Chapter

Approaching Urban Design through the Analysis of Structural Differences within Three Neighborhood Typologies in Basra City

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Abstract

Recognizing the importance of physical environments as a major product of an urban design process for the livability of the built environment, this study focuses on urban planning and design characteristics within three different neighborhood typologies of Basra City. The aim of the study is to support future urban developments in the city based on evidences from the association between the current qualities of neighborhood design and the computed walking minutes of residents. These characteristics are determined from reviewed literature in urban design as reliable physical environmental perceived or objectively measured qualities. The methodology of this study describes four steps of analysis such as: (1) the use of the cadastral maps of the case studies as a source of raw information for objective measurement; (2) the use of objective and subjective measures as defining indicators that are utilized from previous studies; (3) the application of defined indicators for the selected neighborhoods through a comparative analysis; and (4) the conducting of statistical analysis to reveal the influence of the defined indicators on the walking. The findings of this study have led to conclusions on the importance of design attributes to future master planning of neighborhoods especially those of the traditional neighborhood, such as the Al-Saymmar neighborhood in Basra city.

Keywords: New Urbanism, smart growth, urban design, physical environment, neighborhood planning, walking

1. Introduction

New Urbanism and related studies recognize the traditional organization of the built environment as offering more appropriate solutions for a better urban life [1]. In contrast, the modern movement tends to focus on the suburban, automobile-based built environment, with homogenized land use, the diminution of a sense of place and community engagement, and the decline of the role of neighborhood units in the formation of urban environments [2]. The New Urbanism movement adopted certain qualities from traditional neighborhoods that were felt to be particularly positive and reflective of a more compact traditional urban tissue;

key qualities included mixed land use, housing typologies, grid-like streets, and high densities. New Urbanism often expresses the need to, "rediscover the neighborhoods and sense of community through more human scale development" ([1], p.18), and conceives a better "public transit connectivity", more walking among the community, and an increase in the social experience of a community [1]. Along with that, smart growth trend of urban planning seeks to improve the walkability of existing urban sprawl developments by retrofitting their physical environment [3]. In this regard, Talen explained that the retrofitting of sprawling existing developments is achievable through applying quantitative measures of physical environment that are validated by research. Thus, models of those quantitative models can predict, explain, justify, and achieve potential smart growth. However, she addressed a series of challenges that pertained to smart growth studies including "data sources, geographical scales, aggregation scales and spatial resolution" which all have primarily to do with the research outcomes [3, 4]. Moreover, Hillier [5] argues that architects predominantly rely on normative criteria for design and future developments. Nevertheless, master planning represents a strategic framework that comprises several aspects of a particular location, including its physical, social and economic contexts [6]; thus, it is a reality-pertaining activity as much as normative activity. Evidence-based practice (EBP) within planning has recently emerged as a method to link planning practice to research in order to inform decision makers and professionals within urban planning [7]. Thus, this study both suggests a model to improve the existing neighborhoods and also provides feedback to decision-makers around future developments concerning the current master planning of neighborhoods in Basra city (2010–2035).

It is worth mentioning, that the Master Plan is the only official intervention plan by the government of Basra city. The current Master Plan of Basra city, developed by a local firm, (Snafy company) was approved by government officials in 2015 [8]. The statement and criteria for the current Master Plan of Basra city (2010–2035) recognized a common problem in the significant shortage of both residential units and land for new development. Although the importance of neighborhood as a widely considered planning unit primarily concerned with people's living environment, the existing residential land-use organizations of the current Master Plan applies the 'residential quarter unit' for future developments; this is approximately equal to four neighborhoods. Estimated residents in each quarter total 15,000. The units are classified into three types namely, high, medium, and low density housing units, where each type has a different percentage of the total quantity. Of the total area specified for each residential portion, high-density units will comprise 100-units/ha (10%), medium density will total 45-units/ha (25%), and low-density will amount to 35-units/ha (65%). Furthermore, the structure of the residential quarter includes two commercial centers (1 ha), retail space (1 ha), two religious centers (1 ha), health and social centers (1 ha), seven nurseries (2.5 ha), four primary schools (2.2 ha), four middle schools (3.8 ha), four secondary schools (4.4 ha), playgrounds (2 ha), local parks (3.5 ha), roads and open spaces (25.2 ha).

With regard to these aspects of the new Master Plan and further design considerations, is the subject of feedback from our study, which will be based on evidence concerning the walking minutes to occupational activities suggested by Al-Saraify and Grierson [9]. To support feedback, this work suggests a quantitative model adopting several urban design measures applicable to the physical environment at neighborhood scale. The authors explore structural and design differences within three neighborhoods of Basra city, namely Al-Saymmar, Al-Mugawlen, and Al-Abassya. Their buildings, streets, land uses, and edges were quantitatively measured to reveal differences with potential impacts on the walking activity of the residents. Moreover, the walking minutes outcomes of the residents are based on previous work using Q-GIS software and the Neighbourhood Walking to Occupational Activities NWOA model [9]. Then, the walking outcomes are statistically associated with the urban design qualities to explain the extent to which the differentiation of the physical environments may impact on walking.

2. Defining the case studies

The urban form of Basra city was significantly altered by different stages of interventions and this influenced the selecting of the case studies [10]. Also, socio-political conditions influence the formation of the urban form of Basra city over three distinct historical stages, including the Ottoman period (before 1916), the British colony and Iraqi Kingdome period (1916–1958), and Republic period (after 1958) [11]. No official planning system was applied after the old fence decayed. The inner organization of the traditional neighborhoods mostly still the same since it was founded before 1916 [12–14]. In the early 1950s Max Lock was hired by the Iraqi government to make the first Master Plan of Basra city [15]. This Masterplan had been embraced the automobile-oriented development, an orthogonal or grid-like or modern planning vision was applied to the city.

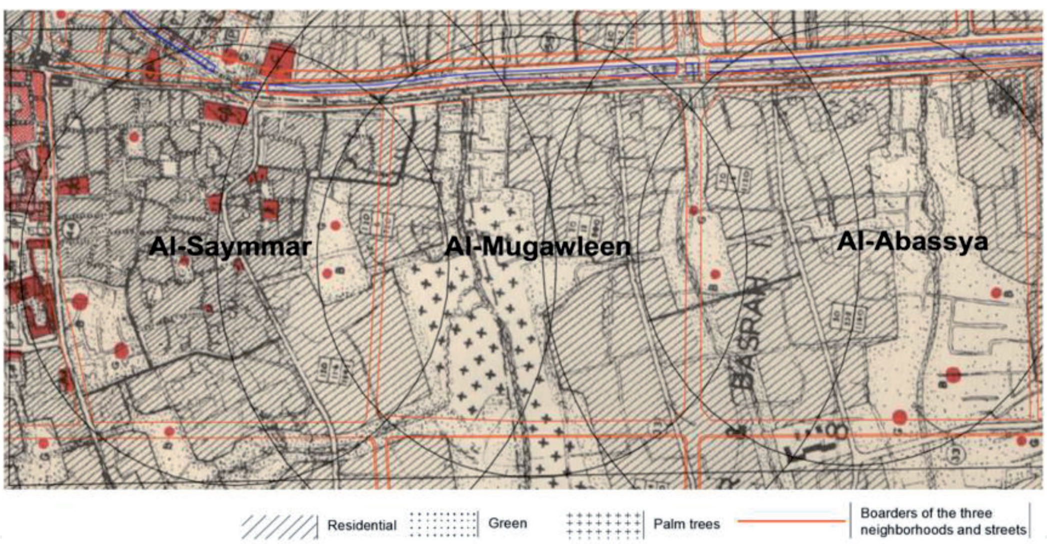

Figure 1.
The current locations of the three neighborhoods located over the master plan of Basra City (authors based on Lock [15]).

Figure 2.
The targeted three case studies (three neighborhoods of Basra city): [10].

Three neighborhoods within Basra are considered by Al-Saraify [10] providing three distinct residential typologies of Basra City with varied potential impact on the physical activity of the residents. A visual comparison between the current status (**Figure 1**) and the proposed Max Lock's master planning of the three neighborhoods (**Figure 2**) shows that the interventions have considerably altered the quality of the neighborhoods' built environments. **Figure 2** illustrates how land uses of the case studies were planned by Lock, however, the peripheral arterial streets around the neighborhoods imposed gridlines which are mostly now utilized as commercial land use that surrounding the residential blocks of the neighborhoods. Thus, this urban tissue systematically sampled for the application of the defined urban design measures of the physical environment.

Within general consensus, the 'walking distance' offers a standard method to sample neighborhoods in behavioral studies, and the range of walking distance falls somewhere in the range between (0.4) and (0.8) kilometer radius [16, 17]. Similarly, health-built-environment studies depend on measuring Euclidian distance, 15-min radius or 30-min network distance that is 600-m radius [18]. Therefore, this study considers (400–600 m), that is, (10–15 min), as optimum ranges covering both the spatial definition of the neighborhood and the requirements of active living lifestyle. Accordingly, the sampled neighborhoods accommodate varied urban design qualities which are investigated in this study include; transportation roads, residential area, and commercial destinations. The centers of the selected neighborhoods were utilized to define the minimum (400-m) and maximum (600-m) ranges of the case studies. Moreover, following Al-Saraify [10] the cadastral maps of the three case studies are created depending on the systematic survey of the original maps and data of the government. The satellite images, PDF maps, and orthoimages were obtained from the Basra local government and georeferenced and geometrically corrected (orthorectified). Moreover, the images were spatially correctly located according to its georeferenced coordination points (*N*: 768546, *S*: 3376180, UTM-WGS 1984, 38 North) into the QGIS free source software by Google. AutoCAD Map 3D was utilized to create a shape file extension (.shp) of the neighborhoods in question that can be added into Q-GIS (**Figures 3–5**).

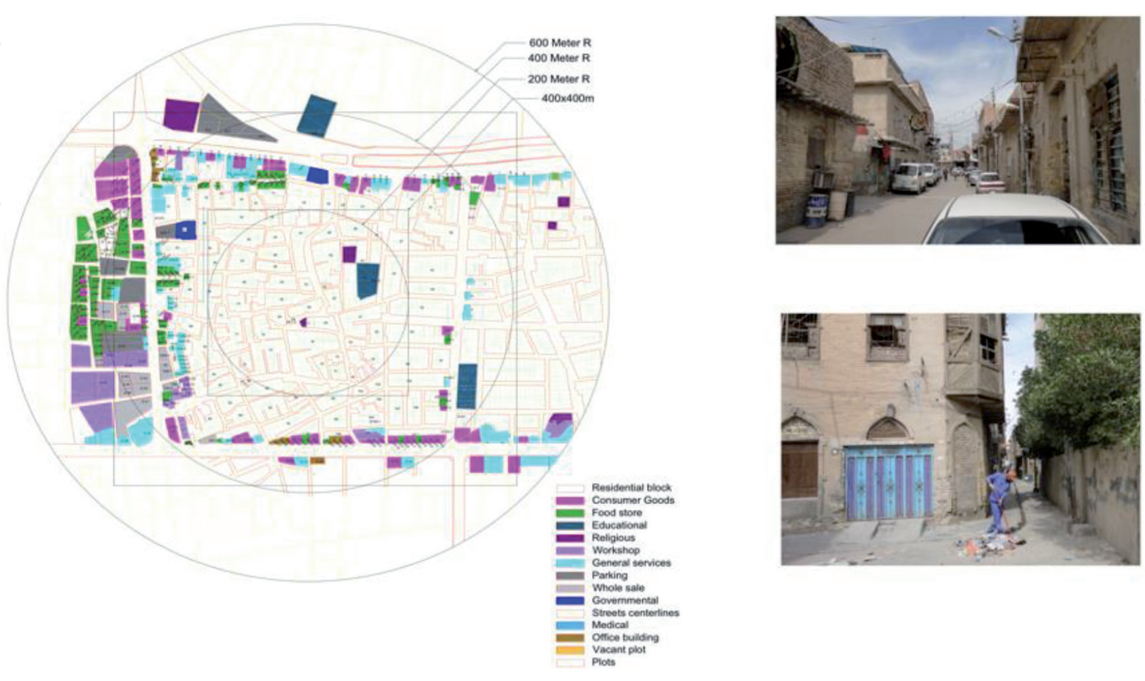

Figure 3.
Al-Saymmar neighborhood cadastral plan: [10].

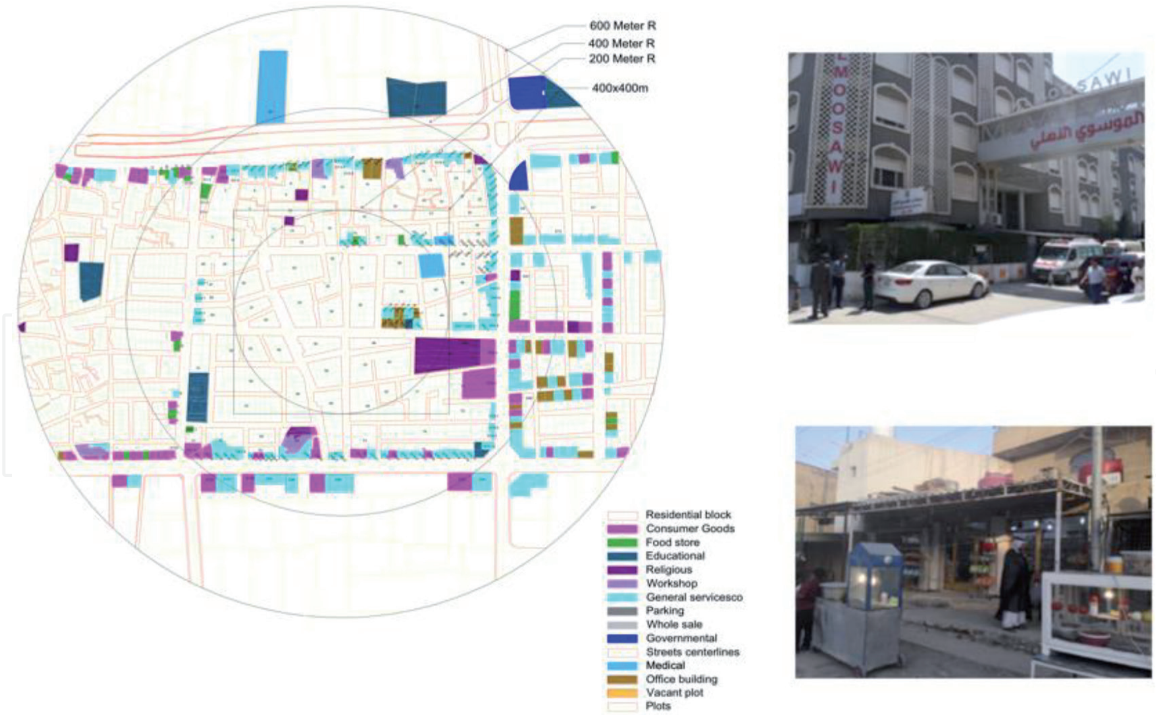

Figure 4.
Al-Mugawleen cadastral neighborhood map: [10].

Figure 5.
Al-Abassya cadastral neighborhood map: [10].

3. Review of the measurement indicators of the urban physical environment

A proponent study by Cervero and Kockelman, addressed three dimensions that are considered responsible for moving demands of residents in the built environment; these include density, diversity, and design. The so-called '3Ds' represent a general umbrella for the measurement of the physical dimension of the urbanism phenomenon. Their study showed how these three dimensions contributed to an increase in the number of walkable streets in San-Francisco [19]. Regarding the issue of density, the intensity of users in urban areas is associated with the concentration of built-up urban developments. Density influences how well human activity and place are related since it influences the availability of urban space. Moudon et al. demonstrated that density and walking are strongly associated and higher density areas are more vibrant and walkable [20]. Although the locations of destinations are defined by the distance factor, the density of the urban area is influenced by locations of activities. This is because the geometrical relationship among components of a higher density area imposes closer distances. Moreover, Frank et al. demonstrated that the residential typologies and their physical layouts could provide a conception of population density. For example, a high-density place could include multi-family housing, apartments, and small residential lots. Moreover, high density is suggested as >6 housing units per acre, and low density is defined as <3 units per acre, while a medium density falls between these values [21]. Therefore, density could be rather a parametric concept that abstractly defines the neighborhood typology. Although density is a reliable measurement in urban planning, there is no particular level of acceptance concerning density. It shifts according to different factors, such as social and cultural contexts. For example, what could be considered as high density in some Western countries could be seen as low density in China or India.

Eq. (1): Block density equation [21]

$$\text{Blocks density} = B_{tot}/A_{tot} \tag{1}$$

B is the total area of blocks, includes the open space inside the block and A is the total area measured by m^2.

Eq. (2): Housing unit density equation [21]

$$\text{Housing density} = H_{tot}/A_{tot} \tag{2}$$

H is the total number of housing units and A is the total area measured by square hectare.

The mix of land use measure is the degree of difference between the land uses that occupy a certain urban area. In other words, this means the degree of proportionating between different types of land use areas within the total area. Similar to density, the mix of land uses is considered to be associated with the increase of walkers in urban areas. In other words, when a place has diverse facilities or destinations, this will encourage users to walk [19, 21, 22]. The impact of land use diversity on users is manifested in the way in which users associate themselves with their neighborhood or with the wider urban area of the city. This is because it provides them with more opportunities. Also, it facilitates their imagination, in accordance with the notion of a cognitive map, as posited by Kevin Lynch. Thus, diverse land use adds to the experience of people providing more motives and resolutions, which encourage walking. Furthermore, studies used a mix of land use as a criterion of the '3Ds' to probe the quality of place in term of its walkability and transportation, and positive correlations were widely noted among several studies [17, 23–25]. The method to compute land use diversity is addressed by Frank et al. [21]. It adopts a mathematical equation to compute the entropy of land use division to a group of land usages, from a baseline of equality between the different portions [21, 26].

Eq. (3): Land use diversity equation [21]

$$\text{Land use diversity} = -\frac{\sum_k pk \ln pk}{\ln N} \tag{3}$$

k is an individual category of land use, *p* is the proportion of total land use, and *N* is the total number of categories.

The design dimension based on Cervero and Kockelman [19] is the streets connectivity which is considered the third indicator in urban planning studies. It is based on the notion that a greater flow of movement highly depends on how easily people and cars can gain access within/through urban areas. Thus, more accessible attractions require more connectivity of streets and walkways. Their study outlined design dimension as the shape and number of streets and nodes. Streets could be a grid or curve-lined shapes, and the intersections are nodes of four or three legs. Regarding the quality of the streets, studies depend on street design criteria as a parametric measure to assess their contribution in terms of walkability and transportation [17, 20, 21]. Connectivity and smaller and denser blocks and streets decrease travel distances and encourage users to walk or cycle. Consequently, they increase place accessibility [27]. New Urbanism supported this finding, proposing that more connected and compacted urban form is generally more accessible and results in lower land consumption. Thus, the pedestrian-oriented areas designed with highly connected streets and a lower ratio of wasted land are not just more walkable but safer. As such these can also be considered as more sustainable areas [27, 28]. Both streets and intersections are useful tools for engineering urban tissue, which define its key urban characteristics. Moreover, many researchers emphasized the importance of these two components in measuring people's movement [29, 30]. In this regard, several forms of measurement were addressed by different scholars, such as: (1) the intensity of nodes per area [21, 31]; (2) the external connectivity, which depends on the number of entrances (related to length in m) into a certain urban area [32]; and (3) the number of street segments normalized by the number of accommodated intersections [33]. However, the node density was more commonly used among urban planning measures of ecological models.

The density of intersections per area was considered a measure of the streets' network connectivity, whereas the presence of three legs intersections or more indicate a greater connectivity, and thus more accessible place [19, 21]. However, different formulas were applied to measure the density of intersections. The first formula was by urban planners, and depends on the ratio of the aggregated number of three and four legs intersection to the total area in question [34].

Eq. (4): Intersection density equation [19]

$$\text{Intersections density} = \mathrm{N}_{\mathrm{tot}}/\mathrm{A}_{\mathrm{tot}} \tag{4}$$

N is the total number of T and X intersections and A is the total area measured by hectare.

Street density is the total length of streets included in a certain urban area, as normalized by the total area, was considered a measure of connective urban tissue [35–37]. Thus, the denser the streets per area, the more connected, and accessible, the place.

Eq. (5): Street density equation [35, 36]

$$\text{Street density} = \mathrm{L}_{\mathrm{tot}}/\mathrm{A}_{\mathrm{tot}} \tag{5}$$

L is the total length to street segments and A is the total area measured in hectare units.

Other studies considered other indicators and the text below explains several reliable indicators that were considered in empirical studies and showed considerable association with walking, namely, external connectivity, Pedestrian Catchment

Area (PCA), pedestrian route directness ratio (PRDR), the clustering coefficient of destinations, the quality of edges, and the enclosure ratio. The external connectivity is the ratio of Ingress/Egress (access) points of the neighborhood to the total length of peripheral streets reveal the extent to which the neighborhood is connected to external urban areas; thus, the greater the distance, the poorer the external connectivity [32].

Eq. (6): External connectivity equation [32]

$$\text{External connectivity} = L_{tot}/E_{tot} \tag{6}$$

L is the total length of peripheral boundaries of the neighborhood, and E is the total number of entrances into the neighborhood.

Pedestrian Catchment Area (PCA): The PCA is the accessible area via the street network, assesses the efficiency of the street network to serve certain destinations or built up urban areas within an acceptable Euclidean walking distance, such as a 200, 400, or 800-m radius, from a given point or important facility, like a transport station [37, 38]. Furthermore, the PCA ascertains that, measuring the extent to which the street network serves blocks, demonstrates a certain level of accessibility into the built-up area, as sampled by a circle (e.g., 200-m radius). The center of the circle is hypothetically considered as the pedestrian departure point and a 200-m radius ring is the proposed walkable shed. Thereby, the total accessible built-up area in a 200-m network distance is normalized by the total built-up area inside the circle, indicating the efficiency of the street network defined by the sampling circle. In some research this is referred to the 'Pedshed ratio' [37].

Eq. (7): Pedestrian Catchment Area equation (PCA) [37]

$$\text{PCA} = AA_{tot}/A_{tot} \tag{7}$$

AA is the total accessible area and A is the total built-up area.

Pedestrian route directness ratio (PRDR) concerns the proximity of the distributed destination in the urban area, which was frequently used in accessibility and transportation related research. This involves the distance, either aerial or real, between a resident's house and the destination (calculated in walking distances, e.g., ¼ mile, ½ mile, and 1 mile). This was considered an influential factor in facilitating the activity of users, especially walking to the nearest destinations [17, 22, 23, 39–41]. Moreover, Randal and Baetz [42] developed the pedestrian route directness ratio (PRDR), which is the ratio between the aerial distance and the real distance. It is an expressive formula because it explains the ease or probability to access certain destinations located within a certain distance-range of residences. Thus, the higher ratios (up to 1) represent the best proximate relationships between origin and destination. In this study, the ratio was adopted to express the proximity caused by the street network design, and the number of destinations measure was considered in different measurement levels. The (PRDR) measure was considered on the neighborhood level of measurement, Eq. (8), and the numerical range of this ratio is ≤1. The 1 value represents an optimum relationship that has identical aerial and real distances, whereas a smaller ratio illustrates that the real route is longer than the aerial distance. In streets, network routes relate between two points, the user's departure station and contextual locations or destinations; meanwhile, the Euclidian distance is the aerial distance between the two points. In this study, a certain number of destinations and one origin are defined for each case study, where the origin is the postulated departure point and the destinations are defined by the survey.

Eq. (8): PRDR equation [42]

$$(\text{PRDR} = \text{Euclidian distance/network length of a route}) \quad (8)$$

The clustering coefficient of destinations suggests that people perceive this as more than a single destination because each cluster provides a range of options. Thus, the cluster has a greater chance of meeting users' needs than an individual destination [22, 43]. Thus, a cluster of destinations is a design process that serves the proximity by compromising the distance and geometrics of destinations; therefore, users maintain a cognitive map of the proximity of their houses to non-residential clusters. However, there is no study that validates any standard measures of a cluster; instead it is simply perceived as a group of destinations proximate to each other to which people take themselves. Each cluster accommodates a bundle of different types of uses instead of single type of land use. The depending bundle criterion was devised by Canter and Tagg, who defined how many clusters could serve a particular urban area [44]. The clustering coefficient is a graph-based measure, developed by Watts and Strogatz, to calculate social networks, which were considered 'small world' networks. If a group of destinations is represented as nodes and a graph was made through connecting the nodes by hypothetical links, then the clustering coefficient is the number of links between all the nodes divided by the total number of links that was postulated as a rational relationship among the nodes. Also, the coefficient represents the degree to which a group of nodes are clustered, by normalizing the number of observed Links to the number of possible Links among the same group of nodes. The implication of a small-world phenomenon, as defined by network theorists Watts and Strogatz [45], to measure the degree of proximities between a group of destinations is promising because there is no equivalent topological measure to represent the relationship among a group of proximate destinations. However, there is no available method to produce a standard measurement of accessibility from this coefficient. In this respect, van der Westhuizen [46] used the ratio of a number of realized links between destinations, normalized by the number of possible links, and reported the significant influence of walking.

Eq. (9): Clustering coefficient equation [46]

$$\text{Clustering coefficient} = \text{observed links/possible links}\ \left(n^2 - n\right)/2 \quad (9)$$

The quality of edges: the studies of walking urban areas linked the quality of street edges with the number of walkers.[1] Jacobs in [2] asserted the link between the quality of streets and street life. A street facilitates the interaction between people because it brings them together, even those who do not know each other. In a street, people do their favorite things: walking, watching, sitting, or choosing their favorite viewpoint. A good street has clearly designed edges, geometry and carefully delineated transparency [2]. The block frontage is an important component of block structure, which impacts on human perception, traffic and pedestrian flow [32, 47–49]. In this study, the method to assess the quality of street edges was adopted from Remali et al. [50], and depends on five factors to assess the quality of elevations. These factors are: the "number of visible units accessible from the street (S); visible diversity of function (F); openness to the public street (O); level of maintenance (M); and level of detail and quality of materials (D)". The frontage quality index (SFOMD) method depends on a Likert scale of seven points, starting with (1), which is the lowest score of the assessment, and ending with (7), which the

[1] The formula $(n_2 - n)/2)$ to compute the possible number of links amongst n nodes is addressed by this study because the original reference did not mention this part: (authors).

highest score of the assessment. The computing of the overall index was adopted from Gehl [51] and Hershberger [52], and combines the five indicators by totaling their raw scores. Thereby, the minimum score for the process is five points, which represents the poorest street quality, whereas, the highest score is 35 points which represents the best possible street quality [50].

Enclosure ratio: studies in urban design have developed different ideas on the relationship between human perception and street room. The enclosure notion defines the sense of place in connection with the relationship between street widths and adjacent building heights. From an architectural point of view, Cullen illustrated that enclosure is an important tool that influences the human perception of a place or the "hereness". Accordingly, the quality of enclosure is defined as a highly-required dimension of a streetscape, because the street-building proportions represent the "outdoor room" of walkers. For example, Ewing et al. indicate that building height and other vertical elements are milestones to establishing well-defined outdoor spaces when they are proportionate with the width of the counter space, or street [53].

4. The measurement process of physical environmental attributes

The measurement of physical environmental attributes, which were addressed in the previous section, are applied to the case studies and discussed in this section based on the cadastral maps of the three case studies. The raw information concerning the essential structure of the case studies is elicited from cadastral maps which were in AutoCAD and QGIS formats (**Figures 3**–**5**), the numerical attributes were entered into an excel sheet and then SPSS software. Then, each individual indicator is computed based on its defined equation and coded in the SPSS based on their initial letters, either on 400-m radius or 600-m radius (**Table 1**). For example, the density indicator has three variables for each case study; thus, it was measured two times to produce six numerical values for three neighborhoods. The two scales are (400-m radius), and (600-m radius). Thus, the codes of the three density variables are DnS1 and DnS2, respectively; this coding is continued for the rest of the independent variables (**Table 1**). From this, independent variables for measures of the physical environment attributes are produced (**Table 2**). Twenty-two independent variables were developed in this study, which resulted from the application of the measured physical environment indicators to the case studies.

4.1 Block and housing units density

The area of the blocks was computed on the two scales 400-m radius and 600-m radius, and the density equations Eqs. (1) and (2) were applied with the assistance of Excel software. Although the block density indicator is computed on two scales, the housing unit density is computed on one scale. Thus, three independent variables were calculated for the densities, which are labeled as BDnSi i = 1, and 2, and HDnS1 (**Table 1**). Moreover, the block density has been measured on the two scales, for the block density on the 400-m radius scale, the highest density was found in Al-Saymmar (0.71), while in Al-Mugawlen and Al-Abassya differed slightly from (0.65) to (0.67), respectively. Furthermore, the block density on the 600-m radius scale was slightly degraded from Al-Saymmar (0.78) to Al-Mugawlen (0.77) to Al-Abassya (0.72) (**Table 2**). The intensity of housing units (HDnS1) was measured only on scale (400-m radius); however, a divergence was noted from Al-Saymmar (41.9) to Al-Mugawlen (25) to Al-Abassya (17.25), in light of the single-family housing per hectare (**Table 2**).

Codes	Content	400-m R.	600-m R.	Tot.
BlkDnSi	Block density (Built-up area)	x	-	1
HUDnSi	Housing units density	x	-	1
LUDv1Si	Land use diversity of all commercial land uses.	x	x	2
LUDv2Si	Land use diversity of the commercial land use without parking, workshops, and wholesale .	x	x	2
LUDv3Si	Land use diversity of all the non-residential land uses.	x	x	2
NodDnSi	Nodes density per hectare	x	x	2
StDnSi	Streets length per hectare	x	x	2
ExtCnS1	External connectivity	x	-	1
PCAS2	Pedestrian catchment area	x	-	1
PRDRSi	Pedestrian route directness ratio (PRDR)	-	x	1
ClsCofSi	Clustering coefficient	x	x	2
SFOMDS1	Quality of edges	x	-	3
EnRS1	Enclosure ratio	x	-	3

i : stands for the two scales

Table 1.
The measurement indicators of the physical environment attributes.

		Al-Saymmar		**Al-Mugawlen**		**Al-Abassya**	
	Unite	S1*	S2*	S1	S2	S1	S2
BlkDSi	ratio	.71	.67	.65	.66	.67	.58
HouDnSi	U/hctr	41.9	-	25	-	17.25	-
LUDv1Si	degree	.94	.94	.70	.75	.79	.73
LUDv2Si	degree	.98	.97	.67	.76	.68	.76
LUDv3Si	degree	.39	.45	.57	.63	.52	.63
NoDnSi	no./hctr	4.16	3.36	2.89	3.33	2.03	1.8
StDnSi	Length/hctr	387	346	324	368	267	250
ExCnS1	no./L.	-	-	-	-	-	-
PCAS1	%	61.67	-	73.18	-	70.4	-
PRDRSi	ratio	.71	.75	.77	.79	.72	.76
ClsCofSi	ratio	.05	.04	.04	.03	.05	.04
SFOMDS1M	Likert	21	-	27	-	30	-
SFOMDS1C	Likert	20	-	23	-	27	-
SFOMDS1CS	Likert	15	-	22	-	25	-
EnRS1M	ratio	2.9	-	2.7	-	2.7	-
EnRS1C	ratio	1	-	1.7	-	1.3	-
EnRS1CS	ratio	1.1	-	1.7	-	.93	-
S1: 400-meter radius **S2: 600-meter radius**							

Table 2.
The computed indicators of the physical environment attributes.

4.2 Mixed land use

The diversity of land use was computed by the entropy equation Eq. (3) and the variables used for that purpose were the different land uses measured by the area. From this, the equation was applied with the assistance of MATLAB software and the categories of land use, for instance, the retail shops and workshops, were entered as a variable of the equation (X1, X2, ..., Xi) in the MATLAB format. Additionally, because the land use categories are not unified across the three case studies, they could have different nature of influence on residents' lives. This study considers different combinations of land uses, or different type-based bundles. The first bundle involved all the commercial land uses, the second bundle involved the retail shops, which are the commercial land use without parking, workshops, and wholesale, and the third bundle included all the non-residential land uses, which are the commercial plus the civic buildings, such as mosques. Moreover, this indicator was applied to the two scales; 400-m radius, and 600-m radius. Thus, six independent variables were calculated for the land use diversity, which were labeled as LUDiv1S1, LUDiv1S2, LUDiv2S1, LUDiv2S2, LUDiv3S1, and LUDiv3S2, (**Table 1**). In terms of the commercial land use variable (LUDiv1S1), on a 400-m radius scale, the degree of diversity demonstrated a significant difference between the Al-Saymmar neighborhood (0.94) and the Al-Mugawlen and Al-Abassya neighborhoods, (0.7, and 0.79), respectively.

Moreover, the same variables, on a 600-m radius scale, had approximately a similar pattern of variance among the three case studies (0.94, 0.75, and 0.73), respectively. In terms of the variable for commercial land use without parking, workshops and wholesale (LUDiv2S1), on a 400-m radius scale the degree of diversity adequately differed between Al-Saymmar (0.98) and the other two neighborhoods, Al-Mugawlen and Al-Abassya, (0.67, and 0.68), respectively. Moreover, the same variable, on a 600-m radius scale, showed an approximately similar pattern of variance among the three case studies; Al-Saymmar brought about a 0.97 degree of variance, whereas, Al-Mugawlen and Al-Abassya each brought about 0.76 degree. In terms of the non-residential land use variable (LUDiv3S1), on scale 400-m radius, the degree of diversity adequately differed between Al-Saymmar (0.39) and the other two neighborhoods (0.56, and 0.52) for Al-Mugawlen and Al-Abassya, respectively. Moreover, the same variable, on a 600-m radius scale, had approximately shown a similar pattern of variance among the three case studies: Al-Saymmar brought about (0.45) degree of variance, whereas Al-Mugawlen and Al-Abassya each brought about (0.63) degree (**Table 2**). Thus, the land use diversity of Al-Saymmar, as measured by the six variables (**Table 2**), is significantly different from the other two case studies, namely the Al-Mugawlen and Al-Abassya neighborhoods.

4.3 Streets connectivity

The QGIS software was used to compute the number of segments, length of each segment, and number of nodes, and these were transferred to an Excel sheet. Moreover, the streets' segments are represented as polyline between two adjacent nodes, or from a node to a dead-end street. The nodes are either X-intersection or T-intersection types. This procedure is conducted twice, on a 400-m radius scale and on scale 600-m radius. In this study, four indicators defined the connectivity, namely: intersections density, street intensity, link-node ratio, and external connectivity. Moreover, each indicator was applied to two scales, (400- and 600-m); however, the external connectivity was only applied to the 400-m radius scale because the 600-m radius scale did not define neighborhood boundaries, but instead the walking ranges. Thus, the total number of variables for this indicator is five namely, NodDnSi i = 1, 2, StDnSi, ExtConS1 (**Table 1**). Moreover, three equations were used to compute these indicators Eqs. (4)-(6).

The intensity of nodes (NodDnS1) on the 400-m radius scale in the Al-Saymmar neighborhood was (4.16), which is approximately double the number in for both Al-Mugawlen and Al-Abassya (2.89, and 2.03), respectively. Moreover, the node density (NodDnS2) on a 600-m radius scale showed a decline in the node intensity per hectare, from Al-Saymmar (3.36) to Al-Mugawlen (2.33) to Al-Abassya (1.8), (**Table 2**). The intensity of street lengths (StDnS1) on a 400-m radius scale showed a significant reduction in total street lengths, from 387 m/ha for Al-Saymmar to 324 m/ha for Al-Mugawlen and 267 m/ha for Al-Abassya. However, the intensity of street lengths (StDnS2) on a 600-m radius scale was the highest in Al-Mugawlen 368 at m/ha, while Al-Saymmar was slightly lower at 346 m/ha, and Al-Abassya illustrated the lowest street density in terms of length at 250 m/ha (**Table 2**). The external connectivity (ExtConS1) on a 400-m radius scale demonstrated an adequate reduction in the number of entrances per mile length, while the Al-Saymmar neighborhood showed the highest score with 28.1 entrance/mile, and the Al-Mugawlen neighborhood showed a moderate score at 20 entrance/mile; meanwhile, the lowest score was in the Al-Abassya neighborhood at 16 entrance/mile (**Table 2**).

4.4 Pedestrian catchment area (PCA)

To apply the PCA indicator, the center of each case study is the center of the 400-m radius, as sampled in the cadastral maps. Every single block was considered a destination that needs to be accessed from the center of the neighborhood within 10 min of walk along the street network. The QGIS Road-Graph tool was utilized to measure the shortest network distance between two spatial points, which are the center of the case study and each individual block falls within the 400-m radius. After the adjustment of the human speed to 5 km/h, only the blocks within a 10-min walk were considered in determining the total accessible area in each neighborhood. Thus, the accessible blocks in ≤10 min were added up, and the resulting total accessible block area was represented as percentage area out of the total block area within a 400-m radius. Thus, only one independent variable was noted in applying this indicator, PCAS1 (**Table 1**). Therefore, the PCA variable illustrates that, in the Al-Saymmar neighborhood, out of 356,135 m^2 of built-up area, there was 219,635 m^2 of accessible area in 10-min of network walking within the 400-m radius area; this is 61.67% of the total built-up area. In the Al-Mugawlen neighborhood, out of 326,500 m^2 of built-up area, there was 219,635 m^2 of accessible area in 10-min of network walking within a 400-m radius area; this is 73.18% of the total built-up area. In Al-Abassya neighborhood, out of 333,600 m^2 of built-up area, there was 2235,600 m^2 of accessible area in a 10-min network walk within the 400-m radius area; this is 70.4% of the total built-up area (**Table 2**).

4.5 Pedestrian route directness ratio (PRDR)

To apply the PRDR indicator, the center of each case study is the center of the 400-m radius, as sampled in the cadastral maps. The retailers are those that inhabitants want to access from the center of the neighborhood in 10 min of walk along street networks. In this regard, the shapefile maps were generated to create the blocks, blocks centroids, and streets networks on the 400-m radius and the 600-m scale. The QGIS Road-Graph tool was utilized to measure the shortest network distance between two spatial points, which are the center of the case study and each individual retailer within the 400-m radius and the 600-m radius. Moreover, because the indicator concerns how well the street network is connected between the destinations and residents' houses, this study designed an approach to test the PRDR for 16 destinations within each case study on each scale. The approach divided the circles of the two scales into 16 sectors then the intersection point of the radiuses with the circles (for the 400-m and the 600-m radiuses) are defined; from this, the nearest destination to those points are considered to compute the indicator. Thus, two independent variables were addressed by the PRDR, which were labeled: PRDRS1, PRDRS2 (**Table 1**). Then, the specified PRDR equation Eq. (8) was utilized to compute the indicators, which must be ≤1. A value of 1 represents an optimum relationship that has identical aerial and real distances; whereas, the smaller ratio illustrates that the real route is longer than the aerial distance. In other words, the street network route distance between the two points relates the user's departure station to the location of a contextual destination; thus, the shorter distance indicates the more accessible destination. The PRDR for the 16 destinations of each case study were averaged to determine how well the destinations of each case study are served by the street network. The PRDRS1 on the 400-m radius scale slightly differed among the three neighborhoods, at 0.73, 0.77, and 0.72 for Al-Saymmar, Al-Mugawlen, and Al-Abassya neighborhoods, respectively. Also, it illustrated similar differences for the 600-m radius scale, at 0.76, 0.79, and 0.76 for Al-Saymmar, Al-Mugawlen, and Al-Abassya neighborhoods, respectively (**Table 2**).

4.6 Clustering coefficient

The clustering coefficient indicator of the physical environment is measured by applying the equation of the clustering Eq. (9), and the major two components to run the equation are the observed number of links among the destinations and the possible number of links. However, there was no clear explanation about how to measure these two components in the reviewed literature; therefore, the criteria to measure these two components are designed by this study. In this regard, the first component of this equation is the observed links between destinations. It considered 5 min as the maximum walking distance between two destinations, which is a 200-m length. Thus, each destination has a potential relationship with all other destination in the 200-m radius. The reason for such an assumption is because, if the distance between every two destinations is not a complete journey for the walker but rather a sub-journey, then the minimum distances mean a better relationship. Based on this criterion, each destination was defined as a center and a straight line was drawn to all other adjacent destinations in the 200-m radius. The required information was elicited from the cadastral maps with the assistance of AutoCAD 3D map software; in this regard, the shapefile maps were generated to both the links and the destinations on the 400-m radius and 600-m radius scales. From this, the layers were added into QGIS software. The resulting total number of links was considered the observed links (numerator). The second component is the possible number of links, even if they did not exist, between the destinations; for this purpose, the equation used was: the number of possible links = $(n^2 - n)/2$ (denominator), Eq. (9), where n is the total number of destinations. Thus, two independent variables resulted from this indicator, on the 400-m radius and 600-m radius scales. The two variables were labeled as ClsCofS1, ClsCofS2 (**Table 1**). Thereafter, on the 400-m radius scale, the clustering coefficient variable CICS1, indicated that the Al-Saymmar and Al-Abassya neighborhoods were identical, at 0.05 for each. Meanwhile, Al-Mugawlen was slightly different at 0.04. Moreover, on the 600-m radius scale, the clustering coefficient variable CICS2, indicated that the Al-Saymmar and Al-Abassya neighborhoods are identical at 0.04 for each. Finally, Al-Mugawlen was slightly different at 0.03 (**Table 2**).

4.7 Edges assessment

The method to assess the quality of street edges was adopted the frontage quality index (SFOMD) [50]: p.108. It depends on a Likert scale of seven points, starting with (1), which is the lowest score of the assessment, and ending with (7), which

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Factors	Al-Saymmar streets			Al-Mugawlen			Al-Abassya		
	M*	C*	Col*	M	C	Col	M	C	Col
S	6	4	3	6	5	4	6	6	5
F	5	4	3	6	4	4	6	5	5
O	4	3	3	5	4	4	6	5	5
M	1	4	4	6	5	5	6	6	5
D	5	5	5	6	5	5	6	5	5
Total scores	21	20	15	27	23	22	30	27	25

M*: main, C*: Collector and Col*: Col-de-sac

Table 3.
SFOMD index, analysis of the edges.

is the highest score. The application of the method depends on observations is conducted by a specialist team and criteria based sampling of the urban tissue. The computation of the overall index concerning the quality of the area was adopted from Gehl [51] and Hershberger and Clements [52], which combines the five indicators by totaling their raw scores. Therefore, the minimum score of the process is five points which represents the poorest quality streets, whereas, the highest score is 35 points, which represents the best possible quality. Thus, one independent variable was developed in terms of the edges assessment, namely: The Frontage quality index (SFOMDS1) on the 400-m radius scale (**Table 1**). Moreover, the principle of sampling the streets is an important issue to avoid bias and to validate the generalization of the results, therefore, this study depends on the selection of three streets segments based on the hierarchal level of the street. From the hierarchical street levels, they define the main street, a connector street, and a cul-de-sac from each case study. The information of the survey was transferred into Excel-sheets for the purpose of analysis. The individual survey sheets were summarized (**Table 3**). Accordingly, three variables were developed from this analysis, which were: the Frontage quality index of the main street (SFMODS1M), the Frontage quality index of the Connecting street (SFMODS1C), and the Frontage quality index of the Col-de-sac (SFMODS1CS) (**Table 1**).

The SFOMD index in Al-Saymmar neighborhood demonstrated the lowest levels of frontage quality, at 21, 20, and 15 points for the variables SFOMDS1M, SFOMDS1C, SFOMDS1CS, respectively. The SFOMD index in Al-Mugawlen neighborhood demonstrated moderate levels of frontage quality, at 27, 23, and 22 points for the variables SFOMDS1M, SFOMDS1C, SFOMDS1CS, respectively. Finally, the SFOMD index in Al-Abassya neighborhood demonstrated the highest levels of frontage quality, at 30, 27, and 27 points for the variables SFOMDS1M, SFOMDS1C, SFOMDS1CS, respectively, (**Tables 2** and **3**). Therefore, the value of the SFOMD index increased in parallel with the increased grid structure among the street typologies. For example, the red level of the SFOMD index, brought about different scores across the three neighborhoods, 21, 27, and 30, for Al-Saymmar, Al-Mugawlen, and Al-Abassya respectively (**Table 2**).

4.8 Enclosure ratio

The enclosure ratio was measured for the sampled streets in **Figures 6–8**, Thus, three independent variables resulted from applying the enclosure indicator on the 400-m radius scale; these were coded as EnRBS1M, EnRBS1C and EnRBS1CS

Figure 6.
Al-Saymmar edges assessment.

Figure 7.
Al-Mugawlen edges assessment.

Figure 8.
Al-Abassya edges assessment.

(**Table 1**). The variables required to apply the indicator are the width of the street and the heights of the adjacent buildings, which were measured directly in this study. Then, the function of the indicator was applied to the sections of all the sampled streets segments. In terms of the main streets (EnRBS1M), the three case studies have a broadly similar value of enclosure ratios, at 2.9, 2.7, and 2.7, for Al-Saymmar, Al-Mugawlen, and Al-Abassya, respectively. In terms of the Connecting streets with the green level of betweenness (EnRBS1C), the highest score was noted with the Al-Mugawlen neighborhood (1.7); Al-Abassya showed a moderate enclosure ratio level (1.3), and the lowest level was noticed within Al-Saymmar (1). In terms of the local streets and the blue level of betweenness (EnRBS1CS), the highest score was noted within the Al-Mugawlen neighborhood (1.7); Al-Saymmar showed a moderate enclosure ratio level (1.1), and the lowest level was noticed with Al-Saymmar (0.93) (**Table 2**).

5. The statistical analysis

The statistical analysis examines the extent to which the indicators of the physical environment are able to explain the variance among the walking outcomes of the individuals. The measured attributes of the physical environment were tested in terms of their predictability for the walking minutes. Thus, their variables are considered predictors (X), which need to be tested in terms of their predictability for the walking minutes (Y). In other words, this analysis tests whether the walking outcome variables can be individually predicted by the measured attributes of the physical environment. For such a purpose, the hierarchal regression analysis was chosen because of its flexibility to enter predictors in a split block with extra predictors. Moreover, the p-value (<0.05) indicates the significance of the models, while the determination coefficient (R^2) explain the potential of the predictors to explain the variance of the outcomes. The hierarchical regression analyses were run to test the predictability of the physical environment indicators, which were individually tested with the walking minutes in one model for each indicator to determine the effect significance of the predictor on the outcome variable (p-value) and the (R^2). Moreover, the SPSS software was utilized for the conducting all the required statistical analysis in this study.

5.1 Findings

The Block density, the predictability of the model was significant ($F(173, 1) = 16.989$, $p < 0.001$, $R^2 = 0.089$). Thus, the singular model was able to explain 8.9% of the variance of the total walking minutes. Also, the test shows that the higher walking behavior outcome score was associated with higher block densities ($b = 11.817$, $p < 0.001$). In term of Housing Units density, the predictability of the model was significant ($F(173, 1) = 26.231$, $p < 0.001$, $R^2 = 0.132$). Thus, the model was able to explain 13.2% of the variances of the total walking minutes. It was showed that the higher scores for walking behavior outcomes were associated with higher housing units densities ($b = 0.040$, $p < 0.001$).

Diversity of all commercial land use on a 400-m radius scale; the predictability of the model was significant ($F(173, 1) = 11.145$, $p < 0.001$, $R^2 = 0.061$). Thus, the singular model was able to explain 6.1% of the variances of the total walking minutes. Furthermore, the higher walking behavior outcome scores were associated with a higher diversity of all commercial land uses ($b = 2.478$, $p < 0.001$). Regarding the commercial land use without parking, wholesale, and workshops variable on a 400-m radius scale, the predictability of the model was significant ($F(173, 1) = 20.176$, $p < .001$, $R^2 = 0.104$). Thus, the model was able to explain 10.4% of the variances of the total walking minutes. Furthermore, the higher scores of walking behavior outcomes were associated with the higher diversity of commercial land use without parking, wholesale, and workshops ($b = 2.390$, $p < 0.001$). In term of the diversity of the non-residential land use on a 400-m radius scale, the predictability of the model was significant with the total walking minutes ($F(173, 1) = 13.947$, $p < 0.001$, $R^2 = 0.075$). Thus, the model was able to explain 7.5% of the variances of the total walking minutes. Also, the higher of walking behavior outcomes scores were associated with a lower diversity of non-residential land use ($b = -3.390$, $p < 0.001$).

Regarding the connectivity indicators; the node (streets intersections) intensity on both scales 400-m and 600-m radius, the predictability of the model was significant ($F(173, 1) = 26.940$, $p < 0.001$, $R^2 = 0.135$) and ($F(173, 1) = 18.678$, $p < 0.001$, $R^2 = 0.097$), respectively. Thus, the models were able to explain 13.5 and 9.7% of the variances of the total walking minutes on the two scales, respectively. However, the higher walking behavior outcome scores were associated with the higher node intensities only on the 400-m radius scale in terms of the total walking minutes ($b = 0.573$, $p < 0.001$). In term of the street intensity on 400-m and 600-m radius scales, the predictability of the two models was significant for the total walking minutes ($F(173, 1) = 27.071$, $p < 0.001$, $R^2 = 0.135$) and ($F(173, 1) = 13.331$, $p < 0.001$, $R^2 = 0.072$), respectively. Also, the models were able to explain, 13.5 and 7.2% of the variances of the total walking minutes, respectively. Moreover, the higher walking behavior outcome scores were associated with a higher street intensity on a 400-m radius scale ($b = 0.009$, $p < 0.001$) and on a 600-m radius scale ($b = 0.005$, $p = 0.001$).

The Pedestrian Catchment Area (PCA) on a 400-m radius scale; The predictability of the model was significant with the total walking minutes ($F(173, 1) = 14.914$, $p < 0.001$, $R^2 = 0.079$). Also, the singular model was able to explain 7.9% of the variances of the total walking minutes. Furthermore, the higher walking behavior outcome scores were associated with the lower value of the Pedestrian Catchment Area ($b = -0.059$, $p < 0.001$). Also, Pedestrian Route Directness Ratio (PRDRS1 and 2) on 400-m and 600-m radius scale; the predictability of the two models was nonsignificant for the total walking minutes were ($F(173, 1) = 0.301$, $p > 0.05$, $R^2 = 0.002$) and ($F(173, 1) = 0.142$, $p > 0.05$, $R^2 = 0.001$). Similarly, the models were inconsiderably explained the variances of the total walking minutes, at 0.2 and 0.1%, respectively. Also, the higher walking behavior outcome scores were not associated with the Pedestrian Route Directness Ratio ($b = 1.231$, $p > 0.05$). Regarding the Clustering coefficient of destinations on a 400-m and 600-m radius scales, the predictability of the two models were nonsignificant for the total walking minutes ($F(173, 1) = 0.142$, $p > 0.05$, $R^2 = 0.001$) and ($F(173, 1) = 2.288$, $p > 0.05$, $R^2 = 0.019$). Also, the models were able to explain, 0.1 and 1.9% on the two scales, respectively.

Frontage quality index of the streets on the 400-m radius scale: the predictability of the three models of the main, Connecting and col-de-sac streets was significant for the total walking minutes ($F(173, 1) = 26.427$, $p < 0.001$, $R^2 = 0.133$), ($F(173, 1) = 26.586$, $p < 0.001$, $R^2 = 0.133$) and ($F(164, 9) = 4.374$, $p > 0.05$, $R^2 = 0.211$), respectively. However, the higher walking minutes were marginally associated with the lower frontage quality index of the main, the connecting and the col-de-sac streets ($b = -0.110$, $p < 0.001$), ($b = -0.145$, $p < 0.001$) and ($b = -0.097$, $p < 0.001$), respectively. Regarding the enclosure ratio of the streets on the 400-m radius scale, the predictability of the three models of the main and Connecting streets was significant for the total walking minutes ($F(173, 1) = 20.840$, $p < 0.001$, $R^2 = 0.108$), ($F(173, 1) = 49.636$, $p < 0.001$, $R^2 = 0.223$), respectively. While, in term Enclosure ratio of the col-de-sac street on the 400-m radius scale, the predictability of the model was not significant for the total walking minutes ($F(173, 1) = 0.428$, $p > 0.05$, $R^2 = 0.002$). However, the higher walking minutes were marginally associated with the lower frontage quality index of the main, the connecting and the col-de-sac streets ($b = 3.720$, $p < 0.001$), ($b = -0.615$, $p < 0.05$) and ($b = 0.103$, $p > 0.05$), respectively.

6. Conclusions

In terms of optimizing livability through neighborhood sizes, the feedback from this study challenges the 25.02 ha suggested by the current Master Plan. Instead, it proposes 50.24 ha, which denotes a 400-m radius, or 10-min walking; that is based supported by other relevant urban planning literature. The walking outcomes and accessible amenities within a 10-min walk were highly associated and found to enhance pedestrian activity. In terms of the percentage ratio of retail space, the findings from this study disagree with the suggested proportion of ~1%. Instead, we propose that mixed types of commercial and retail activity should occupy up to 10% of the total land use. The findings suggest that the ratio should be separated into: food shops (~5%); consumer goods shops, selling items such as appliances or clothes (~2.5%); and general services, such as barbers, coffee shops, or maintenance workshops (~2.5%). In terms of health and religious centers, this study agrees with the Master Plan's proposed approximate proportion of <1% for each. Meanwhile, open space was specified into playgrounds, local parks, roads and open spaces, and this study agrees with the approximate amount of 30% suggested by the Master Plan. However, more walking was observed in the traditional neighborhood (Al-Saymmar), which accommodates more and smaller open spaces. In terms of housing, the evidence from this study suggests 50% for the single-family housing residential typology; therefore it challenges the suggested high ratio of low-density housing within the Master Plan. Finally, no feedback is offered in terms of educational land use, since this depends upon relevant standardizations.

For other planning and design criteria, the indicators applied by this study suggest that the planning of new neighborhoods should, not only be confined to defining the densities and types of land use, but should also consider the topologic relationships, and streetscapes design, as these are important influences on walking. In this respect, further suggestions, in the form of both qualitative and quantitative recommendations, were made by this study. Based on evidence, the recommendations mostly focused on the organization of traditional neighborhoods (Al-Saymmar), which are considered more pedestrian-friendly environments than the more modern developments (Al-Mugawleen and Al-Abassya) because the increase in walking minutes were significantly associated with the higher scores in urban planning and design indicators tested. However, modern neighborhoods were found to be better in other respects than traditional neighborhoods; for example, commercial growth within the center of modern neighborhoods was far greater than in traditional neighborhoods, as was the permeability, and straightness of edges.

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