form of accessibility [2]. This paper argues that design factors can mediate the impacts of density on social aspects. Therefore, this study explores the extent to which design factors can be correlated to the social outcomes of different density areas. To do this, data from an empirical study conducted in the UK, which identified the relationship between density and social sustainability through cases of fifteen neighbourhoods, have been utilised. This paper has conducted further analysis based on these cases using a mixed method with spatial analysis tools. Outcomes show that some of the social results in the UK study such as safety are correlated with spatial factors like normalised angular choice. Moreover, the regression model created from the spatial indices can be used to predict the overall social sustainability index reported by the UK study.

Keywords: Urban density · Social sustainability · Spatial analysis · Space syntax · Urban Network Analysis

1 Introduction

As the world's urban population continues to grow, the shift towards more compact cities seems inevitable in most countries. Many scholars believe making cities more compact is a sustainable strategy which supports the environmental and economic growth of cities while having benefits for the population as well. The social benefits of intensifying the urban areas, however, remain controversial. Some studies argue that higher density areas incur social problems such as lack of sense of safety [1], while other studies provide evidence for the positive impact of high-density urban areas, for example more opportunities for social interactions and equal form of accessibility that promotes walking and cycling [2]. Although a large body of the literature contends that increasing density can improve social sustainability, we argue that increasing density does not always lead to the same impact unless we optimize design factors as well. The dilemma between a compact city and its social impact triggers the necessity to explore

the design role in improving the life quality of the residents while considering this mainstream urban strategy. Therefore, this study, with the focus on computational approaches, attempts to explore how the spatial design factors interact with the change of density. Moreover, the extent to which these design factors can be correlated to the social sustainability outcomes will be investigated. To do this, the paper uses the centrality graph theory and spatial network analysis [3] to study the street and building networks of fifteen suburbs characterised by various density ranges. The qualitative results on the relationship between density and social sustainability have been utilized as stated by the CityForm UK study [1], enabling further computational exploration of the cases possible for this paper. To quantify the network structure of the urban form, mathematical measurements are applied. Most of the methods employ the graph theory to model the urban structure into a more abstract graph consisting of nodes and edges which streamlines its measurement and interpretation. Using centrality, graph theory can identify the most important nodes in a network [3]. One of the primary methods in this approach is space syntax [4, 5]. Allowing for the statistical description of human behaviors such as movement and navigation, space syntax is based on a representation of the space which is inherently social [5]. Another method which is based on the graph theory is the Urban Network Analysis toolbox (UNA), developed in the City Lab at Harvard University; it addresses the buildings and their functions as the third element in the graph along with the street network [6]. This paper explores the correlation between some social sustainability aspects which are investigated in the UK study, namely social interaction, safety and the overall index of social sustainability with spatial indices, i.e. gravity, normalized angular choice and intelligibility. The outcomes confirm that when employing a suitable method, some social outcomes of densifying an area can be correlated and measured with the spatial indices. To measure these social impacts, the study needs to identify the key indicators of social sustainability which can be defined within the realm of the built environment. This can be a challenging task since there is rarely a widely accepted and commonly used category and measurements for this concept exclusively investigating the role of the built environment's design. Moreover, the existing studies generally do not provide a unified category, and some of the results are contradictory or inconsistent.

2   Social Impacts of High-Density Neighborhoods

A growing body of research shows that the concept of "compact city" has the potential to play an influential role in human well-being, quality of life and livability through the provisioning of a state of social sustainability [7–9]. Earlier studies approach this topic via a wide spectrum of definitions and perceptions of social sustainability. For instance, research on the social impacts of 25 medium-sized UK cities confirms the positive role of high-density housing on social equity [10]. Similarly, Yang [11] found that neighborhood satisfaction in high density areas in Portland (US) is higher than the same-attributed neighborhoods in Charlotte (US) which suggests consideration of spatial scale and context in studying the relationship between density and quality of life. Conversely, in Raman's [9] study on six neighborhoods in the UK, the greater

emphasis on layout and design of the neighborhoods, shows that the relationship between density and social sustainability is nonlinear. Instead, the spatial configuration of neighborhoods wields a stronger impact on experiential outcomes rather than density.

In one of the most comprehensive studies named "CityForm", three neighborhoods with different density ranges (high, medium and low) in five UK cities were selected to examine the assertion that denser forms support better transportation, economic viability and social merits. Through questionnaires and interviews, they conducted a research asking residents to describe and rate their living environment based on social sustainability measurements in the dimensions they had defined. The results of this study show that although denser areas facilitate environmental and social equity by providing better access to services and facilities, this process adversely affects the sustainability of a community by reducing perceived safety, social interaction and group participation. This in turn leads to a lack of community stability and sense of place [8, 12]. The same outcomes were extracted in a study on other cases in some small towns outside Helsinki, Finland, whereas the results of the research on the urban core areas were contradictory [13]. Kytta et al. [7] found that the correlation between density and social sustainability is rather complex and context dependent. Similar to previous studies, they demonstrate that high-density areas support better accessibility in both urban and suburban neighborhoods. Nevertheless, contrary to urban areas, better accessibility does not support perceived environmental quality by the residents in suburban areas, which induces poor well-being conditions as well. They believe that this contradiction is a result of misinterpreting the outcomes without considering the specific context or scenario in each case. They found that perceived environmental quality reaches its peak at a relatively high level of density (100 housing unit/ha), and then starts declining as the density increases. Although densifying the cities' inner areas can help to provide better social sustainability, the layout and configuration of density play a more important role than density alone. The same population density can be manifested in a quite different dwelling and built form configuration, layout, and design which can lead to different types of accessibility and physical proximity [14]. However, a limited number of studies attempt to define density based on the design of the physical elements.

3   Indicators of Social Sustainability in the Built Environment

Social sustainability in relation to the design of the built environment comprises various aspects, which can be directly affected by the urban form. In this regard, one major influential factor is accessibility. This is a mediated factor linking social sustainability to the built environment and addresses a major concern in social sustainability – equity. Accessibility is defined by the design layout and spatial configuration of the built environment and impacts on people's experience of living in the environment.

In a nutshell, social sustainability indicators in the built environment include:

- **Accessibility:** which refers to equal and convenient access to the key facilities and services and public transportation. This is how the design of the built environment can contribute to better experiential outcomes of the community and potentially lead to more sustainability.
- **Community sustainability or experiential outcomes:** this dimension refers to the provision of social interaction, social participation, safety and security, sense of place, and community stability which collectively can sustain a livable neighborhood [15].

These indicators have been selected exclusively for the built environment, however, as stated in the previous section, the results of the empirical studies are not always consistent in the densified areas in terms of social impacts. Thus, we argue that optimizing some of the design factors can mediate the impact of density. We assume that the spatial design factor can be correlated to the social impacts of density as the spatial analysis also explains social phenomena through the physical configuration.

4 Mixed Method Using Spatial Analysis

Spatial analysis enables the "morphological description" of a physical entity, for example a building or an urban setting to be directed in a systematic way, and to be associated with the social aspects of the built form. This paper utilizes a mixed method[1] using spatial analysis to analyze the role of design in the trade-off between social sustainability and density. Space syntax serves to explore the socio-spatial aspects of the built form, and the Urban Network Analysis toolbox (UNA) is employed to investigate the spatial accessibility of the cases. The two tools are used in a complementary way to overcome their limitations and measure the intended study goals more comprehensively [16]. To quantify the network structure of the urban form, mathematical approaches are required. Most methods employ the graph theory to model the urban structure into a more abstract graph which streamlines its measurement and interpretation. Graph theory represents the urban network with two key elements: nodes and edges [17]. In the space syntax analyses, the graph represents configurational relationships where spatial elements are nodes connected to each other through lines which denote the relationships. Spatial relations in space syntax analysis are based on the approach that is taken for measuring the distance between the spatial elements of a network. To measure the distances in a network of disaggregated lines, space syntax defines three distances according to the relationships between adjacent segments: firstly, Metric distance or "shortest length" measures the Euclidean distance between the two spatial elements; secondly, Topological distance, referred as "fewest turns", is the number of turns (change of directions) to get to a destination; and thirdly, Angular distance which denotes the angular changes that have to be taken in the travel between

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[1] The detailed justification, mapping and critical description of the method is presented in another paper which is published as part of the CAADRIA 2019 conference proceedings.

two points in a graph [18]. According to the angular distance definitions, Space syntax measures various spatial relations including depth, integration, choice and connectivity. Depth index is measured by the shortest distance between the spatial elements whether metric, angular or topological, based on how it is abstracted in human navigation. This is related to the definition of the connectivity parameter which denotes the number of immediate neighbors of each node. Integration value can calculate the closeness and accessibility of a point in a graph with reference to the other surrounding spaces. Integration is similar to closeness in centrality measurements except that integration calculates the angular distance while closeness takes metric distance into account. This value can predict the number of people presenting in a given area [19]. Choice in the space syntax analysis is mathematically similar to Betweenness centrality which refers to the probability of falling on any shortest path that links any pair of segments for a street segment. Interpretative models of space syntax can be developed using the parameters above whether intuitively or mathematically, which enables the statistical explanations of human behavior.

Addressing the shortcomings of space syntax, UNA includes the buildings' fabric and their function in a weighted graph. Thus, along with nodes and edges in the traditional network analysis, they include buildings as the third element. Unlike space syntax, they follow the conventional assignment of the edges to the streets, which the commuter needs to pass, and nodes to the intersections, where two or more edges meet, and the added element represents the origins and destinations of the traffic. Each building is connected to the closest street from its internode via the shortest perpendicular line. It is argued that in a spatial network, two lines with different building type - for example, one with high rise buildings and the other with detached houses - should not be treated in the same way and receive the same weight in the analysis [20]. Furthermore, missing buildings and activities, and assigning similar weights for all of them regardless of their function, location and distance from a node, overlooks some essential information about land use and density distribution [6]. UNA indices can be utilized for a wide range of analyses, for example from spatial accessibility to trip estimation derived from a particular building to other destinations. Some of the main indices which can be conducted to explore the impacts of density on the accessibility of various services in an area; reach, and gravity. These are explored in more detail below.

Considering each building as a node in the graph, reach measures the number of destinations and opportunities around each node within the radius R which determines the mode of transportation (walking, biking or driving). Each node can be weighted according to the study's desired features, e.g. floors, jobs or residences which can be interpreted as areal density measures [20]. In this case, reach calculates the weights instead of the number of destinations.

$$Reach^r[i] = \sum_{j \in V(G)-\{i\}; d[i,j] \leq r} W[j] \qquad (1)$$

Where [i, j] is the shortest path distance between nodes i and j in G, and W[j] is the weight of a destination node j.

In contrast to the reach index which only informs us about the accumulated weight or number of destinations, the gravity index provides additional information about the

attractiveness of the destinations and associated travel costs based on the distance between two or more nodes in the graph. It is inversely related to the shortest path between building i and other buildings in G. The exponent β determines the distance effect.

$$Gravity^r[i] = \sum\nolimits_{j \in V(G) - \{i\}; d[i,j] \leq r} \frac{W[j]}{e^{\beta.d[i,j]}} \tag{2}$$

5 Analysis

Considering the built form as two networks of streets and buildings, space syntax can be used to analyze the street network. The street layout provides a long-lasting framework that embodies various social behaviors such as movement, interaction and activity. As per density, since this paper uses the data from another research study which already provided data around density and social outcomes, the focus will be on the opportunities that density of the cases has provided through spatial accessibility. Studying the building network, UNA will measure the spatial accessibility according to the contextual condition of the cases particularly addressing building density and attraction distribution.

5.1 Summary of the CityForm-UK Project

The data have been extracted from the CityForm-UK project [21] which was funded by the Engineering and Physical Sciences Research Council conducted in five British cities. Its aim was to explore the extent to which the urban form can contribute to sustainability. As one of the imperative objectives, they attempted to test the claim that a compact city can improve aspects of social sustainability. Following this study, the authors conducted another empirical analysis by choosing three different neighbourhoods of approximately c.2000 households in each to represent a specific range of density. In the case selection process, they targeted those areas that represent the most varied social, economic and urban form. The fifteen cases explored in the UK studies are categorised into three groups, i.e. inner, middle and outer areas. Each of these groups represents a different range of density from low to high. In this paper, we also followed their categories.

5.2 Spatial Analysis

Angular segment analysis was chosen for the space syntax investigation as Hillier et al. [18] have shown that angular analysis (which is based on the angular distance) is more representative of the actual pattern of people's movement given how they perceive the environment. That is, people tend to consider topological and geometric attributes while choosing the shortest path, rather than calculating the metric distance. Accordingly, as the cases are of different sizes, they have been normalized to be comparable using the following formula [22]:

Normalized angular choice

$$NACH = \log CH + 1/\log TD + 3 \qquad (3)$$

Where CH is choice and TD is total depth.

Normalized angular integration

$$NAIN = NC^{1.2}/TD \qquad (4)$$

Where NC refers to the number of nodes and TD is total depth.

Since the CityForm-UK study was conducted almost 10 years ago, the maps were compared with the historical database available from Google Earth Pro to do the adjustments to the network maps. Despite the new developments which have mainly occurred at the building level, the street network of most cases has remained the same. However, there are a few cases whose street network has also been changed. Such alterations have been applied to the cases' maps manually to be as close as possible to the actual network as it looked back in 2006. This was possible with Google Earth providing 3D virtual tours (Fig. 1) and various street views in any direction. The maps were double-checked to control if all the road lines in the map actually meet, and to unlink those lines that do not exhibit continuous traffic flow, for instance, where an overpass bridge cuts the link between two segments. Such circumstances have been inspected and modified in the AutoCAD files.
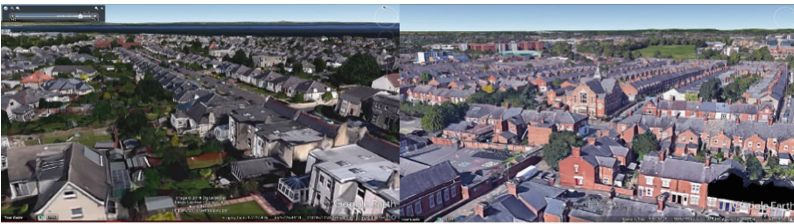
Fig. 1. 3D views from Google Earth in 2006 (in the left) and 2018 (on the right)

We chose to use the road-centreline for our space syntax analysis instead of the conventional axial maps created by the UCL DepthMap software to run the angular segment analysis. There is strong theoretical and cognitive evidence that the angular segment analysis, driven from the road-centrelines, are more representative of the actual patterns of people movement [23]. The same maps were used for the UNA analysis which is done on Rhino 3D. The radius used for both sets of analysis were 600 meters close to walking distances. For analyzing vehicle movement and accessibility higher radius are needed which is not discussed in this paper.

6   Results and Discussion
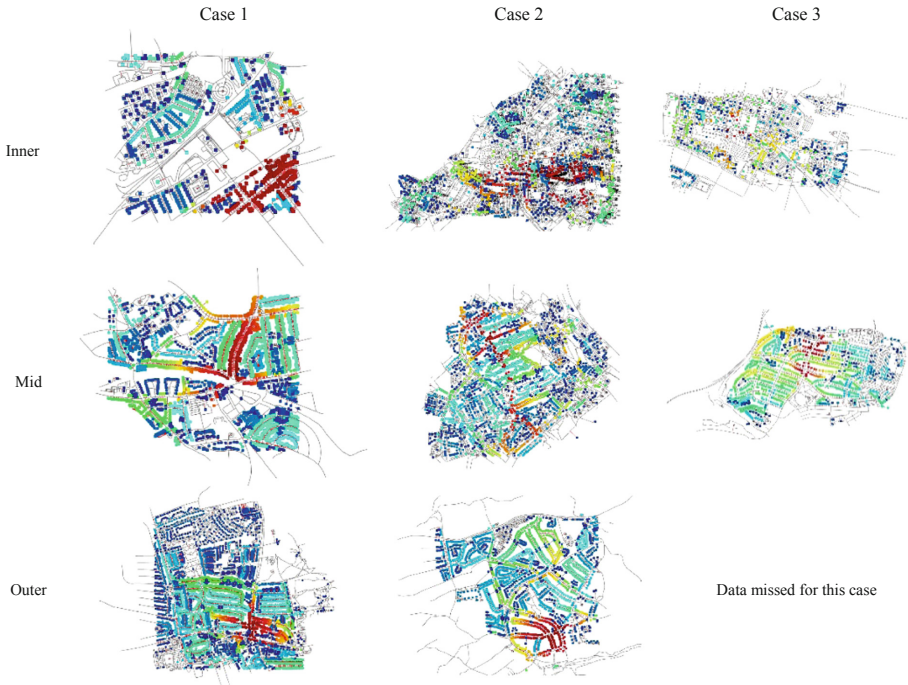
6.1   Spatial Accessibility

As reported in the UK study, the low-density outer areas revealed a better rate of social sustainability. Apart from the socio-demographic characteristics of each neighbour-hood, the outer areas have a relatively high proportion of green spaces. Bearing this information in mind, it is expected that the outer areas are provided with better spatial accessibility on a global level and local level where the residents can reach various destinations easily. It is also confirmed in the UK study that the socially sustainable areas provide an equal level of environmental and social accessibility. We examine this expectation with the UNA toolbox using gravity index. As the buildings are assigned to be the nodes in the analysis, the results examine the accessibility to the buildings in the global scale (r = n). The gravity index, first introduced by Hansen [29], can be assumed as a spatial accessibility indicator for pedestrians. For instance, in one study conducted on several grid layouts from cities throughout world including Adelaide, Manhattan, and London, Sevtsuk et al. [24] show how this index can help explore the role of block size in pedestrian accessibility. They demonstrate that the gravity values are greater in the larger blocks which relates to more pedestrian accessibility [24]. Table 1 shows that the outer areas have a better gravity value and thus better accessibility is provided. This is compatible with the UK study result where the more accessible areas provide better social sustainability, however, it is not consistent with what we expect from denser areas. As density arises, the layout also starts getting compacted and thus the various attraction points are getting closer which implies a better range of accessibility. In this case, however, the lower density area presents a better range of attraction. It could also be due to the layout form which might have a more influential role in improving accessibility than density itself.

Table 1. Descriptive data of gravity index in the three ranges of density

Gravity	Minimum	Maximum	Mean
Inner	1.02	142.38	22.9315
Middle	1.03	66.50	15.6497
Outer	1.07	170.52	44.0369

Figure 2 depicts the accessibility maps of three cases within their three selected areas that represent different density levels. The warmer colors refer to the better accessible areas, while the cooler colors show less accessible areas.

Case 1   Case 2   Case 3

Inner

Mid

Outer   Data missed for this case

Fig. 2. Gravity index shows spatial accessibility in different areas of selected cases

6.2 Visual Accessibility: Intelligibility

Apart from the physical accessibility and the reachness of the cases, visual accessibility has also been identified as an influential factor in the relationship between density and social sustainability. Raman [9] demonstrates that the visibility from and to the main facilities and public spaces in a neighborhood are closely linked to social activities. When the activities and opportunities are visible to people, they tend to participate and use such places more resulting in a higher rate of social activities in relatively higher density areas. Thus, the UK cases have been studied in terms of visual accessibility or as defined in space syntax terms, intelligibility. The intelligibility of a space is a Pearson correlation between the connectivity and integration values of that given area [22]. The middle areas show a higher score of intelligibility while the inner and outer areas, respectively, show the lower scores (Table 2). This has also been confirmed in the UK study where the middle areas are reported to be the safest compared to the inner and outer areas. Furthermore, for the other two categories (inner and outer), it seems that the values vary according to the layout form. Whether in the outer or inner area, the intelligibility values are higher where the cases benefit from a grid layout.

Table 2. Intelligibility index which is measured by the Pearson Correlation coefficient between connectivity and integration

| Category		NAIN	
		Pearson Correlation	Sig. (2-tailed)
Inner	Connectivity	.261**	.000
Mid	Connectivity	.302**	.000
Outer	Connectivity	.143**	.000
**. Correlation is significant at the 0.01 level (2-tailed).			

6.3 Safety and Security

Feeling safe is repeatedly associated with the level of social sustainability and is known as an important identifier of a liveable area. In the UK study, the level of safety and crime rate have been studied as one aspect of social sustainability. They report that the suburbs are or feel safer especially where the layout is a less elemental network (cul-de-sac or grid). Inner areas have the smallest score of being "safe" while the middle areas show a higher score and outer areas the highest.

In the literature, depth is generally declared to have a nuanced association with the rate of crime. Some studies show that the crime rate on the more integrated and thus shallower areas is higher, where there are more people living and are victims of a burglary. Yet other studies also provide evidence for safer environments located in the shallower spaces, so therefore much care should be taken when interpreting the results. As Hillier et al. [5] suggest, the formula of safety does depend on the probability of encountering strangers in a given area. People may not expect to interact with strangers in some deep areas, especially in the residential areas close to their territory, and find it not safe in some spatial configurations like estate housing, while the same encounter with strangers is normal in other configurations, for instance street-based systems [4] (p. 46). Depth index has a lower value in the inner areas and on the contrary, it shows a higher value in the suburban area. This could be due to having a well-connected (as shown in connectivity value as well) and compact network the inner areas that depth rated a lower score. We proceed with the analysis to further explore the potential correlation between the reported safety rate and spatial design metrics. Figure 3 shows a scatterplot investigating the pattern of safety as the spatial metrics arise. We conduct the Kendall's Tau correlation to run the analysis. The data that we are dealing with in this dataset are non-parametric as they reject the assumption of normal distribution, and the sample size is relatively small. Therefore the Kendall's Tau is a suitable correlational test [25]. The Kendall's Tau correlation analysis on the same value shows;

- There is a significant relationship between connectivity and safety, $r = 0.41$, p (2-tailed) < 0.05.
- Choice is significantly correlated with safety, $r = -0.63$, $p < 0.05$.
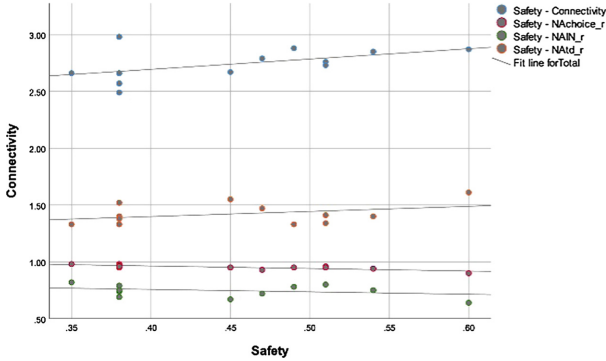
Fig. 3. Simple scatterplot with fit line of NAchoice_r of connectivity, of NAIN_r, of NATD_r by safety

6.4   Overall Social Sustainability Index

The rest of the analysis will focus on the NACH role in improving the social sustainability results and investigate if there could be any pattern explained by this metric in the angular segment analysis (ASA). We have constructed the basic regression models to dig deeper into the potential relationship that design metrics can shape the results on the social sustainability aspects (Table 3). According to the initial findings yielded from this set of analyses, not all the design metrics have a significant meaningful correlation with the various aspects of social sustainability. However, the interesting pattern that is visible in the regression models is the significant role of the NACH in all the models of social sustainability including the overall index. normalized integration in the axial map (normalized with D-value) is effectively used to predict the movement pattern in the design stage so the choice value in the previous analysis of space syntax, axial maps, was not normalized as the integration proved to be enough [26].

However, in the ASA where the distance is based on the directional turn similar to the actual movement behavior, normalized choice turned out to be as powerful as the integration value in the post-prediction of movement, and plays an integral role in the angular segment analysis [18]. Hillier et al. [26] suggest that the normalized integration and normalized angular choice (NACH) can yield a deeper understanding of the spatial morphology. The higher total value of choice means the layout is becoming more segregated. The mean NACH can also measure the level of deviation from a straight line or a regular grid. The maximum value of the normalized Choice is an indicator of the degree of the structure of a city, while the mean NACH can represent the degree of grid-like properties, bearing in mind that these two values do not necessarily have any correlation with each other.

Table 3. Regression model summary, ANOVA test results, and Coefficients

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.811[a]	.658	.463	1.63864

a. Predictors: (Constant), Connectivity, NAIN_r, NAchoice_r, NAtd_r

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	36.181	4	9.045	3.369	.077[b]
	Residual	18.796	7	2.685		
	Total	54.977	11			

a. Dependent Variable: Overall_Social_Sustainability

b. Predictors: (Constant), Connectivity, NAIN_r, NAchoice_r, NAtd_r

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-224.533	93.639		-2.398	.048
	NAchoice_r	176.688	60.788	1.746	2.907	.023
	NAIN_r	-14.761	26.379	-.374	-.560	.593
	NAtd_r	25.718	17.129	1.089	1.501	.177
	Connectivity	13.741	7.756	.866	1.772	.120

a. Dependent Variable: Overall_Social_Sustainability

7 Conclusion

Studies on the social impacts of urban density are sometimes contradictory and inconsistent. We propose that one reason could be due to the lack of studies on the role of design and the specific physical patterns that density can create. This paper aimed to investigate this claim that the design factors can also contribute to the provision of better social sustainability while increasing density. This is especially important when considering the compact city as an inevitable scenario of what future cities will look like and the expected wide range of environmental and economic benefits. Empirical studies of the social impacts of such changes are valuable, however, there is a lack of research and practice on the computational models and tangible guidelines for the future designs or development of existing areas. While computing the social impacts is a difficult task, there is still much potential for minimizing the likely social problems incurred by the design and spatial agreement of the built form. Thus, using a mixed-method spatial analysis approach, this paper attempted to explore how the spatial design factors can be correlated to the social sustainability outcomes provided by

previous studies in the literature. Considering the built form as two networks of streets and buildings, space syntax was used to analyse the street network. The street layout provides a long-lasting framework that embodies various social behaviours such as movement, interaction and activity. The building network, to target density and the opportunities it provides, was investigated through the UNA analysis.

According to the results of the spatial analysis, some of the social sustainability dimansions (introduced in Sect. 3) can be correlated to spatial design factors. Spatial accessibility was explored through UNA analysis using gravity index which matched the UK study recognizing better rate of accessibility in the low-density outer areas reported by the residents. Visual accessibility or Intelligibility was examined with Pearson correlation between connectivity and NAIN yielded from space syntax analysis which showed higher values in the medium-density middle areas. This also was in line with UK study results where they report greater safety for the middle areas. Safety was further explored with NAchoice and connectivity using Kendall's Tau correlation which suggested a significant level of correlation. Finally, various spatial design factors were employed as dependent variables to predict the overall social sustainability rate using multiple regression analysis. While not all the variables showed a significant level of prediction, the main index in the angular segment analysis, normalized choice, received a significant p-value in the regression model. The findings confirm that using a suitable method, some social outcomes of densifying an area can be correlated and measured with the spatial indices.

The study faced several limitations which motivate future analyses of this topic in more detail and with more precision. The measurements of density in this paper do not reveal everything about the design and physical attributes of the cases. Provided that more data are available about density and physical features, the research can benefit from novel methods which attempt to relate the density measurements to the morphology as well. Berghauser-pont et al. [27] believe that to describe the compactness of an area only referring to the Floor Space Index (FSI), reflecting the building intensity, does not adequately capture either its physical density or its spatial features. They have developed a system, Spacemate, which consists of three additional variables, i.e., compactness (GSI), pressure on non-built space (OSR) and height (L) which create a more efficient index in combination to show the distribution of density. According to all these variables, Spacemate provides a comparative platform illustrating the range of intensity and compactness and network density of various cases [27].

Nevertheless, adding density into the spatial analysis measurements, merely focusing on the planar properties of the street network does not seem adequate enough. Thus, mixing Spacemate matrix with the UNA analysis can be useful focusing on the density analysis to the benefits that density can create and to explore the distribution of movement flow among the various beneficiaries that density generates. Another limitation of the study is the availability of data through open online sources such as OSM where sometimes the missing data means that UNA analysis cannot be completed in Rhino 3D. UNA itself is also only a recently developed tool and not currently widely supported by empirical studies. One challenge is that OSM maps require simplification and modification and this needs to be manually done for space syntax analysis in order to be as accurate/similar as possible to the traditional axial maps [28].

This paper is a part of an ongoing research focusing on the impacts of urban density on social sustainability and served as the first step towards the overall aim, by first revealing the correlations with space syntax and UNA measures; and in the next stage, they will be mapping onto explicit design metrics or design. In future studies and looking at new cases, density can be defined with a close relationship to the design and morphology of such scenarios. This will generate a better understanding of the design role. Such explorations will enable planners and designers to identify the most influential design factors and optimize their designs to minimize the potential social problems that can be incurred by the spatial arrangement of the built form.

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