Sustainable Modes of Mobility in New Urban Neighborhoods in UAE: Assessing Walkability and Bikability

Khaled Galal Ahmed

Abstract

Sustainable modes of mobility within local communities are not only enhancing the physical and mental health of the residents, but they have significant social benefits. As residents are encouraged to abandon using their cars to access locally provided amenities, they develop more cohesive social relationships within their local communities. UAE has recently adopted a sustainable development agenda that endorses eco-community development where the conventional car-dependent sprawl urban forms are being transformed into more compact ones. This new trend has been reflected in recent new designs of urban communities in which it is claimed that sustainable urbanism principles, including sustainable modes of mobility, have been considered. However, there is a lack of reliable evidence that can assess the prospective performance of these new urban forms in terms of walkability and bikability. This study compares 'walkability' and 'bikability' scores, that range from 0 to 100, in both a conventionally developed urban sprawl neighborhood, and a recently designed more compact urban neighborhood. For investigating the two modes of mobility, the UMI urban modeling simulation tool has been utilized in this study to test walkability and bikability proximity to the points of interest for the provided local amenities in each of the two case studies. Walkability and bikability scores were obtained through constructing a pedestrian/cyclist travel network and performing a series of shortest path calculations using Dijkstra's algorithm. It has been surprisingly found out that the new neighborhood achieved lower walkability and bikability scores despite being more compact where walkability scored 61 versus 66 for the conventional sprawl case study. The same result has been found out for bikability, where the score was 85 for the former and 96 for the later. These unexpected results indicate that the new 'compact' design has not reached to a sufficient and appropriate degree of compactness that takes into consideration not only the Floor Area Ratio, but also other important walkability/bikability factors including catchment distances, variety and sufficiency of provided amenities, global and destination weights of amenities, street intersection densities and average block length.

Keywords

Walkability • Bikability • Mobility • Neighborhoods • Sustainability • UMI • UAE

1 Introduction

Accessibility, proximity, and mixed-use have been argued as the significant factors that affect any city's urban form and the interrelationship of people, transport and amenities is thus the basis for such a form. Catchment areas for services and facilities significantly define the hierarchical urban from of the city, starting from neighborhood to district to town to city. On the urban neighborhood scale, as the smallest 'building block' or 'unit' of which the city is made up, a mixed population with sufficient density is essential to support local services and facilities which cater for the daily needs of the residents.

As one of its definitions, the neighborhood is described as a territorial locality in which a group of independent people shares accesses to specific amenities located in walking distance from their home, whether they use these amenities or those provided elsewhere. Neighborhood services and amenities would best be located at the center of the neighborhood and around the transport node, to best contribute to the creation of a mixed-use center. Neighborhood service centers would usually encompass a public transport stop, a market place, housing over shops and service outlets, a community park with a community hall, a number of shops

K. Galal Ahmed (✉)
United Arab Emirates University, Al Ain, UAE
e-mail: kgahmed@uaeu.ac.ae

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for daily needs and a small supermarket, a post office counter, a public house, a newsagent, a local bank, a library, local (medical and dental) surgeries, commercial units and other workplaces. The neighborhood should also accommodate several kindergartens, a primary school and youth facilities play and sports areas for children and youngsters, and allotments (Frey 1999).

On the other hand, it is commonly agreed that the distance between any house front door and the local amenities or a transport stop should be within a maximum 10 min walk. The distance between the edge of a neighborhood and its central service area (and a transport node) should be about 600–800 m. Catchment areas for schools and other facilities are not limited to the neighborhood in which they are located but overlap with other neighborhoods. Furthermore, there should be a variety of house types, from flats in high-density low-rise housing to terraces and other forms of family homes. Mixed dwellings and tenure types will encourage a mixture of social and income levels in the neighborhood, which in turn, help secure the viability of community services and local amenities (Barton 2000).

The utilization of high density, mixed land use and short proximity between amenities are effective strategies that decrease automobile dependency and contribute to the utilization of human-powered transportation (HPT) as more sustainable modes of transportation (Sustainable Design Lab 2018). Sustainable modes of mobility within local communities are not only enhancing the physical and mental health of the residents, but they have significant social benefits through encouraging residents to abandon using their cars to access locally provided amenities, and thus, develop more socially cohesive communities. A wide spectrum of research has proved that walkable communities usually have better social capital that intensifies developed social networks, bonds, ties, and connections among local community members. The statistical analysis of the results of a study about the effects of urban qualities, including walkability, on the level of social capital in a local community in Isfahan City, Iran, showed that there is a direct relationship between changes in the qualities including walkability and the social capital indicators (Masoud 2011). In another research, the case study method was implemented to comprehensively examine the correlation between social capital and walkability. A positive correlation between the two aspects has been evidence suggesting that measuring a social aspect of sustainability may be feasible, especially in the context of community development (Rogers et al. 2013).

Paranagamage et al. (2014) conducted a case study to explore the impact of walkability on social capital in Braunstone, Leicester through a massive regeneration program funded by the New Deal for Communities. Braunstone, a typical disadvantaged area in the UK, is distinguished with its persistent socioeconomic problems and a poor physical setting. The study revealed that local facilities and neighborhood walkability provide incentives for longer term residency, and facilitates people interaction, which positively reflected on the community social capital. Paranagamage et al. (2014) added that accessing services by walking boosts people engagement in various local social activities, while poor accessibility to local services and public transport nodes negatively affects participation in social and leisure activities. Also, improving connections beyond the neighborhood is a critical measure in encouraging longer term residency, which, in turn, helps develop social capital. In very recent research, Mazumdar et al. (2018) found that there is a significant relationship between social capital on the one hand, and accessibility to local service destinations through walkability, on the other hand.

2 Research Problem, Question, and Method

UAE has recently witnessed a transformation toward sustainable urbanism associated with changing the conventional significantly sprawl urban forms in housing developments to more compact and efficient ones. It has been claimed that the urban form designs of new residential schemes are considering sustainable urbanism principles, including walkability and bikability. However, there is a lack of reliable evidence that can assess the prospective performance of these new urban forms in terms of walkability and bikability efficiency. With the recent introduction of new quantitative tools such as Urban Modeling Interface (UMI) (Sustainable Design Lab 2018) and Urban Network Analysis (UNA) (City Form Lab 2018), examining the expected degree of walkability and bikability in different urban forms has become much more straightforward and with more reliable results. Therefore, the research poses this question; *to what extent have the urban forms of the newly designed neighborhoods enhanced walkability and bikability compared to the conventional more sprawl ones?*

In order to answer this question, the research adopted the case study method in which walkability and bikability scores, that range between 0 for the worst to 100 for the best, are going to be investigated in two urban neighborhoods; first, is Al Dhaher, that represents a conventionally developed urban sprawl neighborhood, and second, is Al Ghareba, a recently designed more compact urban community in which walkability and bikability should have been taken into consideration as two essential components of its claimed sustainable urban form design.

For investigating these two modes of mobility in the two neighborhoods, the UMI urban modeling simulation tool was utilized in this study. UMI is a Rhino-based design environment for architects and urban planners interested in modeling the environmental performance of neighborhoods and cities with respect to operational and embodied energy use, daylighting potential, and walkability/bikability. Since 2012, UMI has been developed by the Sustainable Design Lab at the Massachusetts Institute of Technology with support from a National Science Foundation EFRI_SEED project, the MIT Energy Initiative, the Kuwait-MIT Center, the Center for Complex Engineering Systems (CCES) at KACST and MIT, Trans-solar Climate Engineering and United Technologies Corporation. The latest UMI Version 2.1 has been used in this study.

3 Measuring Urban Compactness and Mobility Scores in UMI

3.1 Floor Area Ratio (FAR) as a Measure for Urban Compactness

Floor Area Ratio (FAR) is a measure for the degree of physical urban compactness. FAR is calculated in UMI as the ratio of the total gross floor area of each building to the total area of the site it occupies. In order to perform a FAR calculation, two measures must be set. First, is the floor-to-floor height for every building on the Buildings Layer, through the assigned customized template for each building. This indicates the number of floors in each building. Second, is developing a 'Ground' layer on which all ground surfaces must exist. Ground surfaces must be flat and closed surfaces. The FAR calculation is executed from within the UMI Bundle panel's Simulate tab through executing the 'UmiCalculateFAR' Rhino command (Sustainable Design Lab 2018). FAR were calculated for both selected case studies to specify their degree of urban compactness that is going to be linked with their calculated walkability and bikability scores.

3.2 Walkability Score

Walkability score measures the degree to which the neighborhood is *walking friendly*. UMI software is evaluating *walking friendliness* in urban contexts by implementing the widely used benchmark of ¼ to 1½ mile (400–2400 m) walking distances from housing units to essential amenities. The resulting 'Walk Score' expresses the ease of residing in a particular area without depending on private cars. UMI adopted this web-based tool to test proximity of the points of interest representing nine neighborhood urban amenities well-recognized in North America such as schools, restaurants, etc., where each amenity receives a 'weight' based on its estimated importance. Calculating walk scoring requires first constructing a pedestrian travel network, then performing a series of shortest path calculations using Dijkstra's algorithm. Egress points for addresses are then rewarded based on distances to amenities, and a polynomial distance decay function is used to calculate scores. Within a distance of quarter a mile (400 m), a full score is received, and at one mile (1600 m), amenities receive about 12% of the score as a penalty. After one mile, scores slowly decrease with greater distance, until it reaches zero at 1.5 miles (2400 m). There are other reward scores received by examined points based on street intersection densities and average block length (Sustainable Design Lab 2018). In UMI, the default parameters of walking distances, points of interest (amenities) and weights can be customized to suit other urban contexts. Customized parameters for this research are explained in Sect. 5. The walk score of 70 or above defines neighborhoods with walkable access (Koschinsky et al. 2017). Scores between 70 and 100 are usually segmented into five categories indicating the walkability differences where scores from 90 to 100 are reflecting a 'walkers' paradise' because with such score residents can almost walk to all neighborhood services, facilities, and public transportation nodes. Therefore they do not need to own a car. The scores between 70 and 89 suggest a very walkable neighborhood which residents can walk to most of the provided amenities, and thus, they probably do not need private cars. Scores between 50 and 69 indicate that the neighborhood is partially walkable but probably necessitate public transportation, a bike, or a car for accessing the neighborhood amenities. A walkability score below 50 reveals a car-dependent neighborhood, and finally, a score below 25 means residents need to drive everywhere (Trimarchi et al. 2018).

4 Selected Case Studies

4.1 The Conventional Urban Sprawl Case Study: Al Dhaher

Al Dhaher neighborhood is an Emirati citizens neighborhood located to the southeast of Al Ain city urban agglomeration (Fig. 1). It occupies a rectangular shaped lot of about 1230 m × 2280 m with a gross area of about 285 hectares. Developed in 2002, the neighborhood has 460 single-family housing plots. The plot area is either a 45 m × 60 m or 45 m × 45 m. The neighborhood has some planned services and amenities, including eight mosques, two schools, a clinic, and various retail shops. The urban form of the neighborhood was conceptualized as clusters of 10, 12, 14, and 16 housing plots grouped around shared open spaces. The primary services and amenities are located on both the linear center of the neighborhood and on its outer edges. As for the pedestrian network, the urban form of the

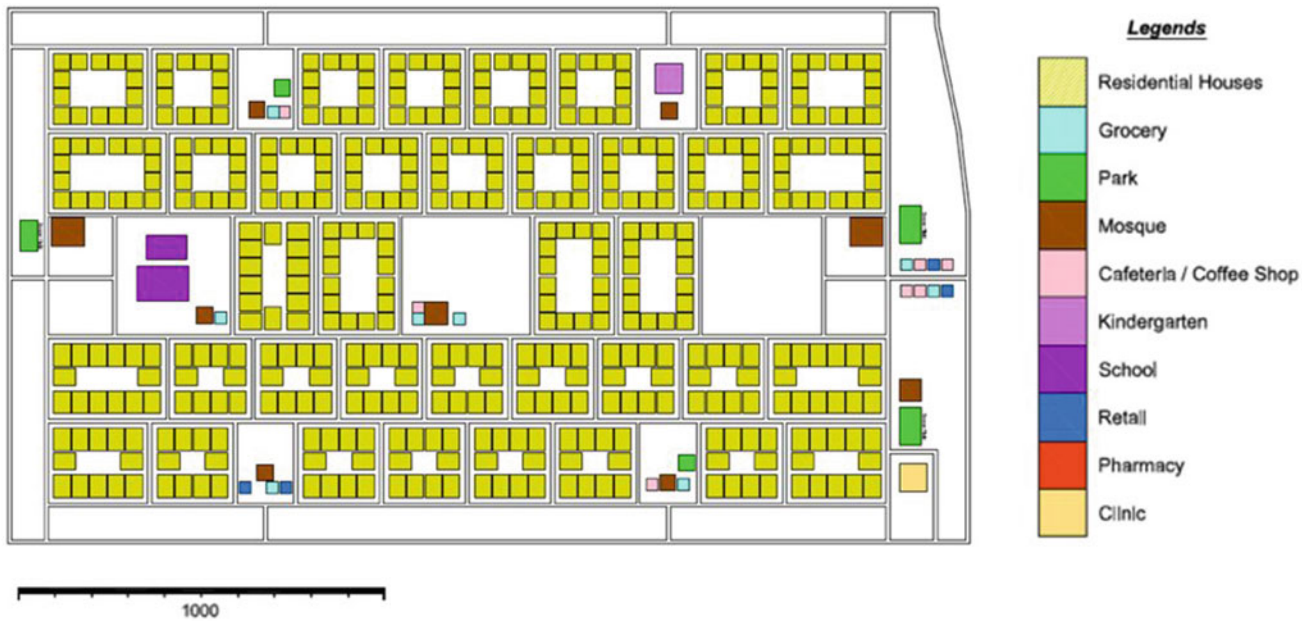

Fig. 1 Land use of Al Dhaher neighborhood showing the distribution of amenities

street/sidewalks grids is orthogonal and almost symmetrical around central horizontal and vertical axes (Fig. 1).

Despite the fact that the neighborhood was conventionally developed as a 'self-contained' community with the envisaged needed services and amenities locally provided for residents, apparently not all of the planned amenities have been actually provided most likely due to the low population density that would make the provision of many of the planned amenities not economically feasible. The calculated FAR of Al Dhaher neighborhood was 0.11, which is a low ratio reflecting the low density that results from the adopted sprawl urban form of the neighborhood.

4.2 The New 'Sustainable' Case Study: Al Ghareba

Al Ghareba is an Emirati citizen neighborhood consisting of 1,022 single-family housing plots on a 155 ha site located approximately 10 km west-south of Al Ain city center (Fig. 2). The critical transit corridor with a future high-speed rail connecting to Abu Dhabi is located 4 km to the north of the site, separated by the Al Maqam Palace. The site is zoned as 'Low-Density Villa Residential' under the future Plan Al Ain 2030. (Department of Urban Planning and Municipalities 2018). Sustainability has been a key consideration throughout the master planning process for Al Ghareba. The master plan and the villas were designed to achieve a minimum rating of 2 Pearls of the *Estidama* sustainability rating system.

In response to the desire for achieving a more compact urban form, the housing plot area has significantly decreased from 45 m × 45 m and 45 m × 60 m in Al Dhaher conventionally designed neighborhood to only 30 m × 36 m with a ground floor area of 430 m^2. Besides the residential use, the master plan land uses include 2 mosques, various local and district retail shops, KG + Cycle 1 school, 2 large community parks, various pocket parks in a form of small gardens considered to be *Baraha* (traditional small open space), linear park, *Sikka* (traditional name for a 2–6 m wide linear pedestrian access) (Fig. 2). The neighborhood infrastructure was developed under the surface leaving the ground level as a habitat reserve. There is also a buffer zone in a form of undevelopable land setback for the protection of the community. A waste area was allocated for waste recycling with municipality pick up, as per *Estidama* requirements (http://www.keoic.com/Projects/Details/1231).

The street/pedestrian sidewalk grid is almost orthogonal with various block sizes, but the bottom left section of the grid is taking a curvilinear form affected by the site

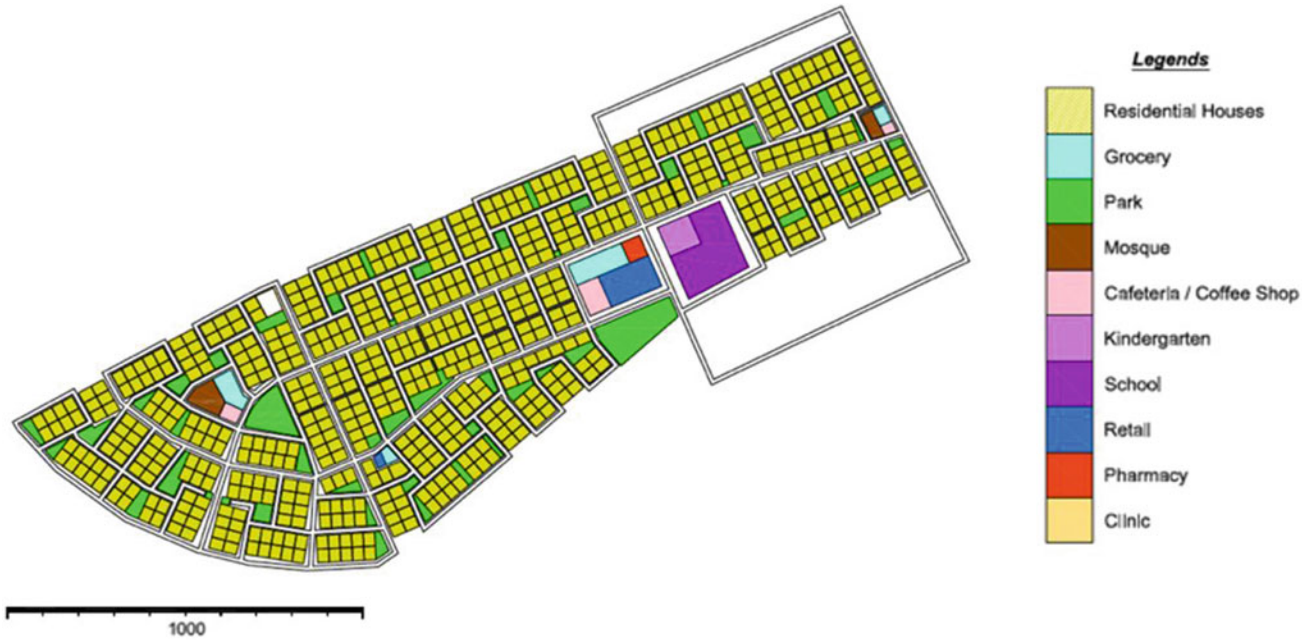

Fig. 2 Land use of Al Ghareba neighborhood showing the distribution of amenities

geometrical shape. The adopted a more compact urban form of Al Ghareba has resulted in a higher calculated FAR of 0.24, which is slightly above the double FAR of Al Dhaher.

5 Preparation for the Simulation Process

5.1 Defining Local Amenities and Catchment Distances for UAE Neighborhoods

In UMI, neighborhood amenities are categorized in a JSON array of amenity categories to which people will try to walk. Because this study is contextual, using a reliable and relevant assessment benchmark is essential. Therefore, a customized list of amenities has been prepared based on the types of amenities indicated by the land use plans of the two studied neighborhoods. This list has been added to the standard amenities of the UMI (Table 1).

In UMI, the two parameters of Minimum Distance and Maximum Distance control how walking trip distances affect walk scores. Minimum Distance is the distance at which penalties begin to be applied. The default value of 400 means that walking trips of 400 m or less receive perfect scores. On the other hand, Maximum Distance specifies the maximum distance people are willing to walk at all. Accordingly, trips more extended than this distance will be ignored. Trips with lengths close to this value will still receive very low scores. For customizing the catchment distances to these defined amenities, some references and standards developed by local municipal and planning authorities in UAE were consulted. These local resources included; Abu Dhabi Community Facility Planning Standards Report, issued by Abu Dhabi Urban Planning Council

Table 1 Localized amenities and catchment distances in UAE neighborhoods

	Amenity type	Maximum catchment distance (m)
1	Mosque	800
2	Neighborhood Park	800
3	Grocery	600
4	School	800
5	Kindergarten	350
6	Cafeteria and Café	800
7	Retails	800
8	Pharmacy	800
9	Clinic	800

(ADUPC) (2014a), Second, Abu Dhabi Public Realm Design Manual, issued by ADUPC (2014b), third, Abu Dhabi National Housing Guidelines For Integrated Communities, Planning Guidelines issued by Abu Dhabi Housing Authority (ADHA) (2016), and finally, Community Facilities Standards issued by the Planning Department, Dubai Government (2018). Based on these local resources, the catchment distances are ranged between 350 and 800 m, i.e., from about 5 to 10 min walk, which are close to the internationally recognized catchment distances (Barton 2000). Table 1 is summarizing these catchment distances. Each type of customized amenities was then assigned a separate layer carrying exactly the name of the amenity type. To ensure that, destination layers were created using the 'Create Amenity Layers' command in the UMI Mobility simulation panel. This automatically created any missing amenity layers, using the names specified in the profile as a reference.

5.2 Customizing the Amenities Weighting for the UAE Neighborhoods

Each amenity in the list of amenities in UMI has these parameters: Name, Global Weight, and Destination Weight. For UMI walkability and bikability simulation and after defining the types of amenities and their distances to the houses for UAE neighborhoods, the Global Weight and the Destination Weight of each amenity type were defined. The Global Weight controls how important an amenity category is compared to other categories, and it is defined based on its importance to the community's everyday life and should be defined on a tripled scale from 1 to 3 while 3 represents the highest importance. The Global Weight parameter has nothing to do with calculating the score within each amenity's category, and rather, it is used to relatively scale each category score before they are summed for the final score. Meanwhile, calculating the score within each amenity's category is controlled by the Destination Weight parameter as described below.

Destination Weight is a JSON array that controls both how many destinations are required for a perfect category score and how the distances to those destinations contribute to the category score. One destination is required for each value in the array, and the values are the relative weights of each destination. For example, the Destination Weight of the kindergarten category is '5, 3'. This means that for a perfect score, two kindergarten destinations are required, and the score for the trip to the nearer of the two is 5/3 as important as the score for the trip to the farther. Several of the categories in the default profile have a value of 1 for their Destination Weight. This means that only a single destination is required. All the default profile categories have decreasing Destination Weight, meaning that the distance to closer destinations is more important. As with global weights, the critical information is the value ratios so changing kindergarten's Destination Weight to '10, 6' in the default profile, for example, would leave scores unchanged.

For customizing these Global and Destination Weights, it was decided whether one or more of an amenity type is needed within the neighborhood. This has been decided based on the defined land use of both studied neighborhoods. So, for example, there are 3 grocery stores in the neighborhood, among which the closest grocery is most likely to be chosen by residents to walk to, and therefore it is weighted as (5), while the second closest one is weighted as (3) that means it is 3/5 as likely as the closest grocery to be chosen. The farthest one is weighted as (1), so it is 1/3 as likely as the second closest grocery to be chosen as a

Table 2 Weighted amenities in the UAE neighborhoods

	Amenity type	Global weight	Number of needed amenities	Destination weight
1	Mosque	3	1	1
2	Neighborhood Park	2	1	1
3	Grocery	3	3	5, 3, 1
4	School	2	1	1
5	Kindergarten	3	2	5, 3
6	Cafeteria and Café	3	5	10, 8, 6, 4, 2
7	Retails	2	5	10, 9, 8, 7, 6
8	Pharmacy	3	1	1
9	Clinic	1	1	1
10	All others	1	1	1

destination. Table 2 summarizes the weighted amenities in the two neighborhoods.

5.3 Developing Neighborhoods 2D and 3D Models for Simulation

The first step before undertaking the UMI simulation analysis of the two neighborhoods was developing digital models for the service buildings and spaces, housing clusters, groupings of housing clusters and the overall neighborhood, showing the plots boundaries and the open space/street grid of each case study. The two neighborhoods were firstly modeled in a 2D format on AutoCAD 2018. In this phase, each building type was assigned a separate layer to ease the UMI analysis later on. Separate layers have been assigned to the street network, neighborhood parks, and neighborhood boundaries. Also, the footprint of every existing building in each neighborhood, that is going to appear later as a solid mass in the Rhinoceros 5 software environment and the UMI Bundle was represented by a single boundary object (or enclosed polyline) in the AutoCAD environment. In this 2D modeling phase, the shape of the whole neighborhood land and the neighborhood parks regions were converted into a combination of enclosed triangular/quadrilateral polylines in order to easily facilitate converting the parks and the neighborhood land into meshes (surfaces) when developing the 3D model in Rhinoceros 5 software. More complex neighborhood and parkland shapes were created through the combination of multiple meshes where all together constituted the desired shape.

Afterward, the completed 2D model of each neighborhood was exported, with its overall appropriately drawn and layered elements including building outlines, street networks, and parks/neighborhood land boundary, to Rhinoceros 5 software, the tool for developing the 3D format of the two neighborhoods. After completing the 3D modeling of all buildings, with their appropriate assigned layer, converting neighborhood parks and the whole neighborhood boundary into surfaces (or meshes), and defining the street networks, the Rhinoceros 5 generated 3D model was converted into a UMI bundle. Within this bundle, a customized building template and amenities list with their customized weights were assigned to each single service building/house in each of the two analyzed neighborhoods, as relevant.

Before conducting the walkability and bikability simulation, the locations of the neighborhood amenities were defined in the UMI environment. To do so, a 'point' was placed at the entrance 'line' of every amenity building. In the case where a single building includes different amenities, more than one 'point' were set (under different amenities layers) at the entrance of this building. Subsequently, the customized amenities types and there amended weights were uploaded, where the existing default amenities profile was exported, using the project settings tab, then, it was edited using a text editor, by adding, removing, or modifying amenity categories as decided and mentioned above. Finally, this customized amenity profile was reimported to the project using the project settings tab.

6 Simulation Results

After undertaking all the pre-simulation steps, the walkability and bikability simulations were conducted. The walkability score for Al Dhaher reached 66 which is a slightly above average walk score, but still less than the claimed walk score of 70 or above for neighborhoods with 'walkable access' (Koschinsky et al. 2017). Figure 3a shows a color-coded result of the simulation in which several houses, especially in the bottom section, are apparently out of the appropriate catchment areas for the neighborhood amenities.

As for bikability, the score reached 96, which reveals that most of the neighborhood's amenities are within 'bikable' distances from houses (Fig. 3b). The simulation analysis of the second case study Al Ghareba resulted in a walk score of 61. Figure 4a depicts the score in color code where it is clear that several houses, especially those located in the bottom left sections of the neighborhood, are considerably out of the walkability catchment area for the neighborhood amenities. On the other hand, the bikability score was 85, which is generally appropriate (Fig. 4b).

Table 3 concludes the comparative results of the two case studies. It is surprisingly revealing that the walkability score in the urban sprawl case study of Al Dhaher is slightly better, on average than that of the more compact urban form case of Al Ghareba. As expected, the same was observed for the bikability score.

One would expect the results to be the opposite with the more compact urban form leads to more walkable neighborhoods, i.e., with a higher walk score. These results though shed light to the fact that the mere compaction of the urban form is not enough to enhance walkability and bikability in neighborhoods but rather, other essential measures should be appropriately addressed in the neighborhood design including; distribution of amenities, consideration of customized weights for the different types of amenities, and the effect of permeability of pedestrian movement grid, which is mostly just sidewalks adjacent to vehicles streets lanes.

In this research, the walkability and bikability scores were calculated based on the catchment areas and weights of

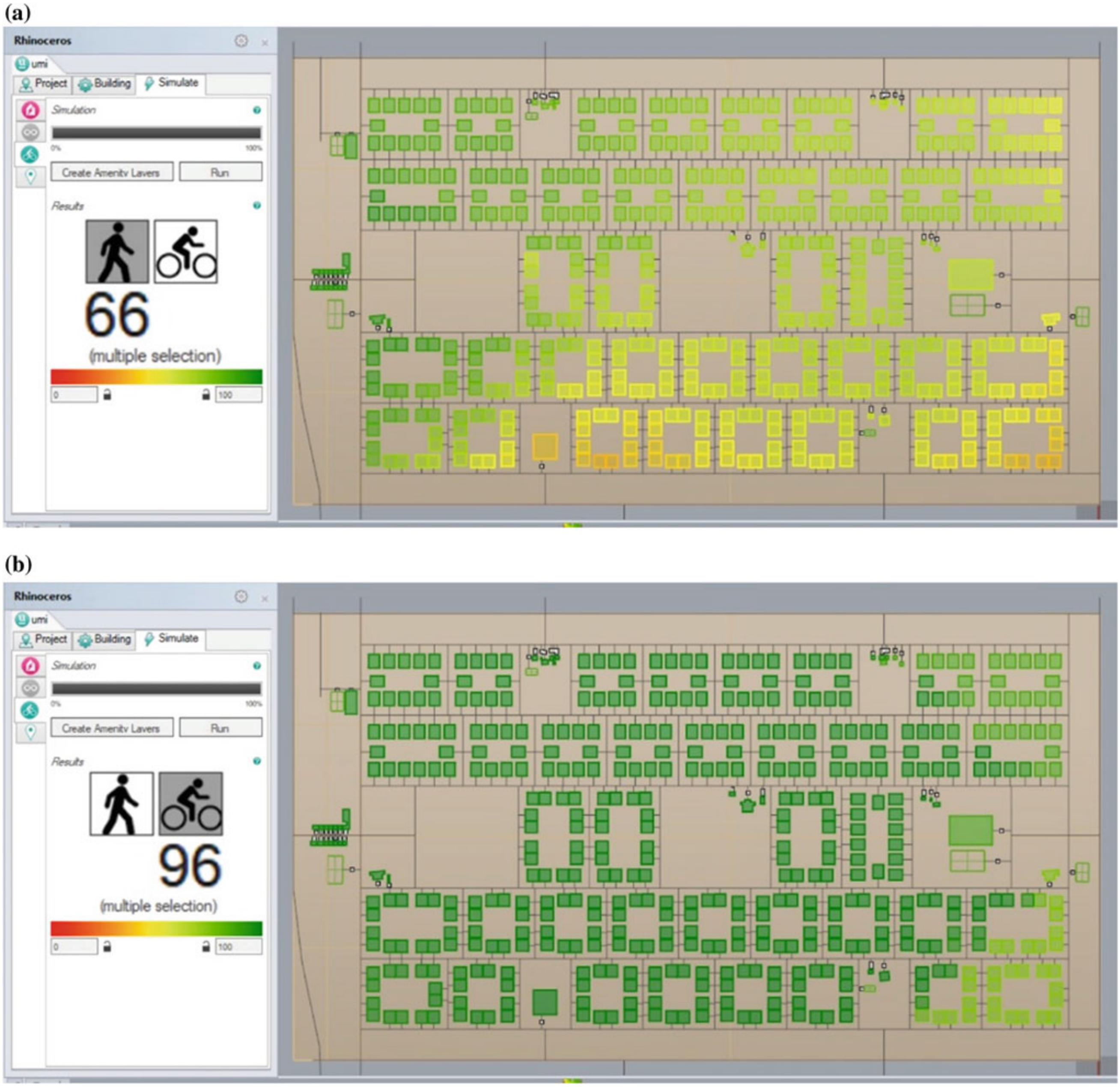

Fig. 3 **a** Walkability score for Al Dhaher neighborhood. **b** Bikability score for Al Dhaher neighborhood

amenities, nonetheless, there are other practical factors that have not been taking into consideration in these simulations. For instance, the existence/absence of dedicated cycling lanes and pedestrian walkways, how safe and pleasant are the cycling lanes and the pedestrian walkways, etc. All these items, apart from the pure simulation, are significant and should be taken into consideration side-by-side with other issues discussed in this research.

7 Conclusions

UAE is witnessing a remarkable change toward sustainable urban development. The recently designed and developed neighborhoods have more compact urban forms that are envisaged to encourage human-powered transportation (HPT). Such more sustainable modes of residents

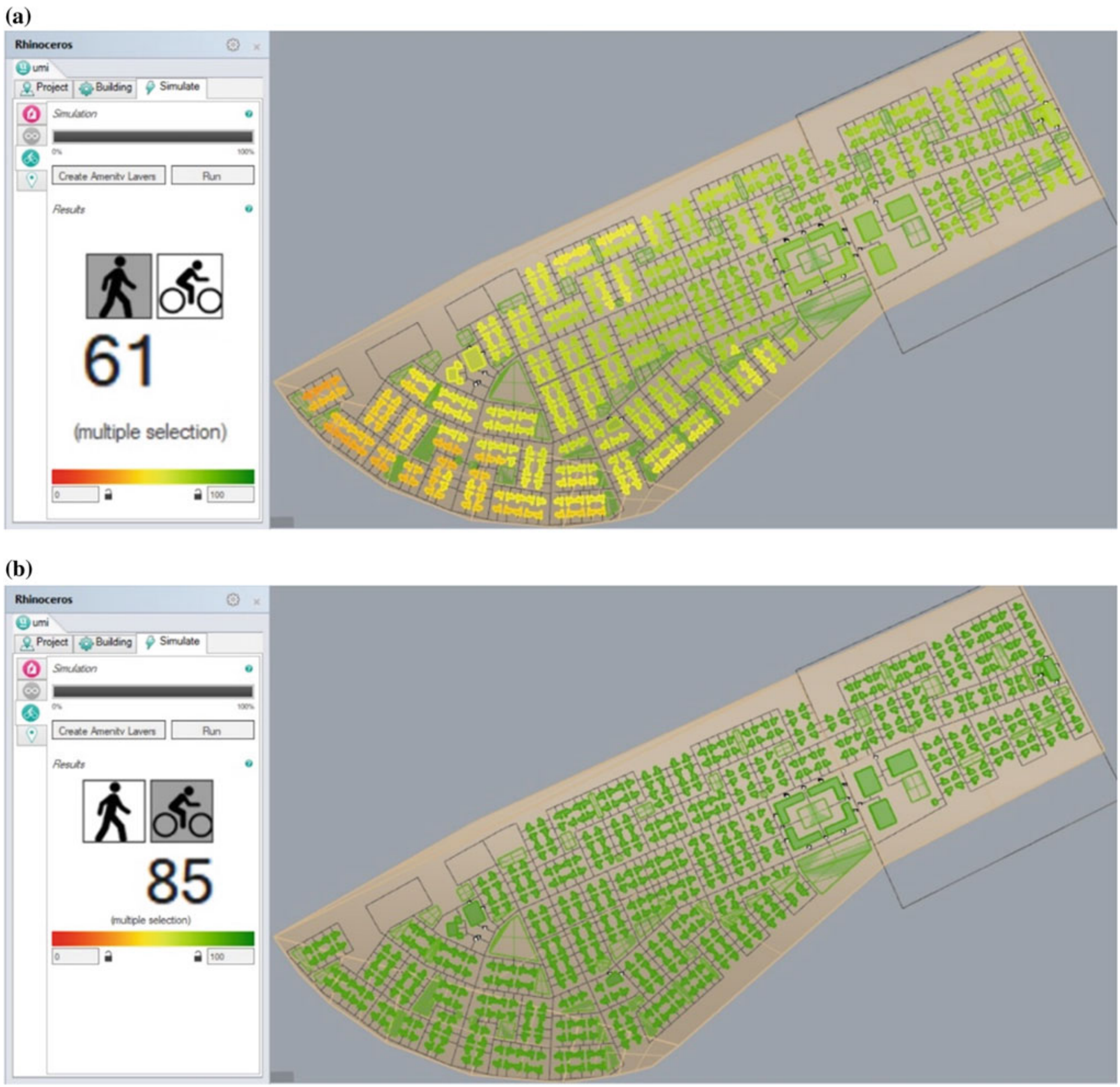

Fig. 4 **a** Walkability score for Al Ghareba neighborhood. **b** Bikability score for Al Ghareba neighborhood

Table 3 Comparing Walkability and Bikability scores in the two neighborhoods

Neighborhood	FAR	Walkability score	Bikability score
Al Dhaher Conventional sprawl urban form	0.11	66	96
Al Ghareba More compact urban form	0.24	61	85

commuting especially walkability are not only leading to a better living environment with reduced pollutions and GHG emissions but also help attain cohesive and interconnected communities with precious social capital. The research investigated how walkable is the newly claimed to be sustainable neighborhoods with their more compact urban forms if compared with conventional neighborhoods in UAE. Al Dhaher and Al Ghareba neighborhoods in Al Ain were selected to represent the conventional urban sprawl of FAR of 0.11 and the more compact recently designed neighborhood of FAR of 0.24, respectively. The conducted UMI simulations, with customized parameters for walkability distances and amenities, on both neighborhoods have surprisingly revealed that the new neighborhood had less walkability score than that of the conventional neighborhood and was also much behind the 'walker's paradise' score of 90 and above. The calculated scores of the two neighborhoods were in the range of 50–70 score category, which revealed that the neighborhood is 'partially walkable' and thus, it necessitates public transportation, a bike or a car for accessing the neighborhood amenities. These results mean that walkability has not reached its desired target that, if realized, would help achieve eco-friendly urbanism for new neighborhoods through encouraging residents to abandon using their cars to access locally provided amenities and thus reduce energy consumption and pollution. This can be referred to the fact that these new designs are still noticeably fragmented. Once truly a compact urban form is realized, walkability and bikability would significantly enhance in a way that contributes positively to the cause of sustainable residential urbanism.

Finally, to enrich the research about the walkability and bikability potentials for newly developed neighborhoods in the UAE, other design and influential urban measures, beyond the catchment distances and weights of amenities, should be investigated in further research. These include, for example, reducing the number of car parking plots, provision of affordable and reliable public transportation systems, increasing petrol tax to limit the reliance on private cars, introducing car parking charges, and considering the provision of multipurpose trips in neighborhood land use design.

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