Built Environment Attributes and Walking Patterns: A Case Study of Abu Dhabi Downtown

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Abstract

Walkability is crucial in sustainable urban design. Our understanding on the walkability in cities in hot and arid climate needs to be improved due to shortage of our knowledge and previous studies about this. Thus, this study aimed to demonstrate the value of sustainable urban design in enhancing downtown Abu Dhabi residents' walking experience. Urban neighbourhoods' quality of walking environment and the scale of the downtown's super block in Abu Dhabi Main Island were measured. In addition, it is examined how its urban design influences walking behaviour by selecting two study sites based on land use diversity. To measure them, the current study investigated the (1) walkable distance in Abu Dhabi; (2) scale of pedestrian movement; and (3) potential purpose of walking patterns of pedestrians of urban infrastructure. Site observation and surveys were carried out for collecting data that supports people's perceptions linked to walking purpose, quality, frequency, and intensity. To analyse these data, the geographic information system was employed. With this study, walking distance for the utilitarian purpose service in Abu Dhabi block cover by 0.5 miles. There is the active movement regardless of the extreme weather conditions both weekday and weekend. This study data could potentially guide designers and policy-makers to create a healthier walking environment for Abu Dhabi residents as well as some cities in hot and arid climate.

Keywords: Walkability; Land use; Urban form; Pedestrian movement

1 Introduction

In a sustainable community, walkability is an important planning factor that can promote city scales and socioeconomic benefits (Speck, 2013; Claris & Scopelliti, 2016). Walkable neighbourhoods are crucial for sustainable communities as they encourage good health (Alfonzo, 2005), lead to economic improvement (Carmona et al., 2018), reduce CO_2 emission (Chapman et al., 2018), and bring about social development for the community instead of car-based urbanism. Talen (2013) revealed that a Google Scholar search for a "walkable neighbourhood" returned 500 entries, 96% of which had been published since 2000, demonstrating scholars' interest in walkable environments. Academic and practicing planners access the links between the built environment and physical activity as an influence for individual health (Cervero & Kockelman, 1997, 2000; Handy et al., 2002; Moudon et al., 2006). Several studies have presented examples of how to build transportation infrastructure, (e.g., direct proximity or transit-oriented development); support travel behaviours through urban forms (e.g., density, diversity, and design); and create positive walking experiences for individual pedestrians' safety and comfort (Neighborhoods, 1998). However, these factors of creating a sustainable community with walking behaviour are a debatable question in the United Arab Emirates (UAE); the National Bureau of Statistics of UAE recorded the summer temperature to be 38~42°C, and reached to 48°C in August, high air temperatures exceed the comfort zone range. The current

study aims to demonstrate the value of sustainable urban design in enhancing Abu Dhabi downtown residents' walking experience. To find out how the built environment influences pedestrian movement in a walkable neighborhood, we conduct empirical observation in two sites in different land-use characteristics of blocks. To measure the scale of pedestrian's movement framed on demographic composition, the number of pedestrians who passed by the street segment in the downtown superblock (approximately 200 m × 200 m) is counted. For walking, a random survey is administered to identify the preference of micro-scale of urban design elements (mainly land use store pattern) and preferred times for walking.

2 Literature Review (Factor of Walkability)

Walkability has received significant attention because of its role in sustainable development and its diverse benefits associated with public health, social life, sustainable environment, and the economy. As per Speck (2013), walkability is important for determining how a city is sustainable, healthy, and vibrant. Shimitz and Scully (2006) supported the idea that a pedestrian-friendly street design may help residents' biological health, contribute to positive lifestyle changes, and improve overall quality of life. Additionally, a pedestrian-friendly walkable environment enhances the street vitality (Gauvin et al., 2008). In post-modern urban planning, walkability is how safe and convenient on foot in their neighbourhood and it involved the many discourse and efforts how to define and measure walkability.

As outlined in Handy (2002) and Frank and Pivo (1994), the dimension of density can increase opportunities for walking or cycling rather than using a car through compact city development. With a similar logic, other dimensions of built environments, such as design and diversity, also affect people's travel mode choices. For example, Ewing and Cervero (2010) found a strong correlation between land use diversity and different frequencies of walking based on the type of amenity. Another built environment aspect, "connectivity and accessibility," is an essential criterion for enhancing walkability in terms of pedestrian comfort (Hillier and Hanson, 1989; Legeby, 2010). These two aforementioned elements help public transportation network planning and facilitate the desired and intended use of city development. Moreover, many scholars have measured connectivity, accessibility, and proximity with street configuration to analyse built environment characteristics (Legeby, 2010). Handy (2002) claimed that street connectivity, mixed use development, and good design improve the attractiveness of walking and bicycling despite physical and psychological barriers. Another aspect of walkability research focuses on the purpose of walking. Owen (2004) examined walking and walking environments in terms of aesthetic attributes, convenience of facilities, destination accessibility, and car perception, finding that "walking for exercise" differed from "walking to destination." Lee and Moudon (2006) individually observed micro-scale environment elements and proposed destination, distance, density, and route (3D+R) with objective measures. In their study, the number and accessibility of amenities had a solid relation to walking time (Cerin et al., 2007). Additionally, walkability increased when more grocery and retail shops, churches, and schools were in the neighbourhood, and when amenities were closely located, there was a positive relationship to the destinations within a 5-min walking distance (Southworth, 2005; Lee and Talen, 2014). Talen (2013), who is a new urbanist, emphasized a small, walkable block size with wide sidewalks and trees. Walkable neighbourhoods also sustain pedestrian-based services within walking distance, and social interaction and a sense of community contribute to a safe neighbourhood environment and increase the property value of the community. Walkable access to amenities creates a "pedestrian shed," where destinations are within a 5-min walking distance or a

radius measuring approximately 400 meters, considered to be the distance that people are willing to walk before opting to drive (Mehta, 2008).

2.1 Physical Built Environment and Characteristics of the Research Sites.

Since 1963, Abu Dhabi has been characterized by extensive growth as a modern city concept (Bani Hashim, 2015). During that period, the old core of the downtown expanded along the northern shoreline (Corniche), and the Airport Road became the main link to areas situated in the mainland. With the increase of oil prices, the city grew rapidly between 1972 and 1980. The urban form of the 1970s was characterized by arterial roads in a gridiron pattern, square blocks, and buildings within the superblocks. During this period, the inner part of the superblocks started to form, including secondary service roads that ran parallel to the arterial roads, passageways between buildings for pedestrian movement, etc. High-rise buildings were constructed at the perimeters of the superblocks, while mid- and low-rise buildings were built inside. Commercial and mixed buildings were 30-floors tall. From 1975 to 1979, 628 buildings were built in Abu Dhabi's mainland, which is a significant increase compared to the construction of 90 buildings during 1970–1974 (Bani Hashim, 2015).

This study focuses on the city's central downtown area built during the 1970s urban evolution (Figure 1). The superblock is situated in one of highest population density areas in the Abu Dhabi Main Island (average density = 156.5 ppl/acre). Designated as a visual climax of high-rise building composition in the early development stage (1970s–1980s), the buildings exhibit distinctive characteristics in terms of their height: high-rise at the rim of the superblock and low-, mid-, or high-rise in the middle. Numerous studies have investigated how density, land use, street connectivity, and perception affect walking patterns. Various methodologies were utilized to evaluate walkability quality for the examined areas. The ways of measuring walkability have been discussed from planning and transportation to the environment and health fields, with various theories on pedestrian movement (Frank and Pivo 1994; Handy et al. 2002; Newman 1996). To measure pedestrian movement objectively, researchers created audit tools and developed measurement methods, qualitative and quantitative (Lee and Talen, 2014).

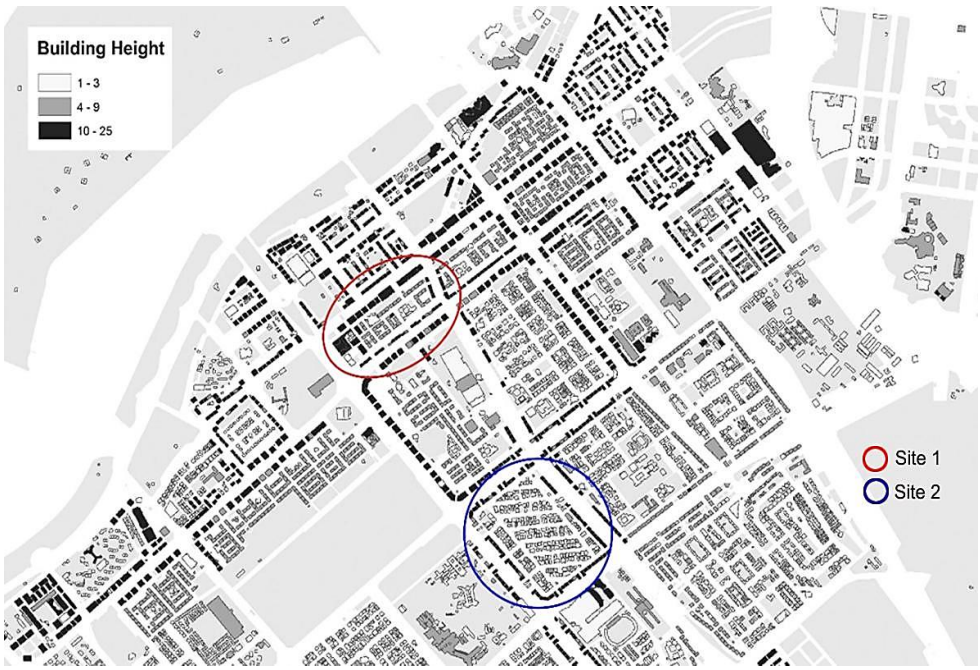

Fig. 1: Building density based on height. Case study area: Hamdan St. Block (Site 1; circled in red) and Al Falah St. Block (Site 2; circled in blue)

Fig. 2: Study Site 1 (left): High- and mid-rise typology; Study Site 2 (right): High-rise and low-rise typology

3 Materials and Methods

3.1 Physical Built Environment and Characteristics of the Research Sites

To analyse what extent the built environment and individual perception affect walkability in the region, two different land use feature were chosen. Both are located in Abu Dhabi's central district constructed during the 1970s along with the most significant streets in the city centre. The site design is based on principles of modern urbanism, especially the gridiron street pattern. An individual, single block is considered a super block (forming a square, some of which are more than 400 × 400 m), with secondary service roads running parallel to the arterial roads and pathways between the buildings for pedestrian movement. Assuming Abu Dhabi block size covers a walkable distance of about 0.25 mile (400 m), the current study measured the walkable distance for an individual block boundary. The methodology is designed to capture pedestrian natural movement in the research sites with survey analysis.

As we can see the table 3, the main difference between the two sites is their land uses and building densities. Site 1, Hamdan Street block (Sector E3-01), has an area of 0.2598 km^2 and comprises high-rise buildings[1] constructed along the perimeter of the superblock, with mid-rise buildings on the inner side. As both building types are used for commercial and residential purposes, the area contains low-rise retail stores and high-rise buildings for residential use. Further, Site 1 has a high percentage of diverse land use characteristics, such as various types and scales of retail businesses, offices, public institutional uses for school or mosque, and vertical residential buildings. Site 2, Al Falah Street block

[1] Low-rise buildings have 1–3 stories, mid-rise buildings have 4–9 stories, and high-rise buildings have 10 stories or more.

(Sector E18-01), has an area of 0.4175 km^2 comprising high-rise (commercial and residential) buildings along the perimeter of the block and low-rise residential villas or one- to two-story buildings in the inner block. Site 2 was primarily designed for residential use or single land use, with small-scale retail business at the boundary of the block. Additionally, Site 2's street layout of the superblock interior is rotated in the east–west direction instead of being parallel to the Corniche.

The analysis of walkable environment characteristics at each site was conducted by targeting residents and visitors in two different areas that had varied building densities. Considering the site characteristics in detail (Table 3) shows that they are alike in population with diverse housing components from single to multi-families: Site 1 has a population[2] of 38,880 and an area of 0.18 km^2 (215.55 ppl/acre), while Site 2 has a population of 44,987 and an area of 0.22km^2 (146.49 ppl/acre). Since Abu Dhabi was designed as a car-oriented city, pedestrian sidewalks on both blocks lacked consistency in terms of sidewalk width, design, street furniture, and trees. Site observation was conducted at the end of winter and spring, which is a suitable time for collecting pedestrian movement data in consideration of the culture and temperature of the region. Because of Arabic cultural customs, including *qayloulah* (afternoon nap), more active movement is observed on the streets after 4 p.m.

Site observation was conducted at both sites over a 2-week period, including weekdays and weekends, from January 2015 to early April 2015. Observations were carried out on sunny days with an average temperature of 32 °C between 4:30 p.m. and 7:00 p.m. This time of the day was chosen because it has the most active movement. To investigate how many people walked and moved around, a pedestrian audit was conducted at both sites. The method employed was a cross-section counting method[3] developed by Bauer, which counts pedestrian numbers at various time stamps. To achieve reliable observation data, counting points in each area were designated to 25 points from a block in Site 1 (high- and mid-rise with mainly retail shops) and 23 points from a block in Site 2, (high- and low-rise with mainly residential villas). For precise and rigorous observation, pedestrian movement and counting were observed at two levels: (1) the block perimeter and (2) selected intersections of the internal blocks. Entry points and the middle of each street segment were taken as additional counting points. As this study investigates how different urban forms or configurations indicate different walking patterns in each block as well as the natural pedestrian movement in Abu Dhabi's downtown area, observations were conducted at various points of urban characteristics at each site.

4 Results

4.1 Site Observation

Site 1, Hamdan Street, is a 4 km stretch in the heart of the capital city, known for its retail hubs, commercial buildings, and apartment complexes (a ground floor, mezzanine, plus 18 floors). With large new developments constructed in Abu Dhabi within the last decade, this area could be considered the old downtown. The Hamdan street area shows the most dynamic pedestrian movement and traffic congestion in Abu Dhabi.

The area is one of the oldest neighbourhoods with affordable shopping outlets, a series of hotels, and a vertical residential community close to the Corniche and Madinat Zayed. Retail businesses on the

[2] The population as mentioned in the GIS data from 2016 provided the number of floors through building footprints.

[3] Cross section counting method: The most basic measurement of a crowd is pedestrian counts at a cross section. A cross-sectional count is a pair of pedestrian numbers and time stamp indicating the number of people that crossed a particular virtual gate (henceforth called counting line) either since the last measurement or exactly at the indicated time stamp. This method enables obatining information on volume flow, flow rates, and (for suitable configuration and directional counts) occupation level/average pedestrian density

ground floor include jewellery shops, clothing shops, cafés, restaurants, food outlets, electronic stores**,** fruit markets, travel agencies, and vegetable markets. The Hamdan street area is a geographically significant location in the early development Abu Dhabi during the 1970s. There are many various ethnic groups,[4] mainly Arabs, Filipinos, Indians, and Pakistanis, in the area. A noticeable finding is streets can be used as a social gathering place for the same ethnic group of blue-collar workers every Friday. Site 2, Al Falah Street, is a family-friendly environment with many facilities at hand's length. The locals consider it the landmark of Emirati's residential area. In the block, there are many restaurants and an array of retails shops for residents, such as supermarkets, a school, a mosque, a medical centre, and a bank in the building complex surrounding the block. The perimeter comprises high-rise apartment complexes and a two-story villa inside the block. The street pattern of the internal block is uniquely faced to the north and south rather than parallel to the Corniche.

Although the two sites have different land uses, building heights, and density characteristics, they have similar streetscape features. Examining the micro-scale urban elements of Sites 1 and 2 revealed that the 2.5-m wide sidewalk is narrow and makes people feel uncomfortable while walking, especially during busy times. A parking ticket machine (Mawaqif pole) located in the middle of the pedestrian pathway restricts the flow of pedestrian movement. Overall, parking spaces and car traffic are prioritized over pedestrian movement. It is rare to find parks or benches for neighbourhood visitors. At some instances, people were observed sitting in informal areas, such as road curbs, building corners, or building entrances. The alleyways (Sikka) are unhygienic and unsafe places with no maintenance, although they have the potential benefit to create shade for pedestrians.

4.2 Pedestrian Counting (Scale of Pedestrian Movement)

To measure how many people moved around during the peak time (from 4:30 p.m. to 7 p.m.) at the two sites (weekdays and weekends during winter and spring), a pedestrian audit was conducted. An auditing point was designed based on the segment in the street, and the land use pattern was the average number of pedestrians within a 5-min interval at each observation point. Generally, Site 1 had a much higher number of pedestrians than Site 2, and in both regions, the number of pedestrians was higher on weekends than on weekdays (total average for Site 1: 1,800 people on weekends, 1,073 people on weekdays; Site 2: 322 people on weekends, 289 people on weekdays) (Figure 3). As the spider web diagram (Figure 4) shows, the two sites had comparable seasonal patterns of winter and spring but different patterns for weekdays and weekends. Figure 3 shows that Site 1 (mixed land use) had a more consistent pattern across weekends and weekdays than Site 2 (residential area) owing to particular land use features. Although Site 2 (Figure 3) showed s comparable pattern, movements that are more pedestrian were observed on weekdays in the area surrounding the Site 2 block owing to pedestrians passing by on their way to other blocks. With the diurnal pattern for Site 2, the weekday movement follows the shade direction of the perimeter's high-rise building depending on the time.

For Site 1 (mixed land use area), a high number of pedestrian movement in the perimeter corner (253 people on weekends), pedestrian crossing (119 people), and bus stops (206 people) was observed. Inside the block, inner street segment shows a high number of pedestrians in the inner segment from perimeter (188 people) and around the mosque (142 people). Specifically, a huge pedestrian movement was bordered in the Bangladeshi ethnics' social gathering area inside the small block

[4] According to the World Atlas data, the ethnic composition of the UAE in 2019 was as follows: 11.6% Emiratu South, 59.4% Asian (38.2% Indians, 9.5% Bangradeshis, 9.4% Pakistanis, and 2.3% others), 10.2% Egyptians, 6.1% Filipinos, and others 12.8%.

(comprising a seven-storied height); as its street is open, many people come and chat in the street (119 people). Some people sit on the curve with their group instead of using small pocket park inside of Site 1. Street can be social gathering space instead of movement.

For Site 2 (residential villa area), most of the natural movement was recorded near the retail stores, and many people were seen to pass through the internal long segment (segment of point 7, 17, 20) rather than the pedestrian pathway next to the road for going to other blocks. In Al Falah Street, a high number of pedestrian movement occurred around the bus stop (28 people on weekends), the perimeter of the block. Pedestrian movement was rarely observed inside the block surrounding the residential villa block. The inner segment between the villa shows the seldom movement (4–17 people), mosque entrance (19 people), and Indian ethnic restaurants (34 people).

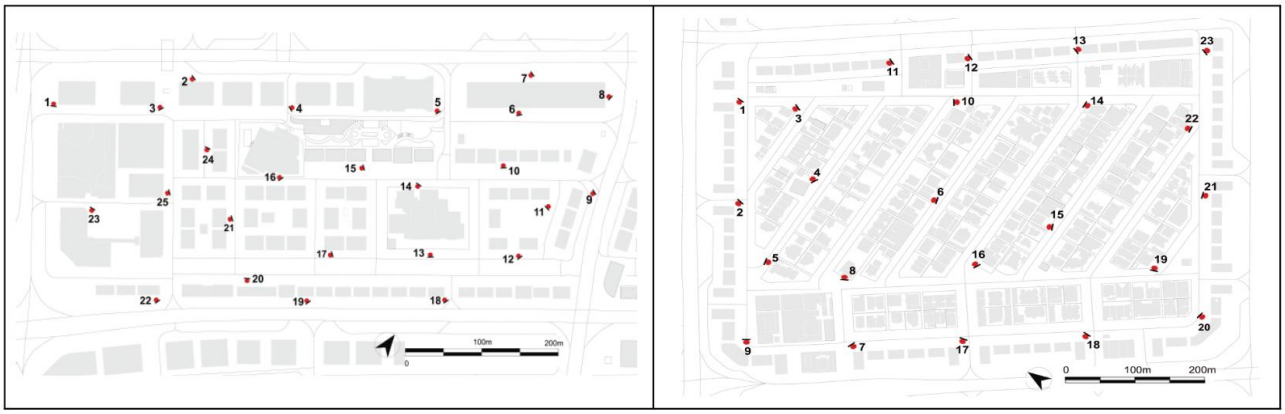

Fig. 3: Pedestrian counts points for Sites 1 and 2

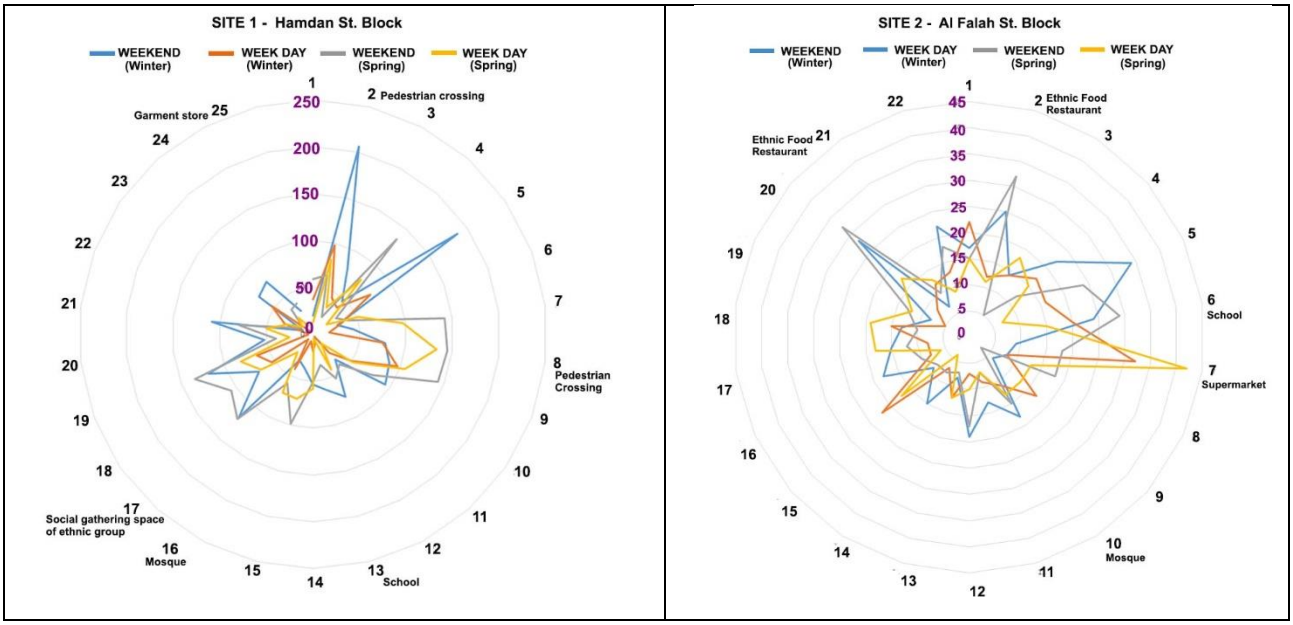

Fig. 4: Spider web diagram of Sites 1 and 2

5 Conclusion

The main finding of the current study can be given that walking behavior in both blocks in Abu Dhabi is strongly associated to a physical built environment. Subsequently, pedestrian perception of the city is found the positive aspect of walking environment in downtown block. The connectivity and accessibility, measured by the ratio between the number of intersections and straight lines in GIS, were sufficient for pedestrian movement. However, consistency of sidewalk pavement in microelement from design perspective is low, although the ratio of overall pavement in sidewalk is

high. The block size is too big to achieve an approachable physical metric for a neighborhood community as a small block size for frequent street access. This research also found the similar results that pedestrian movements in Abu Dhabi have relevance of land use and density to walkability. The design of land use and density are important factor to enhance the walkability in Abu Dhabi downtown. High-density areas with multi-land-use with small stores showed the highest pedestrian movement. Site 1 (Mixed land-use area) showed around four times higher pedestrian movement than site 2 (residential area). In a various ethnic group of pedestrians, Indian sub-continent ethnic has been observed at highest percentages in the block. The current study findings expand our understanding of hot arid region's walking environments and highlight the requirements for enhancing walking experiences. These observed results and analysis of the physical built environments show the potential of walkability to adapt to the other GCC countries and cities in hot arid climate conditions.

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