EVALUATING WALKABILITY AT THE NEIGHBORHOOD AND STREET LEVELS IN RIYADH USING GIS AND ENVIRONMENT AUDIT TOOLS
Tahar A. Ledraa
King Saud University, College of Architecture and Planning
P.O.Box 57448 Riyadh 11574
tledraa@ksu.edu.sa

(Received August 1, 2015 and Accepted December 1, 2015)

Abstract
The paper sets out to evaluate walkability in Riyadh. Many scholars have examined the issue of walkability at the macro-scale level of the neighborhood. To better understand walkability however, it is crucial to scrutinize it at the micro-scale of the street as well. Here again, it is important to bear in mind that the streets in a neighborhood are not all homogeneous but are of different types (main street, local residential, dead-end streets, etc.). Differences in street types will lead to differences in walkability scores. The study used quantitative objective measures together with qualitative subjective measures to evaluate walkability. GIS-derived walkability indicators were used to assess neighborhood walkability. Whereas, environment audit tools were adopted to evaluate street walkability. The results indicate that older traditional inner-city neighborhoods performed better than newer suburban neighborhoods with regard to walkability. Main street types tend to outweigh other street types as they have diverse land use mix, higher densities and relatively better sidewalk design. Main streets of lower socioeconomic status neighborhoods tend to have far better walkability scores than their counterparts in higher socio-economic status (SES) areas.

Key Words: Neighborhood walkability; Riyadh; GIS; Environment Audit

1. INTRODUCTION AND PROBLEM STATEMENT
Although walking is an essential human activity and an important form of transport, policymakers in Riyadh seem to have ignored. They regarded it more as an obstacle to car movement instead. Since Riyadh citizens own on average 274 cars per 1000 inhabitants and make some 7.4 million car trips per day (ADA, 2013), relying on walking for transport has therefore, never been an issue. Rather than making a pedestrian friendly environment through passing measures to improve walkability in the city, city planners showed an entire bias to city-motorized form of transport. They chose to pour huge investments to build more multi-lane free-flow high-speed roads that render walking activity so unpleasant, and even unsafe and dangerous. The measures taken tended to discourage free outdoor pedestrian movement to cater for driving instead. The result was that road infrastructure was so developed and improved for cars to move freely and speedily. The pedestrian infrastructure however, was left over and neglected. Even worse, walking in the city has become so unpleasant and difficult to a point where no one dares to interfere with car movement.

The present paper sets out to examine the built environment correlates with walking behavior within the context of Riyadh. Its main objective is to examine walkability in the city at both the
neighborhood and street levels. For that, a mixed approach using both GIS applications and environment audit tools is adopted. GIS applications are used to handle objective quantitative measures at the larger neighborhood level, while the audit tool serves to evaluate walkability at the street level to ascertain subjective qualitative factors.

The research question of the study focuses on how neighborhood form design can impact walkability and reduce heavy reliance on car use for moving around? Measuring walkability however, should not be restricted to the evaluation of the effects of neighborhood form variables, but should also include an assessment of the street features effects as well. The traveller’s trip between origin (usually home) and destination (work or service location) and the quality of the walking experience are also of paramount importance in affecting the decision to walk.

2. Literature Review

The past decade has seen a growing interest in walkability research, so much so that neighborhood walkability is currently at the forefront of discussion topics in urban planning and urban design. Many cities are now adopting plans with goals around neighbourhood walkability and pedestrian friendly public spaces. An understanding of the built environment attributes that encourage or constraint such walkability is therefore, necessary.

The scholarship research suggests that both quantitative and qualitative measures are proxy for neighborhood walkability. Quantitative measures account for macro-scale general neighborhood urban form variables. They relate to variables like population and building densities, street length per hectare, block and street intersection densities, mixed land use and street network patterns. In her review of the literature on neighborhood walkability, Talen (2013) reported that more than 200 research articles have been published on the issue of neighborhood form and its impact on walkability.

Qualitative factors however, delineate the micro-scale street level specific features and path quality. They indicate pedestrian route quality, continuous sidewalks, street trees, building facades, accessibility, destinations attractiveness, streetscape aesthetics, and perception of safety, liveliness, cleanliness, sense of place and enclosure. The importance to capture walkability at the street level comes from the fact that an individual is more exposed to the micro-features of the environment when walking than when driving (Talen, 2002).

This conclusion should not overshadow the fact that urban form at the macro-scale of the neighborhood affects walkability at the micro-scale of the street. Scholarly research has shown a positive relationship between pedestrian friendly environments and the amount of walking. Bernick and Cervero (1997) and Handy (1995) report that residents who lived in pedestrian-oriented environments like traditional neighborhoods were more likely to walk to service destinations more than those who lived in suburban car-oriented environments. Similarly, Krizek (2003) reported that people who lived in walkable neighborhoods are more likely to go to transit stations on foot than those who lived in more automobile-oriented environments.

Researchers have often focused upon urban form characteristics that are conducive to walkability. The urban form approach defines a walkable neighborhood as one where daily services and amenities are accessible within five to ten minutes walk, which is approximately one-quarter to one-half a mile (Ewing, 1999). It usually uses variables such as housing density, land-use diversity, neighborhood street patterns as measured by street length per hectare, intersection density as expressed by the number of three-way and four-way intersections per square kilometer, and by dead-end density which is the number of dead-ends per square kilometer, block density and average block size. The hypothesis is that the higher the densities of residents, intersections and blocks and the lower the dead-end street density the more walkable the neighbourhood would be.

Although distance or physical proximity is an important measure of the effects of urban form on walkability, it is by no means the only one. Mixed land use patterns and streetscape features were found to have strong impacts on neighborhood walkability (Larsen et al, 2009). Street connectivity as assessed by street intersection density is another measure (Frank et al, 2005). Another study found block density to have a strong positive association with walkability in the sense that shorter blocks give greater potential for movements and ease of walking through space (Dill, 2004). Schlossberg (2004) and Dill (2004) used an origin-destination walkability index, called pedestrian route directness (PRD) to measure the effect of urban form on neighborhood walkability. The index consists of computing the ratio between the distance as the crow flies and the network pedestrian-based distance between an origin (usually residence) and a destination (service amenity).

In their review of the literature, Sallis and al. (2004) drew attention to connectivity and proximity as recurring variables determining the walking behavior of pedestrians. Whereas in their study of walkability, Leslie and colleagues put emphasis on the association between walking activity and the built environment attributes (Leslie et al; 2005). In an extensive research on walkability, The London Planning Advisory Committee (2005) came up with the five Cs, namely connectivity, conviviality,
conspicuity, convenience, and comfort as encompassing the main criteria determining walkability of an area or a street. Other scholars found walkability to be associated with land use mix, street connectivity, proximity or distance to destination services, residential density, perception of route safety, retail accessibility and ease of moving between origins and destinations (Cervero and Kockelman, 1997; Krizek, 2003; Pikora, 2003; Saelens, 2003; Sallis and Frank, 2003; Schlossberg, 2004).

Ewing, Pendall and Chen (2003) found the characteristics of sprawl such as low density, segregated land use patterns and heavy reliance on the private car for movement to be a deterrent for walking in suburban neighborhoods. By contrast, a walkable neighborhood would have the opposite characteristics that is, residential density, land use mix patterns, and accessibility of street network. For that matter, Litman (2004) used land use, accessibility, roadway Connectivity, such as the relative location of common destinations and the quality of connections between them to measure neighborhood walkability. Whereas Moudon, et al (2006) used variables like residential density, block size, sidewalks, attractor destinations, deterrent destinations and, perceived number of central activities to calculate their walkability index.

In her report on walkability of local communities, Leslie and colleagues used GIS applications to compute a walkability index based on neighborhood attributes such as connectivity, residential density, land use attributes and, net retail area (Leslie et al; 2007).

There seems to be a consensus in the scholarship literature about such variables like connectivity, proximity, land use mix, density and safety as determinants of walkability within a neighborhood.

It is clear from the above account that a large body of scholarship research has embarked on examining the issue of walkability at the neighborhood level. Walkability at the street level however, has not received much attention. An attempt is therefore needed to fill in this void by looking at the determinants of walkability at the street level as well.

In the same vein of thought, many scholars have levelled some criticisms to assessment approaches relying on crude measures of walkability. The use of variables like distance between trip origins and destinations, dwelling density and land use intensity may be missing out on important qualitative attributes and urban design aesthetic qualities.

By the same token, many critics have argued against the use of transportation planners and traffic engineers models to capture walkability. Such walkability models include variable measures like street width, number of lanes, walking speed and traffic flow. This approach would have been appropriate if the focus is on travel flow efficiency. What matters in walkability experience however, is not how much efficient is the travel fluidity but rather how much such a walking experience is satisfying and pleasurable?

Similarly, the inclusion of pedestrian route qualities as measures of walkability would respond to the criticism against urban form approaches and car-centered methods relying more on objective quantitative measures of walkability. The argument is that if macro-scale crude measures are critical to evaluate walkability at the neighborhood level, micro-scale elements are also very significant in supporting walkability at the street level (Owens, 1993; Calthorpe, 1993, 2002; Duany, 2001; Schlossberg, 2004, 2007).

In the literature, neighbourhood streets are often taken as if they were all homogeneous and of the same type. In the present study, the streets were categorized into main streets, local streets and dead-end streets. This categorization was necessary because main streets are often the most walkable segments in a neighbourhood as they have diversified land uses, more articulated building design and complete sidewalks with all required amenities. Local and dead-end streets tend to be mainly residential with relatively fewer amenities. Differences in walkability measures between different street types are therefore expected.

3. Measuring Walkability

As long as objective quantitative measures alone cannot account for the full variance of neighborhood walkability, it is imperative to include perceptual qualitative measures to the model to increase its explanatory power. Similarly, macro-scale neighborhood attributes must be added to the micro-scale features along the pedestrian trail if the level of walkability assessment is to be improved. Considerations of the pedestrian infrastructure such as street trees, wide continuous sidewalks, transparent facades, street connectivity, low traffic volume and lower vehicular speed, pedestrian signals and islands and traffic calming measures are all believed to support the shaping of a pedestrian-friendly environment. In that regard, many scholars have constructed models in which they introduced urban form variables together with those variables related to path design quality, perception of street safety from crime and traffic, and streetscape aesthetics (Pikora et al., 2002; Emery et al., 2003; and Day et al., 2006).

In his attempt to develop a normative definition for a “walkable” neighborhood, Ewing (1999) distinguishes between three classes for pedestrian-friendly design features: essential, desirable and
nice. The essential features are medium-to-high densities, mix of land uses, short to medium length blocks, two- or four-lane streets, continuous sidewalks, safe crossings, appropriate buffering from traffic, and street-oriented buildings. Whereas the highly desirable features are: supportive commercial uses, grid-like street networks, traffic calming and closely spaced shade trees along access routes, little dead space, or visible parking, nearby parks and other public spaces and small-scale buildings. The nice additional features are: streetwalls, functional street furniture, coherent, small-scale signage, special pavement, and lovable objects, especially public art.

In examining the relationships between urban form and pedestrian accessibility, Pikora and colleagues (2002) developed a Systematic Pedestrian and Cycling Environmental Scan (SPACES) instrument to collect data about the micro-scale street features to measure the physical environment for walking activity. The SPACES model includes five factors: functional, safety, aesthetic, destination, and an added subjective assessment element. In all, some 37 elements of built environment features are measured. Some of which include characteristics describing the walking path such as street characteristics, perceived attractiveness, land uses, and slope and path obstructions.

In their endeavour to capture neighborhood walkability, Lee and Moudon (2003) undertook an exhaustive review of the 31 audit tools with over 200 built environment macro- and micro-scale features to evaluate walkability. They then devised a model to scan the association between urban form elements and neighborhood walkability called the Behavioral Model of Environments (BME). The model was based on three main sets of attributes to assess the qualities of both the origin and destination of the walk trip, the quality of the travelled path, and the surrounding areas. Since the Model seeks to account for personal characteristics, physical environmental factors, and latent demand for walking, the variable measures to evaluate these environmental attributes were further grouped into four classes that is spatio-physical, spatio-behavioral, spatio-psychosocial, and policy-based.

For that matter, Emery and colleagues developed a collaborative community-based approach for both objective quantitative and perceptual qualitative data collection called the Walkable Places Survey (WPS). The audit instrument serves participants to conduct first a walkability evaluation of their public spaces such as a streetscape, intersection, or plaza while walking. Then, they rate the quality of their experience once the walking is done. The audit includes measures of traffic volume, traffic speed, sidewalk and buffer width, surface quality, location factors, and supportive amenities such as street lighting and furniture (Emery et al., 2003).

In their study of urban form and walking behavior, McMillan (2005) outlined a theoretical framework to explain children’s trip to school. She found that other factors related to perception of safety and socio-economic variables tend to have a profound impact on the choice to walk to school more than physical urban form elements. McMillan’s model reveals that urban form elements are not the only determinants of neighborhood walkability. Other mediating factors or non-built elements such as neighborhood safety from traffic and crime, cultural norms, parental attitudes are also that much important (McMillan, 2005).

Clifton and colleagues (2006) for their part, devised another pedestrian environment audit instrument, known as the Pedestrian Environment Data Scan (PEDS). The PEDS audit tool provides a comprehensive method to evaluate the effect of urban form on pedestrian behaviour at both the neighbourhood macro-scale and the street micro-scale as well. The auditing tool includes some 78 measures of streetscape characteristics.

Based on an exhaustive review of the literature, Day and Boarnet et al. (2006) developed another audit tool known as the Irvine Minnesota Inventory. It was designed to measure a wide range of built environment features that are potentially linked to neighborhood walkability. The Irvine Minnesota Inventory includes 162 items, organized into four domains: accessibility (62 items), pleasurability (56 items), perceived safety from traffic (31 items), and perceived safety from crime (15 items).

The Walk Score group (http://www.walkscore.com/) developed an approach to measure the trip from residential units to the locations of businesses and amenities within U.S. neighborhoods. The scoring consists of computing measures of walkability on a scale from 0 to 100 based on walking routes to destinations such as grocery stores, parks, schools, restaurants, and retail businesses. Duncan and Carr studies of estimating access to walkable neighborhood amenities have lent some validity to the Walk Score approach (Duncan et al. 2011; Carr et al. 2010).

To sum up, both macro-scale measures of the general neighborhood characteristics and the micro-scale street features must be taken into account if our understanding of the variables impacting walkability is to be improved.

4. Methodology and Data Collection

To collect data on urban design characteristics of the concerned neighborhoods, a survey was conducted. The researcher and some fourth year undergraduate students in urban design at the department of urban planning at King Saud University in Riyadh Saudi Arabia, carried out on-site observations to gather urban design data.
The study neighborhoods were selected to cover a wide-ranging set of demographic characteristics, locations, planning and design features, and neighborhood types. The selected neighborhoods range from higher socioeconomic (SES) to lower SES neighborhoods, from relatively low-density to high-density, from traditional-oriented design to conventional modern-design and from inner-city traditional neighborhoods to suburban neighborhoods (Table 1; Figure 1).

In all, 12 different Riyadh neighborhoods were selected through a purposive sampling procedure aimed at maximum variation of environments. Some neighborhoods were included as they were assumed pedestrian friendly as is the case with traditional inner-city neighborhoods. Whereas others were chosen as they tend to impede walkability such as newer residential neighborhoods with conventional suburban development.

Table 1: study neighborhoods

<table>
<thead>
<tr>
<th>Neighborhood</th>
<th>Location</th>
<th>Planning style</th>
<th>SES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deera</td>
<td>Inner city</td>
<td>Traditional</td>
<td>low</td>
</tr>
<tr>
<td>Shmeasey</td>
<td>Inner city</td>
<td>Traditional</td>
<td>low</td>
</tr>
<tr>
<td>Badeea</td>
<td>Urban</td>
<td>Modern</td>
<td>low</td>
</tr>
<tr>
<td>Olaya</td>
<td>City center</td>
<td>Modern</td>
<td>medium</td>
</tr>
<tr>
<td>Sulaymaniya</td>
<td>City center</td>
<td>Modern</td>
<td>medium</td>
</tr>
<tr>
<td>Al-Jazeera</td>
<td>Urban</td>
<td>TND</td>
<td>medium</td>
</tr>
<tr>
<td>Hamra</td>
<td>Suburban</td>
<td>TND</td>
<td>medium</td>
</tr>
<tr>
<td>Maseef</td>
<td>Urban</td>
<td>Modern</td>
<td>medium</td>
</tr>
<tr>
<td>Waha</td>
<td>Urban</td>
<td>Modern</td>
<td>medium</td>
</tr>
<tr>
<td>Mohamadiya1</td>
<td>Urban</td>
<td>TND</td>
<td>high</td>
</tr>
<tr>
<td>Mohamadiya2</td>
<td>Urban</td>
<td>Modern</td>
<td>high</td>
</tr>
<tr>
<td>Sahafa</td>
<td>Suburban</td>
<td>Modern</td>
<td>High</td>
</tr>
</tbody>
</table>

TND: Traditional Neighborhood Development

Figure 1: study neighborhoods in Riyadh

To evaluate walkability within the concerned neighborhoods, the study adopts a mixed approach where measures cover both the macro-scale neighborhood level and the micro-scale street level.
It compares land use patterns, densities and types of street networks between neighborhoods.

Macro-scale data about neighborhoods like land use patterns, street density, residential density, block density, and the like were taken from GIS data provided by Al-Riyadh development Authority (ADA). GIS software is used to evaluate the quantitative objective neighborhood attributes like the spatial distribution of land-use patterns, street characteristics and residential densities.

To collect information on the physical character of a neighborhood and its streetscape features, an urban design audit instrument was used. It consists of a systematic observation of both sides of street segments. The auditing includes urban design attributes of each street segment and the blocks within the neighborhood. The data collected includes observations of traffic patterns (vehicle speeds, number of lanes), pedestrian counts and urban design features within the neighborhood. Other measures include street network pattern (grid, cul-de-sac, loop, etc) neighborhood character (traditional, suburban), and also pedestrian infrastructure such as sidewalks (continuous, broken), urban furniture, speed bumps, intersection signals, etc.

To develop the study’s audit instrument for measuring built environment features, an exhaustive review of four published audit tools was undertaken. The audits include Systematic Pedestrian and Cycling Environment Scan (SPACES), the Pedestrian Environment Data Scan (PEDS), the Behavioral Model of Environments (BME), and the St. Louis audit tool. Based on this review a list of built environment and urban design attributes was established. These attributes were often assumed in the literature to have an impact on street walkability. To ensure greater accuracy and reliability, the study used the PEDS audit protocol manual.

The study’s audit tool included 24 observed themes. It was designed to be used by auditor observers. All items in the audit inventory were measured through in-person observation. Each segment to be observed was identified and printed on a map before data collection.

To complete the neighborhood walkability auditing, a survey was conducted among pedestrians to inquire into their perceptions about the walking experience. Subjects were asked a battery of questions about their perception of the walking trip and the reasons for walking. Respondents were also asked about their own perception of the walking experience, how attractive and pleasurable it is, and also how safe from traffic and crime it is.

The auditing was administered in Arabic. It was designed for completion in approximately 15 to 20 minutes per segment. Interview items were conducted in situ. The interview survey was anonymous; no information was collected on the identities of those who completed surveys.

The study is undertaken under the contention that walkability is affected by destinations and the characteristics of the routes to get to them. The closer and more attractive the destination the more influence it exerts on people to reach it. The better and more varied the aesthetic appeal of the scenery along the street segments leading to such destinations the more enjoyable and pleasurable the walking experience will be.

Because the focus of the present study is on both the macro-scale and micro-scale walking environments. Both neighborhood walkability and street walkability are the dependent variables for the study. They are computed by summing up all scores at the street level by use of an environment audit instrument and a survey questionnaire interview. A total of 104 items covering all 24 themes, were used to calculate such scores. For comparisons between walkability scores at the neighborhood level and at the street level, average scores were calculated for each study neighborhood and street type.

The scoring system for the audit inventory consists of assigning each walkability indicator with a numeric score ranging from 1 (the least desirable) to 4 (the most desirable). As far as the questionnaire interview items are concerned, they were attributed scores on a Likert scale ranging from 1 (the least desirable) to 4 (the most desirable). No neutral points were considered as they are not statistically helpful (Rossi et al., 1983).

5. Analysis and Discussion

The selection of the study neighborhoods was made to allow comparison of walkability differences between suburban and inner-city neighborhoods, between higher and lower SES neighborhoods and also between higher and lower density neighborhoods. Differences in built environment characteristics and street configurations were also taken into considerations.

In exploring the findings of GIS-derived walkability indicators and their respective densities within each neighborhood as shown in table 2, it appears that the higher the residential density, the street density, and the block density the more walkable the neighborhood is. This finding seems to be corroborated by the results of the neighborhood walkability audit instrument presented in table 3. The two neighborhoods (Deera and Shmeasey) that had higher values of quantitative GIS indicators have also had the best overall walkability ratings as
they scored by far the highest rankings 61 and 62 respectively.

These results show that people living in traditional inner-city neighborhoods are more inclined to walk than those living in newer suburban neighborhoods. The GIS data indicate that inner-city neighborhoods, represented here by Deera and Shmeasey, tend to have a more compact design as shown by their higher residential density (36.8 and 54 units per hectare respectively), higher block density (2.7 and 4.8 blocks per hectare) and concomitantly higher street density as measured by street length per unit area (335.5 and 493 meter/hectare respectively). By contrast, suburban neighborhoods as represented by Sahafa and Hamra, show lower residential densities (4 and 6.9 units per hectare as presented in Table 2).

Table 2: GIS-derived walkability indicators and their respective densities within each neighborhood.

<table>
<thead>
<tr>
<th>Neighborhood</th>
<th>Residential Dwellings units/ha</th>
<th>Street m/ha</th>
<th>Block density units/ha</th>
<th>Commercial density (m²/ha)</th>
<th>% public open space</th>
<th>Average block Length &amp; Width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deera</td>
<td>36.8</td>
<td>335.5</td>
<td>2.7</td>
<td>154.4</td>
<td>26</td>
<td>131</td>
</tr>
<tr>
<td>Shmeasey</td>
<td>54</td>
<td>493</td>
<td>4.8</td>
<td>454.3</td>
<td>35</td>
<td>106</td>
</tr>
<tr>
<td>Badeea</td>
<td>14.5</td>
<td>236</td>
<td>1.3</td>
<td>560.3</td>
<td>85</td>
<td>183</td>
</tr>
<tr>
<td>Olaya</td>
<td>5.9</td>
<td>217.0</td>
<td>1.3</td>
<td>2216</td>
<td>36</td>
<td>213</td>
</tr>
<tr>
<td>Sulaymaniya</td>
<td>15</td>
<td>251</td>
<td>1.6</td>
<td>687.1</td>
<td>33</td>
<td>171</td>
</tr>
<tr>
<td>Al-Jazeera</td>
<td>20.3</td>
<td>134</td>
<td>0.6</td>
<td>0</td>
<td>37</td>
<td>389</td>
</tr>
<tr>
<td>Hamra</td>
<td>6.9</td>
<td>162.5</td>
<td>0.6</td>
<td>0</td>
<td>29</td>
<td>273</td>
</tr>
<tr>
<td>Maseef</td>
<td>13.1</td>
<td>253</td>
<td>1.6</td>
<td>586</td>
<td>32</td>
<td>171</td>
</tr>
<tr>
<td>Waha</td>
<td>12</td>
<td>222</td>
<td>1.4</td>
<td>138.4</td>
<td>31</td>
<td>176</td>
</tr>
<tr>
<td>Mohamadiya1</td>
<td>25.3</td>
<td>246</td>
<td>3.9</td>
<td>0</td>
<td>48</td>
<td>115</td>
</tr>
<tr>
<td>Mohamadiya2</td>
<td>6.2</td>
<td>255</td>
<td>1.5</td>
<td>581</td>
<td>34</td>
<td>167</td>
</tr>
<tr>
<td>Sahafa</td>
<td>4</td>
<td>196</td>
<td>1</td>
<td>794</td>
<td>41</td>
<td>200</td>
</tr>
</tbody>
</table>

The older traditional neighborhoods in the downtown, tend to have a residential density up to 13 times higher than the newer ones in the suburbs. These sharp differences in residential density would certainly lead to significant variations on walkability. The above finding echoes what is previously suggested in empirical studies. The literature suggests that neighborhoods with a higher residential density beyond the threshold of 15 units per hectare tend to promote walking (Frank, Schmid, et al. 2005). The two traditional inner city Riyadh neighborhoods (Deera and Shmeasey) corroborate this finding as they show a residential density well beyond this threshold.

Overall walkability scores are shown in Table 3. The results reveal that six out of twelve study neighborhoods have a walkability score well above the average. The traditional inner-city neighborhoods have ranked by far the highest on walkability score. This finding could also be attributed mainly to their downtown location. The downtown usually draws residents from many parts of the city to benefit from the presence of shopping facilities, varied businesses and catering establishments along their busy streets. The downtown is also perceived as attractive for walking not only for its diverse economic activities but also for its liveliness and considerable amounts of human activities as well (Figure 2).

Another reason may be the fact that Riyadh downtown residents tend to be mainly of lower socioeconomic status who may not be able to afford buying a car. As they cannot afford to spend more money from their meagre income on transport, walking would therefore, be more out of an
Residents of the more affluent suburban neighborhoods tend to own more than one car per household (often one car per adult male). As such they do not feel the necessity to go for utilitarian walking as they heavily rely on the private car to get to any destination.

Riyadh inner city neighborhoods are known for the lower socioeconomic status of their residents. Because of their economic hardship, they may be more inclined to walk to their neighborhood main street rather than using the private car to get to farther destinations. As the main street carries more pedestrian traffic and more varied businesses, it creates more vibrancy and pedestrian friendly ambience which add up to the liveliness on the street and hence attracts even more people and businesses.

The results suggest that the socioeconomic status of neighbourhood households does not seem to indicate any association with walkability scores. Although lower SES neighborhoods tend to show relatively lower walkability scores, higher SES neighborhoods did not have the highest scores either. The data collected in this case study do not seem to indicate any association linking SES to walkability (Table 3).

### Table 3: Average Walkability audit scores along different street segments of study neighborhoods.

<table>
<thead>
<tr>
<th>Neighborhood</th>
<th>Walkability Score</th>
<th>SES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Main street</td>
<td>Local</td>
</tr>
<tr>
<td>Deera</td>
<td>43</td>
<td>15</td>
</tr>
<tr>
<td>Shmeasey</td>
<td>42</td>
<td>16</td>
</tr>
<tr>
<td>Badeea</td>
<td>25</td>
<td>8</td>
</tr>
<tr>
<td>Olaya</td>
<td>31</td>
<td>12</td>
</tr>
<tr>
<td>Sulaymaniya</td>
<td>35</td>
<td>14</td>
</tr>
<tr>
<td>Al-Jazeera</td>
<td>23</td>
<td>12</td>
</tr>
<tr>
<td>Hamra</td>
<td>25</td>
<td>8</td>
</tr>
<tr>
<td>Maseef</td>
<td>29</td>
<td>8</td>
</tr>
<tr>
<td>Waha</td>
<td>27</td>
<td>9</td>
</tr>
<tr>
<td>Mohamadiya1</td>
<td>29</td>
<td>28</td>
</tr>
<tr>
<td>Mohamadiya2</td>
<td>29</td>
<td>8</td>
</tr>
<tr>
<td>Sahafa</td>
<td>31</td>
<td>9</td>
</tr>
<tr>
<td>Average score</td>
<td>30.8</td>
<td>12.3</td>
</tr>
</tbody>
</table>

Dead-end streets with a score=0 indicate the neighborhood does not have dead-end streets.

The low walkability scores shown for the minor residential streets (local and dead-end streets) are mainly attributed to their character of being usually pedestrian hostile streets since they lack many walkability features like sidewalks, sense of attractiveness and safety as is shown in (Table 3) and (figure 3). There is only one exception to this conclusion which is related to the residential local streets of neighborhoods with TND design layout.
Neighborhood design layout seems to have a strong impact on walkability scores. In exploring the findings from the three neighborhoods with TND design layout that is, Al-Jazeera, Hamra and Mohammadiya1, they seem to have the highest overall walkability ratings. This finding echoes what is often suggested in the literature that neighbourhoods with TND design layout are...
pedestrian friendly. The housing units in these neighborhoods are clustered around some shared common places that usually serve for socialization and gatherings of local residents (Fig 5). It must also be mentioned that these common pedestrian spaces enjoy complete sidewalks, informal surveillance, often well maintained and taken care of which provide a sense of security and feeling of safety. One may safely conclude that TND design inducing such characteristics as upkeep, social control and defensible space are good predictors for overall neighbourhood walkability.

It is interesting to note that the main streets of these TND neighborhoods did not score very high on walkability, but their dead-end streets did. The dead-end streets in this case are the common shared spaces referred to above. This is a striking difference with all the remaining study neighborhoods where the most noticeable thing about residential streets (local and dead-end streets) is the large amount of segments without sidewalks and adequate amenities. Not only do they have incomplete sidewalks but also suffer from poor sidewalk conditions. Having a sidewalk in disrepair hampers walkability just as lacking a complete sidewalk. Even where much of the sidewalks are in good repair as in the case of suburban neighborhoods, the lack of their maintenance and upkeep makes them less walkable. Sidewalk condition may also be an important predictor of total walkability within an area.

6. Street density

Street density tends to have an important association with walkability. The higher the street density is the more pathways to destinations are. This also implies a connected street network and hence, a more pedestrian friendly neighborhood. Here again, a comparison of street densities reveals that inner city traditional neighborhoods as represented by Shmeasey and Deera, have more streets per hectare than suburban neighborhoods as shown in Sahafa and Hamra (Table 2). These results suggest that on a neighborhood level, inner city traditional neighborhoods are more walkable than those situated on the city fringes because residents have more direct, and therefore shorter, routes to destinations (figure 4). However, these findings do not say much about the quality of the walking experience which is supposed to have a critical influence on the decision to exercise walking along the streets.

Streets that have a visually appealing building articulation and an aesthetically catching design tend to attract more people to walk than those streets with little aesthetic appeal. Streets with a distinctive ambience and outstanding character seem to have a special charm to attract people to roam in. These kind of streets are usually those with mixed and varied land uses and places that are seen as destinations for people to walk in. On the contrary, those streets lacking such characteristics and appeal tend to be less walkable. This explains why neighbourhood main streets have turned out to score very high on walkability (Table 3).

The same effect can be found with sidewalks of landscaped streets, of higher density areas and of commercial streets. Perceived street aesthetics and their visual appeal tend to have a positive association with neighborhood walkability as the existence of interesting views and pleasing vistas along the street may motivate people to walk. The results of the auditing tool tend to confirm this claim.

7. Walkability by street type

Knowing that streets in a neighborhood are not homogeneous but of different types like main streets, local residential streets and dead-end streets. The above results do not say much about differences in walkability by street types. These two points are discussed in the following paragraphs.

When comparing walkability scores by street types, the main streets seem to outweigh the local and dead-end streets in their impacts on walking behavior. This conclusion was more pronounced for both newer suburban and older traditional neighborhoods alike as revealed by the walkability audit instrument survey. The evidence suggests that neighborhood main streets score significantly higher in walkability ratings than the two remaining street types. The average walkability scores for main streets, local and dead-end streets are 30.8, 12.3 and 5.2 respectively (Table 3). The explanation may reside in the fact that main streets have diverse land uses and complete sidewalks provided with a full range of amenities. The remaining two types of streets (local and dead-end streets) however, often lack many sidewalk amenities. Some of them lack even a proper sidewalk (Figure 3). Poor street conditions, degraded physical environment, the presence of some kinds of antisocial behaviour, littering and graffiti drawings, constitute some common features in older neighborhoods and lower SES areas. These features tend to create threatening situations on the streets and hence, instigate some feeling of apprehension, unease and insecurity which may deter people from walking particularly for the most vulnerable groups like women, children and the elderly. This may explain why minor residential streets tend to have lower walkability scores. This finding substantiates what other scholars like (Seefeldt et al. 2002) and Ross (2000) have found. They argue that being unsafe and less secure, residential streets of lower socioeconomic status neighborhoods tend to be less walkable. Such feeling of insecurity and fear pushes residents to be less inclined to walk or stroll along their neighbourhood streets unless it is necessary. Similarly, Giles-Corti and Donovan (2002) also
claimed that unsafe streets because of threatening situations like crime and speedy traffic, tend to have a negative impact on neighborhood walkability.

By contrast, main streets are often associated with higher levels of perceived safety as there is a lot of eyes on the street as many windows overlook its space. Since many people roam in most of the day, this ensures some sort of informal surveillance over the street providing a sense of security and safety for those walking along.

The main streets in Riyadh are usually arterials of 30 to 60 meters wide. The municipality urban regulations adopted for these streets allow higher building density up to six storeys and mixed uses. Local and dead-end streets however, are minor residential streets and as such, the municipality codes do not permit more than two storey building height. These differences in urban regulations imposed by the Municipality may explain in part the very low walkability scores of residential streets and the relatively higher ratings of the main streets (Table 3).

It is interesting to note that residential streets of lower SES neighborhoods did not rate high on walkability. As they lack well-kept pavements, complete sidewalks and many amenities they have not rated high on walkability.

8. Block sizes

Shorter block sizes and hence, narrow streets seem to have a positive effect on walkability as their sidewalks tend to attract more people to roam in. The data provided in Table 3 show that neighborhoods with the highest walkability scores have also the shortest blocks as measured by their average length and width. The Deera, Shmeasey and Mohamadiya1 have scored 61, 62 and 57 on walkability (Table 3) and have turned out to have also the shortest width and length block measures (131, 106 and 115 meters respectively) (Table 2).

In line with this vein of thought, many researchers as is the case with the advocates of the New Urbanism and Smart Growth movements, have argued for shorter blocks, more enclosed space in between, narrower and more interconnected streets to promote walkability (Jacobs: 1961; Duany and Talen: 2002). Studies of “road diet” projects tend to confirm that reducing road lanes hence more spatial enclosure, would curtail crash accidents and hence help improve traffic safety (Huang, Stewart, and Zegeer 2002; Knaap and Giese 2001) which would have at the end, a strong positive influence on street walkability.

9. Conclusions

This study examined the determinants of walkability both at the macro-scale neighbourhood level and the micro-scale street level. In an attempt to better understand the determinants of walkability at both the macro and micro-scales, the analysis integrated subjective qualitative measures with objective quantitative measures. For this, the study used GIS-derived neighbourhood data coupled with environmental walkability audits and interview questionnaire survey data for the computation of walkability indicators at both neighbourhood and street levels.

Walkability at the larger macro-level of the neighborhood was found to be associated with objective measures such as street density, block density, and land use diversity. Whereas walkability at the micro-level of the street was correlated with subjective measures pertaining to sense of security and traffic safety, upkeep, landscape aesthetics, pleasantness of the streetscape visual appeals, and the availability of good pedestrian infrastructure such as buffered continuous paved sidewalks, quality of street amenities, and traffic safety.

The inclusion of micro-scale analysis is necessary to understand the effects associated with the finer aspects of the street sidewalks that influence walking. Such aspects cannot be captured using the course data of geographic information system (GIS) required for macro-scale analysis.

It is therefore recommended that a whole bunch of measures should be taken if neighbourhood walking behavior is to be stimulated in Riyadh neighborhoods, and also if pedestrians are to be encouraged to walk along the streets. Among such measures could be, increasing residential and block densities to increase the conspicuity of pedestrians on the street, land use diversity along the main streets, street landscaping, reducing vehicle speed, and well-designed continuous sidewalk and adjoining facades.

Well-designed sidewalks, provision of street amenities of quality and pedestrian infrastructure are also necessary elements that local planning decision makers should take into consideration to promote walkability along neighborhood streets.

Other measures related to traffic safety should also be considered. In this regard, measures to reduce street width and number of lanes are necessary. Such measures could be narrower street network and shorter block sizes which would lead to relatively safer and hence more pedestrian friendly streets. The issue of traffic safety can be further enhanced even for multiple lane street types, through traffic calming measures such as roundabouts, street signals, and curb extensions, tree buffers between pedestrians and the running cars, and raised medians with raised crossings or speed humps as they provide a break or stopover to cross the road in two stages.

As far as the neighborhoods with conventional suburban development are concerned, these results...
illustrate that they can be retrofitted through the provision of adequate pedestrian amenities and well-designed streetscapes to significantly influence the overall walkability along the streets. Urban design qualities such as connectivity and legibility, human scale, tidiness, pleasantness of physical surroundings attractiveness, enclosure and imageability are also important attributes to promote walking.

References

Evaluating Walkability at the Neighborhood and Street Levels in Riyadh Using GIS and Environment Audit Tools

42. Schlossberg, Marc A and Nathaniel Brown. (2004). “Comparing Transit Oriented Developments Based on Walkability Indicators”. Transportation Research Record: Journal of the
Transportation Research Board, No. 1887, pp. 34–42.
45. The London Planning Advisory Committee (2005) Improving walkability: Good practice guidance on improving pedestrian conditions as part of development opportunities. September 2005