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Title: Post-pandemic planning: Do we have enough and efficient access to parks?

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Introduction: The COVID-19 pandemic has placed neighborhood parks as a key asset in mitigating the negative implications of extended lockdowns, when parks turned into a sanctuary for residents. With increased scholarly work focusing on developing pots-pandemic neighborhoods, providing access to community parks *via* efficient routes, is central to such debate. Network connectivity provides a comprehensive assessment of the efficiency of network systems.

Methods: A total of 16 samples, from the city of Abu-Dhabi, have been selected to study their network connectivity, with regard to accessing parks. Three distance-based connectivity measures are used: the pedestrian route directness (PRD), the count of redundant routes Redundancy Count (RC), and the route redundancy index (RI). The samples reflect different street's typologies and their urban form attributes are quantified.

Results and Discussion: Connectivity analyses results are interrupted with regard to the quantified physical attributes. Findings indicate that gridded, and semi-gridded layouts provide more direct routes to parks, but less route's redundancy. Conversely, interlocked, and fragmented networks, when having sufficient intersection densities, have less direct routes but more redundancy. The inclusion of alleyways proved to alter typologies into gridded ones and improve both route directness and redundancy. The majority of the selected samples reported sufficient levels of route directness. The current design and planning guidelines, implemented by the Department of Transport and Municipalities are overly descriptive with regard to how neighborhood parks are accessed; therefore, the study's methodology provides a possible more evidence-based approach to policy development.

KEYWORDS

connectivity, street networks, COVID-19, route directness, route redundancy, Abu-Dhabi, parks, urban form

1 Introduction

The restricted mobility and social gathering measures, mandated during the recent COVID-19 pandemic, caused mass disruption to normal lives and active living (Caroppo et al., 2021); this included work (Espitia et al., 2022), education (Onyema et al., 2020), healthcare (Bashshur et al., 2020) and most notably urban living (Mouratidis and Papagiannakis, 2021). Jáuregui et al. (2021) discussed, in one of the world's leading medical journals, the Lancet, the critical role of urban design and planning in offsetting the negative ramifications of possible future pandemic scenarios. He argued for accelerating change towards designing cities that are highly conducive to active mobility, which prioritize parks and public open spaces as key assets to post-pandemic urban living. Access to parks and urban green spaces, during the pandemic, helped millions of people maintain their mental and physical health (Slater et al., 2020). Many studies highlighted the impact of the built environment on accommodating easier access to parks (Lai et al., 2020; Megahed and Ghoneim, 2020).

The relation between physical activity and the built environment, therefore, has been explored to further advance sustainable urban design agendas, centered around pedestrian needs. New-urbanism ideals with regard to neighborhoods planning and design, for example, is focused on locating daily necessities within walking distance to reduce car dependency, by ensuring that streets, pedestrian routes, and sidewalks are highly connected (U.S. Department of Housing and Urban Development, Congress for the New Urbanism, 2002). Handy et al. (2002), in discussing which features of the built environment impact residents' physical activity and wellbeing, pointed out that walkable environments have certain attributes in terms of density, land-use mix, and street systems. Specifically, walkable streetscapes showed consistently higher degrees of connectivity, which can be defined as "the directness and availability of alternative routes from one point to another within a street network" (Handy et al., 2002). During the pandemic, Wargent and Talen (2021) highlighted how the extended lockdown durations has motivated people to rediscover their neighborhoods by stating that "Now many of us will be more aware of how walkable our neighborhoods are and more attuned to the importance of access to local amenities" (p.2). Pots-pandemic neighborhoods design agendas, therefore, should emphasize highly connected street networks that ensures active mobility to parks and urban green spaces.

This study addresses the impact of streets' network connectivity, in the city of Abu-Dhabi, on ensuring efficient travel to neighborhood parks. A total of 16 samples, grouped into six typologies, have been selected from different neighborhoods to evaluate the connectivity of street networks within 1-km network-based distance from local parks. Connectivity is evaluated using three measures. The first is the Pedestrian Route Directness (PRD) which assesses whether routes, connecting residential plots to the park, support travel at short distances; the second is the Redundancy Count (RC) which return the count of alternative routes available for travel at distances with minimum deviations from the shortest route; the third is the Redundancy Index (RI) which provides insights on the efficiency of the alternative routes with regard to their distance deviations, from the absolute shortest path. Paydar and Kamani Fard (2021) study on the hierarchy of walking needs, during the pandemic, revealed that people's preferences were concerned with minimizing crowds contact and deviations from the shortest path. Therefore, it can be argued that route redundancy emerges as a decisive factor in post-pandemic cities. This study offers two unique contributions to the literature. First, the article uses street network connectivity, in terms of both route directness and route redundancy, to assess whether current street typologies in Abu-Dhabi neighborhoods provide efficient routes to connect the residential plots to their local park. Second, the article complements network analysis results with conventional morphological analysis that quantifies the physical attributes of the network system in terms of: network density, percentages of 4-way intersections, intersection density, average distance between intersections, the average block size, the average distance to the park, and the network hierarchical composition (e.g., percentages of arterials and/or collectors). This allows the depiction of the built environment with a critical perspective, thus informing policy and the process of building better walkable communities. Key research questions answered by this article: 1) Are Abu Dhabi's neighborhood network system designed to promote route directness and choice to urban parks? 2) How the physical attributes of network systems impact route directness and choice to urban parks? 3) Do Abu Dhabi's public realm planning and design guidelines provide effective polices with regard to accessing parks *via* efficient connected routes? And how the outcome of this research can enhance planning policies that address different network typologies to ensure better access to parks.

2 Literature review

2.1 How the pandemic changed daily activities

Extraordinary regulations have been mandated to curb infection rates during the recent COVID-19 pandemic resulting in limited movement, travel, activity participation and mobility choices worldwide (De Vos, 2020). Governments resorted to extreme measures in order to prevent the airborne Corona virus transmission; this included enforcing social distancing, lockdown of public indoor spaces, and home-confinement, which cumulatively impacted people's mental and physical health (Armbruster and Klotzbucher, 2020; Bustamante et al., 2022). Daily lifestyle habits, therefore, have been disturbed and typical daily activities, such as physical travel to school and work, were replaced by online ones (Mouratidis and Papagiannakis, 2021). This resulted in drastic changes to urban mobility in terms of travel frequency, mode choice, and distance. For example, different countries implemented distance-based mobility restrictions that confined people's movement to their neighborhoods (Glavan et al., 2022). In France, in Spring 2020, movement from each household was restricted to be within a 2-km distance (Kakderi et al., 2021), while in Australia, the distance was bound to a 5-km radius from each household (Reuters, 2021). In terms of travel mode choice, social distancing constraints disturbed public transportation services causing them to be either halted or restricted in capacity (Kamga and Eickemeyer, 2021; Basu and Ferreira, 2021); as a result, their use rates dropped significantly (Hu et al., 2021).

Mobility preferences shifted towards active modes of travel such as walking and cycling (Nikiforiadis et al., 2022). A key study by Hunter et al. (2021) of 10 metropolitan areas in the United States reported significant insights about walking behavior before, during, and after the pandemic. Their data indicated that 75.45% of pre-pandemic walking was utilitarian with an average daily distance of 432.78 m while recreational walking, although lower in frequency, was longer in terms of daily average distance at 1495.24 m. Their evaluation of walking during the pandemic indicated a reduction in utilitarian walking frequency by 39.2%, a trend that has persisted even after the ease of lockdown measure. On the other hand, recreational walking demonstrated an increase in distance and frequency, exceeding utilitarian walking in many cases. Active travel, walking and cycling, was observed to become a primary source of mobility in many cities during the pandemic (Barbarossa, 2020; Nikiforiadis et al., 2022); this motivated local municipalities, such as in London and Mexico City, to improving or adding new cycling lanes and widening sidewalks to accommodate increased pedestrian flows while maintaining social distancing (Frangoul, 2020; Shaping Pots-Covid Mobility in Cities, 2023).

Mouratidis and Papagiannakis (2021) acknowledged that walking and cycling were recognized as safe mobility option during the pandemic. Their study also indicated that "Green spaces were considered to be increasingly important during COVID-19 as they provided space for performing leisure activities with a lower risk of infection" (Mouratidis and Papagiannakis, 2021, p.3), thus "helped mitigate the negative implications of COVID-19 for quality of life" (Mouratidis and Papagiannakis, 2021, p.4). Green spaces, therefore, emerged as sanctuaries and gained increased significance. Living within a close proximity to green spaces has motivated many city dwellers to relocate to suburbs; a phenomenon that was observed in North American cities such as Boston, New York, Los Angeles, Toronto (Saunders, 2020; Ramani and Bloom, 2021), and in other parts of the world including London (The Guardian, 2020), Stockholm (Vogiazides and Kawalerowicz, 2022), as well as Spain (González-Leonardo et al., 2021). These new urban living dynamics positioned the suburbs as an attractive alternative to inner-cities, they also re-prioritized parks as an indispensable attribute of post-pandemic living (Frumkin, 2021; Mouratidis and Papagiannakis, 2021). Central to the debate on post-pandemic approaches to planning policies and practices is the work on "enhancing public spaces and on the rethinking of roads to promote walking and cycling" (Barbarossa, 2020, p.12).

2.2 Connectivity to parks

Urban green spaces, including parks, are recognized as an integral part of the built environment (Pfieffer and Cloutier, 2016); this is because they contribute towards the wellbeing of the residents by providing recreational activities (Larson et al., 2016) and by improving the livability of neighborhoods (Baur and Tynon, 2010). Their impact on reducing levels of stress and fatigue, on residents, have also been established in the literature prior to the pandemic (Wood et al., 2017; Sugiyama et al., 2018). Geng et al. (2020) analyzed parks visitation trends, during the pandemic, in over 90 countries and found that parks received more visits since the spread of COVID-19. This was attributed to the role of parks in mitigating the negative implications of the pandemic over the residents' mental and physical health. A study by Ugolini et al. (2020) revealed that the rate of people, in Italy, who opted for parks at distances less than 200 m slightly increased (no more than 10%) and visits to parks at a farther distance (more than 500 m) slightly decreased (by 9% on average). The study also indicated that walking was the primary mode of mobility towards parks, and farther away parks "were probably appreciated by some respondents precisely for the opportunity they offer to do more physical exercise" (p.8). Access to Parks is often evaluated in terms of distance, Euclidean or network-based, as well as the count, total area, or density of parks (Zhang et al., 2011; Nicholls, 2001). Other studies analyzed the routes to parks which provides a more comprehensive approach in understanding the physical environment around parks (Zhou and Xu, 2020; Dills et al., 2012). Lee (2019) expanded this notion by introducing a methodology to evaluate the urban morphological context of parks using urban form variables, such as parcel and block size, plot density, building setbacks, and street intersections, to name a few.

Cities of the Arabian-Gulf have also been subject to mobility restrictions during the COVID-19 pandemic, and the earlier discussed implications were also observed in the Gulf region (Cheikh Ismail et al., 2020). The restricted movement implications were further amplified by the challenging hot weather especially with other public places, such as shopping malls, being under lockdown. This research explores the efficiency of routes connecting residents with their local neighborhood parks in Abu-Dhabi. The urban system of Abu Dhabi has implemented aggregates of superblocks, in the form of low-density suburbs, during its urbanization process which started back in 1970s (Elsheshtawy, 2008). Similar urban expansion strategies are also observed in other GCC cities (Choguill, 2008). The urban expansion started initially at Abu Dhabi Island and grew gradually towards the mainland. Prior to 1990s, neighborhoods were designed with reasonable densities, integrated street systems with alleyways to accommodate pedestrians, and grided street systems with mixed land-uses towards the edges. After 1990s, neighborhoods street typologies became fragmented with looping or curvilinear streets, residential densities decreased, and service centers accounting non-residential land-uses were housed in centralized locations (Bani Hashim, 2016). In terms of parks provision in the city, Department of Transport and Municipalities (DMT) manages 531 ha of developed parks that serves a total population of almost one million (0.54 ha per 1,000 resident). The Abu Dhabi Island has 386 ha of parks (0.67 per 1,000 residents), while the mainland, predominantly suburban areas, has 145 ha of parks (0.36 ha per 1,000 residents) (Abu Dhabi Urban Planning Council, 2011). These values are well below the adopted planning guidelines in most countries; the American Planning Association standards for recreational areas, for example, mandates a minimum of 4 ha per 1,000 residents (Leonard and Egan, 2014). With the population of the city is projected to grow by 2030, the DMT is planning to increase parks area to 1.3 ha/1,000 resident (Abu Dhabi Urban Planning Council, 2011).

2.3 Measuring connectivity to parks

Jabareen and Eizenberg (2021), in illustrating aspects of current urban forms failure during the pandemic, explained that "the common allocation of parks and open spaces, ranging from the metropolitan-scale park to the neighbourhood park, was insufficient in providing residents under restricted-movement orders the open space they needed." (p.5). On this vein, this research seeks to understand how the current urban context of Abu Dhabi's neighborhoods impacts route connectivity, in terms of directness/shortest travel distance and redundancy/multiple routes to the park. Leslie et al. (2007) explained that the degree at which a neighborhood is walkable refers to "the extent to which characteristics of the built environment and land use may or may not be conducive to residents in the area walking for either leisure, exercise or recreation, to access services, or to travel to work." (p.113). Therefore, mobility decisions are found to be sensitive or highly impacted by the physical attributes of urban form (Porta and Renne, 2005; Lee and Moudon, 2008; Frank and Engelke, 2005). Gori et al. (2014) study highlighted the association between active transportation, walking and cycling, and the availability of a pedestrian friendly street network: "Increased distances and poor connectivity usually discourage walking and bicycling and, consequently, physical activity" (p.38). Other studies have also emphasized on street connectivity correlation with walkability (Saelens et al., 2003; Porta and Renne, 2005). Larranaga and Cybis (2014) describe how the street pattern (grid-like, curvilinear, etc.), the nature of intersections, and their density and frequency at smaller distances, are used as indicators of pedestrian-friendly urban settings.

This article adopts Network Connectivity, which is conceptually concerned with evaluating distances and availability of sufficient pedestrian routes, to evaluate the efficiency of current street systems with regard to extended walking distances towards parks, that are up to 1-Km away from residents. This is because common walking distance threshold are at 15–20-min walk, at a moderate peace, which corresponds to approximately a 1-Km distance (Stessens et al., 2017; Nicholls, 2001). Some studies suggest that people are less likely to visit parks that are beyond this distance threshold (Toftager et al., 2011). Networks with higher values of: intersection density (Reilly and Landis, 2010), street density (Handy, 1996), intersection ratio (Peponis et al., 2007), and link-node ratio (Ewing, 1997), are regarded as more connected for ensuring better route connectivity between origins and destinations. Those metrics, despite being favored for ease of calculation, fail to capture the interplay among the multiplicity of other variables and fail in capturing the impact of the network's pattern (Peponis et al., 2008). Additionally, when planning standards have implemented them as numerical benchmarks, they proved to be susceptible to "gamification" (Guinn and Stangl, 2014). Other connectivity metrics that measure the size and configuration of blocks in terms of their density (Cervero and Radisch, 1996), perimeter (Song and Knaap, 2004), area (Hess et al., 1999), or mean length (Cervero and Kockelman, 1997) have also proved to conceal obstructing configurations of blocks that impedes travel at shorter distances despite meeting the planning standards benchmarks (Guinn and Stangl, 2014). Because distance is a detrimental factor in active travel, many studies suggest that "the concept of street connectivity for walking can be better captured with distance measures between home and particular activities important for walking, than broadly with variables such as average block size or intersection density" (Lee and Moudon, 2008, p.214). Therefore, three distance-base measures: Pedestrian Route Directness, Redundant Routes Count and Route Redundancy Index, are selected to evaluate network connectivity. Because street systems are only one aspect of the urban form, other physical attributes are also quantified and used in explaining the analyses results. Those attributes include: network and intersection density, distance between intersections, percentages of arterials/ collectors in the network, average block size, percentages of 4-way intersections, and average distance to the park. The complementary role these attributes play in defining urban spatial systems is highlighted in Southworth's (2005) description of a walkable city, where he explains that actual walking requires fine grained patterns and interconnected continuous routes to minimize distances, thus a topology of "a high density of intersections and small block size" results in a "high degree of connectivity" (Southworth, 2005, p.250). Additionally, studies like Marshall et al. (2014) and Winters et al. (2010) have emphasized the combined effect of considering the network structure, in terms of percentages of collector, arterials and local streets, alongside other attributes when evaluating active mobility.

3 Methodology

3.1 Selection of samples

To evaluate connectivity to green spaces, 16 residential neighborhood parks, within superblocks, have been chosen (Figure 1). The selected samples are grouped into six different typologies and accounts for diversity in networks typologies, residential densities and parks' locations within the superblocks. Additionally, the selected samples represent different planning phases and are strategically scattered across the city, including its more established central districts in the Island as well as its newer outlying developments. Wheeler (2015) indicated that streets' patterns are among the most key deterministic physical features of the urban form that significantly shape walking behaviors. Therefore, the selected samples are categorized into six main groups based on the street's typology/pattern. The groups are: grid-iron, semi-grid, semi-grid with a service spine, semi-grid with a service core, interlocked with a core and two additional samples with hybrid patterns of a compartmentalized semi-grid, and another with a diagonal semi-grid and a service core (Figure 2). Connectivity is evaluated for the network captured within the park's service area, of a 1-km network-based distance, in two scenarios: streets only, and a combined network of alleyways and streets. This offers a realistic prediction of the contribution of pedestrian-only routes/alleyways in improving access to local parks at shorter distances. Therefore, samples' attributes with regard to: network and intersection density, percentages of 4-way intersections, average distance between intersections, average distance to parks, percentages of arterial/ collectors, and average block size are evaluated individually, per sample, for both network scenarios, streets only (Table 1) and streets and alleyways (Table 2), in order to evaluate their impact on the network connectivity.

Aerial photos and GIS information were provided from Abu Dhabi Department of Municipalities and Transport (DMT). The provided GIS data is used to identify the parks' centroids in each superblock, and consequently the network-based service area within a 1 km, is generated. All the residential plots that have a shortest route to the local park, within that distance threshold, are captured with this service area (Gori et al., 2014). Most studies adopted a maximum walking distance of 1 km to assess connectivity to local playgrounds and parks (Van Herzel and Wiedemann, 2003; Tsou et al., 2005). The parks' entrances are also identified to ensure the analysis accuracy in terms of simulating actual traveled routes from residential plots to the local park. Therefore, residential plots, located within the 1 km service area, are used as origins for trips to each of the park's entrances, that are deemed as destinations.

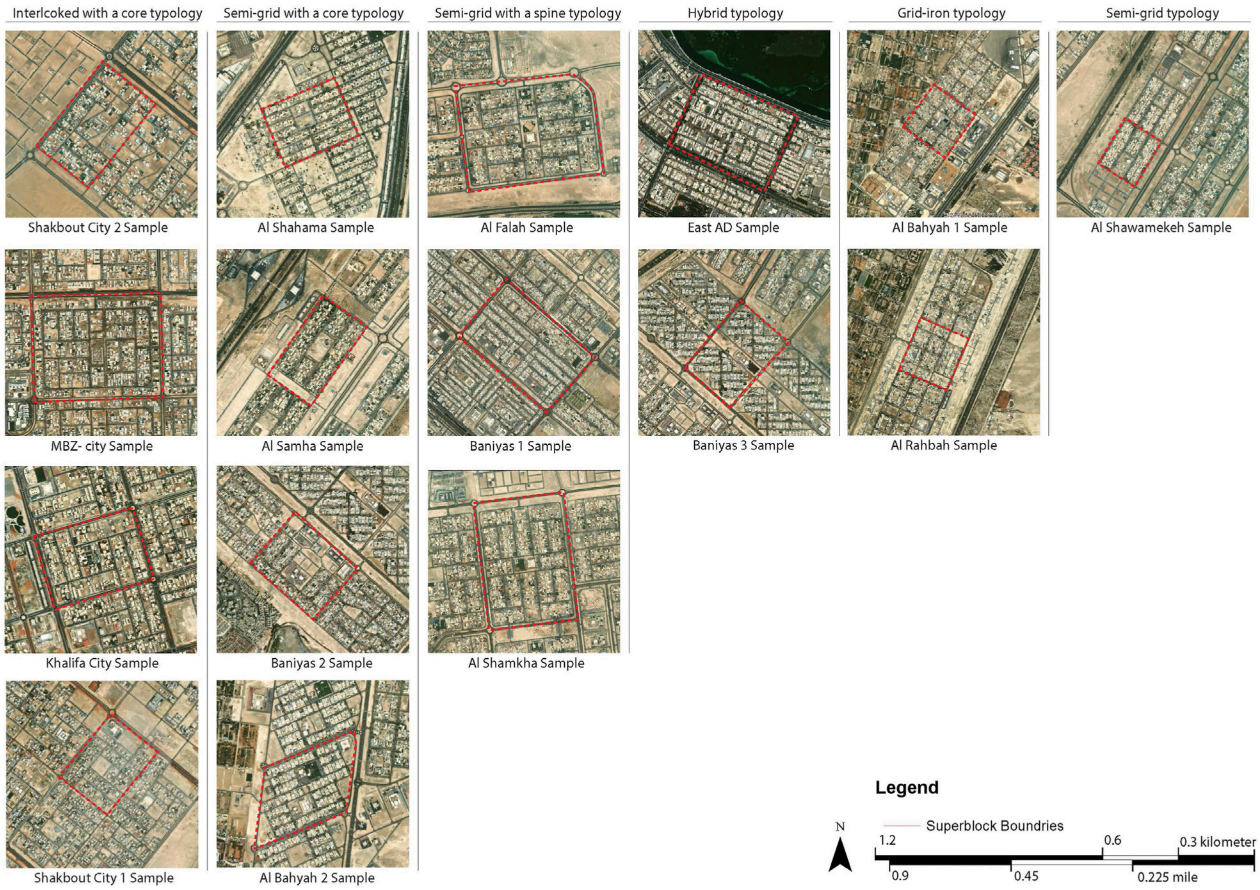

FIGURE 1
Satellite images of the selected samples showing superblock's boundaries (Esri, 2022).

3.2 Network analysis metrics

Pedestrian connectivity evaluates the directness of available routes between pairs of locations at shortest distances (Randall and Baetz, 2001). This concept is mainly concerned with the spatial structure of the street network (Porta and Renne, 2005) and how its attributes are detrimental to pedestrian trips in terms of frequency and distribution (Ozbil et al., 2011). However, when pedestrian travel is examined, it is found that deviations from the shortest routes are common (Basu and Sevtsuk, 2022). While alternative route choice is impacted by a multitude of variables, such as path comfort and safety, distance is usually found to be the most critical to be minimized by pedestrians (Sevtsuk and Kalvo, 2022). Additionally, the count and type of intersections, or turns, are found to impact route choice (Hillier and Iida, 2005; Lue and Miller, 2019). Therefore, connectivity is used to characterize streets networks in terms of two aspects: the first is whether routes can ensure connectivity to destinations at shorter distances, and the second is the availability of a multitude of routes/route redundancy, with a minimum deviation from the absolute possible shortest route connecting an origin with a destination. Tal and Handy (2012) offered a definition of connectivity that accounts for both aspects, route directness and route redundancy, by explaining that connectivity is "a measure of the quantity of the connections in the network and thus the directness and multiplicity of routes through the network" (p.48). Therefore, three metrics are used to evaluate streets' network connectivity in the selected samples: the Pedestrian Route Directness (PRD), the Redundancy Index (RI), and the Redundancy Count (RC). The former evaluates how direct the routes are and the two later ones describe the diversity of available alternative routes that are within a minimum distance deviation from the shortest route.

3.3 Pedestrian route directness

The first metric used to quantify the network connectivity is the Pedestrian Rout Directness (PRD) (Stangl, 2012). The Pedestrian Route Directness metric is favored over other connectivity measures for being distance-based, and for providing intuitive results (Guinn and Stangl, 2014). PRD is calculated as the ratio of the network distance between an origin and destination to the Euclidean distance or to the straight-line distance separating those points. The resulting value is used to evaluate how direct or efficient a route is; values closer to one are deemed as the most efficient. Utilizing the attained GIS data, the identified residential plots' centroids, that lie within the 1-Km service area of the local park in each sample, are treated as origins and the parks' entrances as destinations. The PRD value is

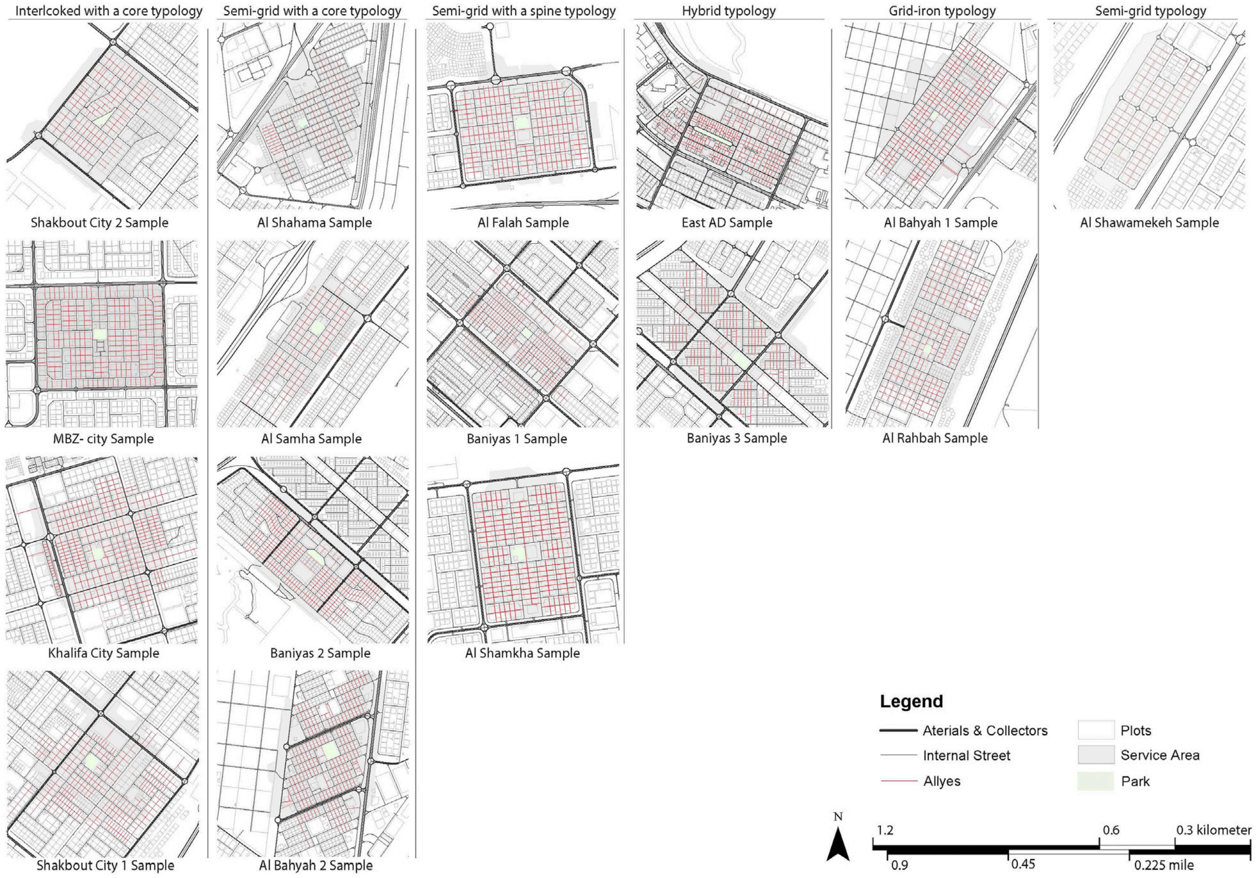

FIGURE 2
Selected samples showing parks' locations and the 1-km distance based service area.

calculated for trips generated from each origin, a residential plot captured by the service area, to each park's entrances, and then averaged per residential plot. Previous studies of street connectivity have shown that for suburban developments, the typical PRD threshold value is between 1.5 and 1.6 (Hess, 1997; Hess et al., 1999; Randall and Baetz, 2001). Additionally, Abu Dhabi's sustainability rating framework "Estidmama" has adopted 1.5 as a threshold when evaluating street connectivity. Therefore, the same value of 1.5, which indicates that the shortest routes are at maximum 50% longer than the Euclidean distance, is used to benchmark the average PRD value of each sample as passing or failing. PRD values are averaged within each sample and the sample's average PRD value is used an indicative of its route directness. Samples with an average PRD value lower than 1.5 are deemed as passing, suggesting that most of residential plots in that sample are connected to the local park with efficient routes.

3.4 Network route diversity: Redundancy index and count

Two metrics are used to quantify the availability of alternative routes, Redundancy Index (RI) and Redundancy Count (RC). Ozbil et al. (2011) study indicated that network connectivity can be described using a multitude of measures, including route choice which can be explained as "how many shortest paths between all possible paired origins and destinations go through each space." (p.126). This emphasizes two aspects. First: an expanded understanding of connectivity as addressing both distance and route choice. Second: the presence of multiple alternative routes that can be traversed with minimum deviation from the shortest route is an indicative of a more connected network. Similar to route directness, the pedestrian route choice measures, Redundancy Index and Count, are impacted by different attributes that can be either qualitative such as the sidewalk availability and continuity (Broach and Dill, 2016), or quantitative such as land use (Borst et al., 2009), or density and building heights (Guo, 2009; Hahm et al., 2017). The focus of this study is the quantitative attributes of street network, in terms of distance, network density, intersections and layout, in providing efficient multiple routes to parks. To ensure that alternative routes have reasonable deviation from the shortest route distance of no more than 20%, a value of 1.2 for the Detour Ratio is used, which is a factor that controls the maximum allowed deviations in distance from the shortest route (Sevtsuk and Mekonnen, 2012). This is with regard to the hot-arid climate of Abu-Dhabi and the fact that in such climate, pedestrians, when considering alternative routes, opt for shorter distances. For each residential plot, the count of alternative routes connecting them

TABLE 1 Quantified physical attributes for the streets only network scenario.

Network scenario	Typology	Sample's name	Sample's area	Arterials/ Collectors percentage	Network density	Intersections density (intersection/Ha)	4-Way intersection percentage	Average block size (Ha)	Average distance to park (Km)	Average between intersections (Km)
Streets Only	Grid Iron	Al Bahya	138.11	26.82	0.13	0.28	0.08	5.21	0.57	229.00
		Al Rahbah	111.20	0.00	0.11	0.30	0.08	5.38	0.57	200.00
	Semi-grid	Al Shawamekeh	57.30	0.00	0.16	0.80	0.00	6.03	0.47	219.00
	Semi-grid with spine	Al Falah	129.04	0.00	0.17	0.37	0.01	6.62	0.59	277.00
		Baniyas	117.04	27.59	0.23	0.55	0.04	2.53	0.61	261.00
		Al Shamkha	148.30	56.77	0.17	0.23	0.00	6.75	0.61	240.00
	Semi-grid with a core	Al Shahama	133.20	0.00	0.29	1.95	0.19	2.11	0.65	217.00
		Al Samha	79.70	10.00	0.14	0.31	0.03	6.26	0.74	274.00
		Baniyas-2	112.40	52.57	0.18	0.52	0.02	4.13	0.60	243.00
		Al Bahya-2	99.40	51.90	0.20	1.00	0.05	2.21	0.64	145.00
	Interlocked with a core	Shakbout-2	129.45	0.00	0.14	0.54	0.00	7.17	0.79	284.00
		MBZ	134.00	0.00	0.12	0.48	0.01	5.63	0.62	265.00
		Khalifa City	120.36	55.01	0.14	0.35	0.03	7.07	0.69	254.00
		Shakbout City	129.60	42.70	0.15	0.40	0.04	7.14	0.66	345.00
	Hybrid	East AD	104.80	32.00	0.28	2.63	0.07	1.77	0.67	100.65
		Baniyas-3	133.39	41.58	0.20	1.05	0.02	2.36	0.69	182.00

TABLE 2 Quantified physical attributes for the streets and alleyways network scenario.

Network scenario	Typology	Sample's name	Sample's area	Arterials/ Collectors percentage	Network density	Intersections density (intersection/Ha)	4-Way intersection percentage	Average block size (Ha)	Average distance to park (Km)	Average between intersections (Km)
Streets and Alleyways	Grid-iron	Al Bahya	138.11	17.47	0.26	2.80	24.03	0.51	0.58	56.00
		Al Rahbah	111.20	12.30	0.30	2.73	41.12	0.59	0.58	77.50
	Semi-grid	Al Shawamekeh	57.30	13.32	0.30	3.37	22.28	0.57	0.45	50.00
	Semi-grid with spine	Al Falah	129.04	35.84	0.27	2.36	45.07	0.59	0.57	66.00
		Baniyas	117.04	15.87	0.29	2.44	67.72	0.58	0.60	63.50
		Al Shamkha	148.30	29.87	0.32	2.35	35.53	0.60	0.59	69.00
	Semi-grid with a core	Al Shahama	133.20	20.71	0.36	1.99	22.64	0.65	0.55	79.00
		Al Samha	79.70	26.61	0.28	1.91	38.16	0.56	0.57	71.00
		Baniyas-2	112.40	26.24	0.65	3.74	36.19	0.38	0.63	53.00
		Al Bahya-2	99.40	28.07	0.30	1.91	34.74	0.33	0.57	56.00
	Interlocked with a core	Shakbout-2	129.45	12.09	0.32	3.05	19.24	1.10	0.71	47.00
		MBZ	134.00	26.21	0.30	3.26	14.87	0.45	0.63	58.00
		Khalifa City	120.36	28.05	0.37	3.19	42.97	0.39	0.58	60.00
		Shakbout City	129.60	17.49	0.36	3.01	23.08	0.61	0.60	59.00
	Hybrid	East AD	104.80	16.15	0.18	5.18	16.94	0.72	0.50	86.66
		Baniyas-3	133.39	26.11	0.30	2.56	27.78	0.42	0.70	50.00

TABLE 3 Connectivity analyses results for the two network scenarios.

Typology	Sample's name	Sample's average pedestrian route directness (PRD)		Sample's average route redundancy index (RI)		Sample's median route redundancy count (RC)	
		Streets only	Streets and alleyways	Streets only	Streets and alleyways	Streets only	Streets and alleyways
Grid Iron	Al Bahya	1.36	1.29	1.68	3.52	1.00	30.00
	Al Rahbah	1.40	1.34	1.49	4.61	2.00	39.00
Semi-grid	Al Shawamekeh	1.44	1.24	1.47	3.52	12.00	9.00
Semi-grid with a spine	Al Falah	1.42	1.30	2.65	4.47	1.00	27.00
	Baniyas	1.42	1.30	1.70	4.73	1.00	24.00
	Al Shamkha	1.49	1.33	1.38	4.48	1.00	26.00
Semi-grid with a core	Al Shahama	1.51	1.35	2.29	3.94	4.00	18.00
	Al Samha	1.90	1.36	1.41	3.74	1.00	12.00
	Baniyas-2	1.43	1.37	2.00	5.86	2.00	29.00
	Al Bahya 2	1.76	1.62	2.00	4.63	2.00	20.00
Interlocked with a core	Shakbout 2	1.59	1.38	1.61	3.32	3.00	18.00
	MBZ	1.50	1.37	1.89	4.77	5.00	25.00
	Khalifa City	2.00	1.41	1.51	3.00	3.00	18.00
	Shakbout City	1.64	1.40	1.32	3.32	1.00	26.00
Hybrid	East AD	1.95	1.47	3.21	3.51	19.00	112.00
	Baniyas-3	1.96	1.58	2.14	3.60	2.00	29.00

with each of the local park's entrances, providing that they are 20% at most longer than the absolute shortest route, is calculated and averaged. However, unlike the case with the PRD value, the median is used to represent the sample's Redundancy Count instead of the average. This is because the median value was found to be a better representative of the generated analysis results, considering the large disparities in the count of redundant routes between plots. The Redundancy Index refers to the ratio between the sum of the network length of all the alternative routes to the shortest path's length connecting the same pair of nodes (Sevtsuk and Mekonnen, 2012). Redundancy Index enables the determination of how much more network distance can be traversed *via* alternative routes that are at most 20% longer than the shortest route, thus offering the opportunity for more parts of the urban setting to be visited (Sevtsuk and Kalvo, 2022). As with the PRD index, the Redundancy Index is calculated from residential plots centroids to each of the park's entrances and averaged. The average of those values is then used to represent the sample's Redundancy Index. Values closer to 1 indicate either no route diversity or that the available alternative routes exceed the shortest route length by more than 20%; values larger than 1 indicate route diversity. Therefore, the value of 1 has been selected as a benchmark of determining if a residential plot has route redundancy when traveling towards local parks, at reasonable distances.

4 Results

Results of the network connectivity for both network scenarios, in terms of route directness (PRD), Count of Redundant Routes (RC), and Route Diversity Index (RI) are summarized in Table 3. The impact of urban form on connectivity to local parks, whether for strolling or towards the park itself as a destination, has been explored by quantifying the physical features of the network system. It is found that connectivity levels are impacted by both the typology, in terms of how streets and blocks are configured, and by the individual characteristics observed in each sample, such as percentages of arterials/collectors found in the sample's network, densities of the network and intersection, and the average block size. Alleyways are also found to improve connectivity significantly; this is due to their impact in reducing travelled distances to local parks. The inclusion of alleyways increases the typology griddness by supplementing the network with redundant shorter routes, increasing intersections, and reducing the average block sizes. The count of redundant routes is impacted by the typology in terms of intersection density. Redundancy Index is found to provide insights about the efficiency of alternative routes, in terms of distance. When, for example, two samples have equal counts of alternative routes and average distances to parks, the sample with the lower RI index indicate more efficient redundant routes.

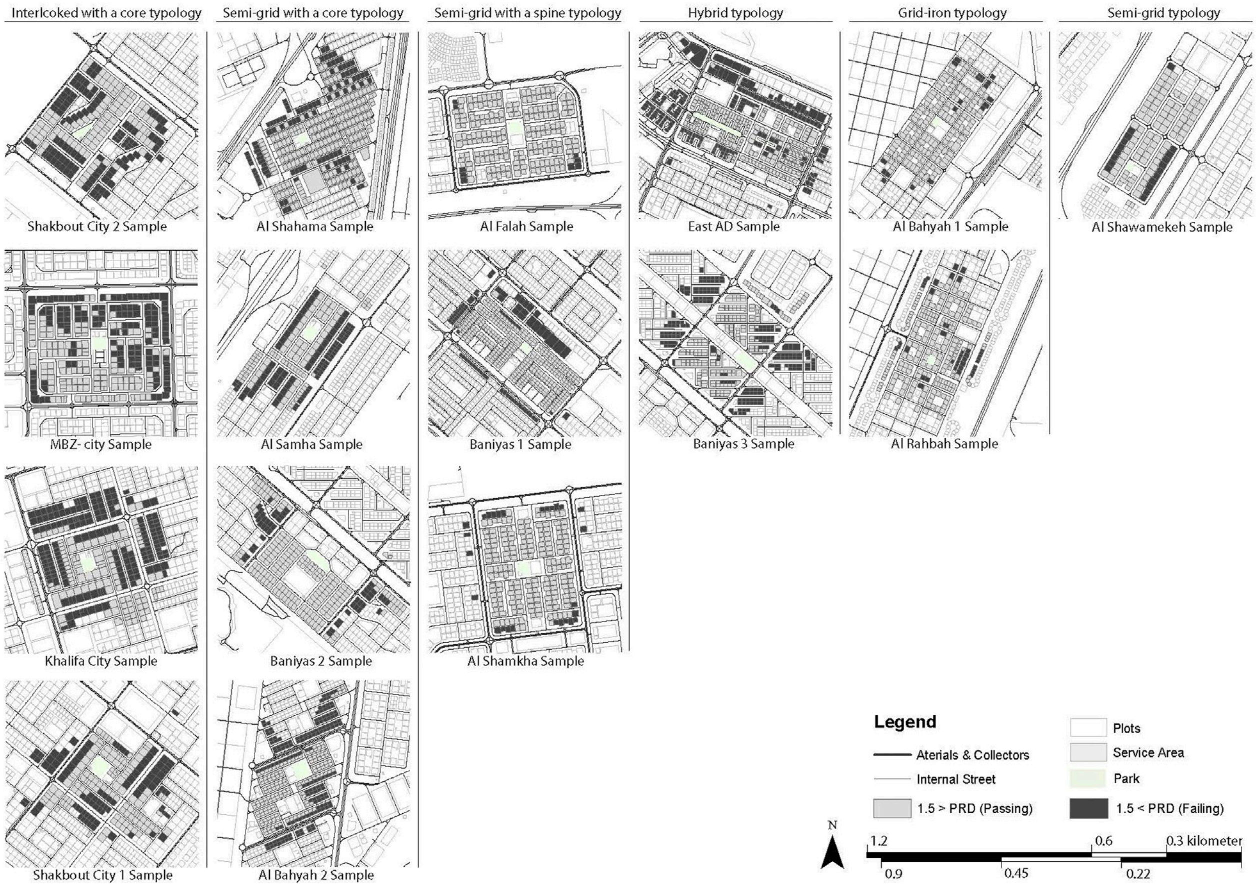

FIGURE 3
Samples showing Pedestrian Route Directness (PRD) analyses results for the streets network.

4.1 Network scenario: Streets

Connectivity results for the streets only network scenario are depicted in (Figure 3), which indicates the passing and failing plots in each sample in terms of the PRD measure, in (Figure 4) which indicates the plots with route redundancy in each sample in terms of the RI measure. Samples with a grid-iron topology, Al-Bahya and Al-Rahba, are found to have the lowest average PRD value at 1.36 and 1.40 respectively. This is intuitively attributed to their gridded layout which results in shorter average distances to local parks at (0.57 km). However, in terms of the availability of redundant routes, RC values indicate that most of the residential plots has a median of 2 route choices to the park, and RI values indicate that their combined lengths are almost 1.5 times longer than the shortest rout's distance. Since redundant routes in this analysis are bound to 20% deviation at most from the shortest route's length, such results suggest that more redundant routes may exist but with larger distance deviations. This is attributed to the low network and intersection densities in Al-Bahya and Al-Rahba. The next efficient typology, in terms of route directness, is the semi-grid found in Al-Shawamekh. The average PRD value of this sample is at 1.44, below the test threshold. Shortest routes of some plots, in this sample, traverse longer block faces resulting in an overall higher average PRD than the previously mentioned samples, despite having lower average travel distance to parks at (0.47 km). RC value indicate the availability of a median of 12 routes per residential plots, with a minimum deviation from the shortest distance (RI = 1.47), suggesting that such routes are efficient in terms of distance. The relatively high median RC value is attributed to the middle blocks' configuration, which provide the possibility of adjacent plots to access the park by traversing their relatively short faces. Another efficient typology is the semi-grid with a central service spine; three samples belong to this typology group: Al-Falah, Baniyas, and Al-Shamkha, all with average PRD values below the test threshold. This is attributed to the location of the parks within the central spine, thus routes leading to parks can be traversed at almost equal distances from all directions. The average shortest route distance in those samples is relatively low (around 0.60 km). Route diversity, however, in this typology is impacted by the frequent T-type intersections which reduces the count of available redundant routes. Therefore, the median RC value for those samples is one, suggesting that the majority of plots are connected with only one efficient route to the park.

Less efficient typologies have a service core with either a street pattern of semi-grid or with an interlocked pattern. The former typology includes four samples: Al-Samha, Al-Shahama, Al-Bahya-2, and Baniyas-2. Except for Baniyas-2, all of other samples have an average PRD value above 1.5. The low route

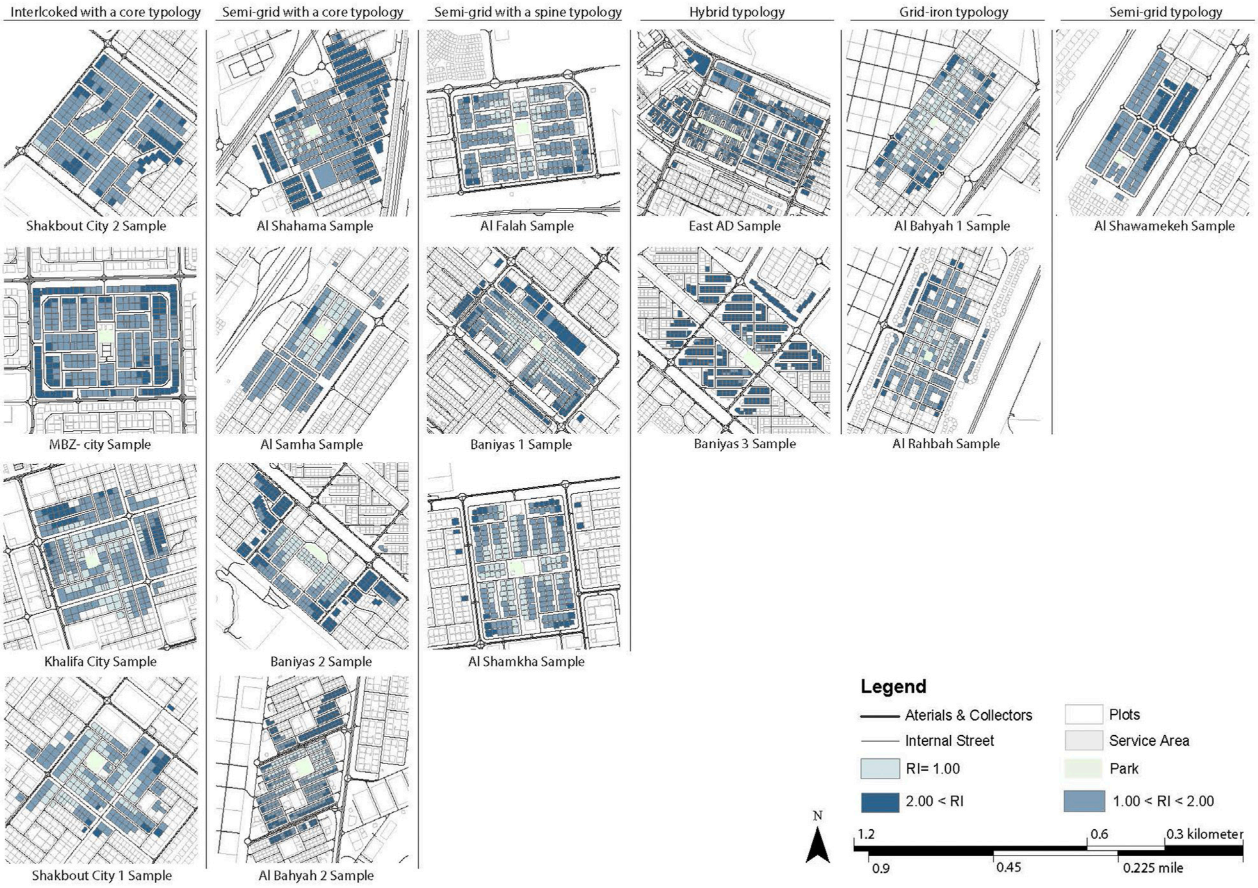

FIGURE 4
Samples showing Route Redundancy Index (RI) analyses results for the streets network.

directness values in Al-Samha and Al-Shahama (PRD = 1.90, and 1.50 respectively) are attributed to the block's configuration and face length (exceeding 0.65 km). The longitudinal blocks, in both samples are resulting in longer average shortest routes towards the local park (at 0.74 and 0.65 km) respectively. For Al-Bahya-2, the low average PRD value (PRD = 1.76) is attributed to the street's hierarchies included in its network, where 51.90% of it are arterials/collectors which impede route directness. Baniyas-2 has similar network composition in terms of arterials/collectors, but its average PRD value is at 1.43, suggesting significantly better route directness than Al-Bahya-2. This is attributed to its block configuration which alternate in direction, thus allow for the shorter rather than longer block faces to be traversed. This illustrates the extent to which the typology impact network efficiency. Both of Baniyas-2 and Al-Bahya-2 samples have a median of 2 redundant routes per residential plots, the RI value is also at 2 for both, suggesting a rather high cumulative distance deviation from the shortest route. Al-Shahama median RC value indicates higher count of redundant routes at 4 per residential plot, and the RI value at 2.29 suggests that those alternative routes are relatively efficient distance-wise. This is mainly attributed to Al-Shahama having the highest intersection density, among the typology samples, and the lowest average block size.

The other less efficient typology is the interlocked block configuration with a service core. It includes four samples: Khalifa-city, MBZ-city, Shakbout-city-1 and Shakhbout-city-2. The typology's street patterns, and block configurations result in longer block faces and T-type intersection. Therefore, routes traversed to reach the nearest intersection tend to be longer on average. This is evident from having longer shortest routes to the local parks on average, when compared with samples of other typologies. MBZ-city is the only sample in this typology with an average PRD value of 1.5 which meets the directness threshold. Unlike other samples in this typology, MBZ has an average block size lower than 7.0 ha and a service area that includes local streets only. Conversely, Khalifa-city and Shakhbout-city-1 samples have larger block sizes on average (7.0 ha or higher) and a service area that includes arterials and collectors (percentages of arterials/collectors in both samples are 55% and 42% respectively) which compromises route continuity. As a result, the average PRD values of those samples are above 1.5. Shakhbout-city-2 sample, although it includes local streets only, it is route directness is impacted by the large average block size at 7.17 ha, resulting in an average PRD value above the test threshold. In terms of route redundancy count for samples belonging to this typology group, the lack of sufficient intersection densities is

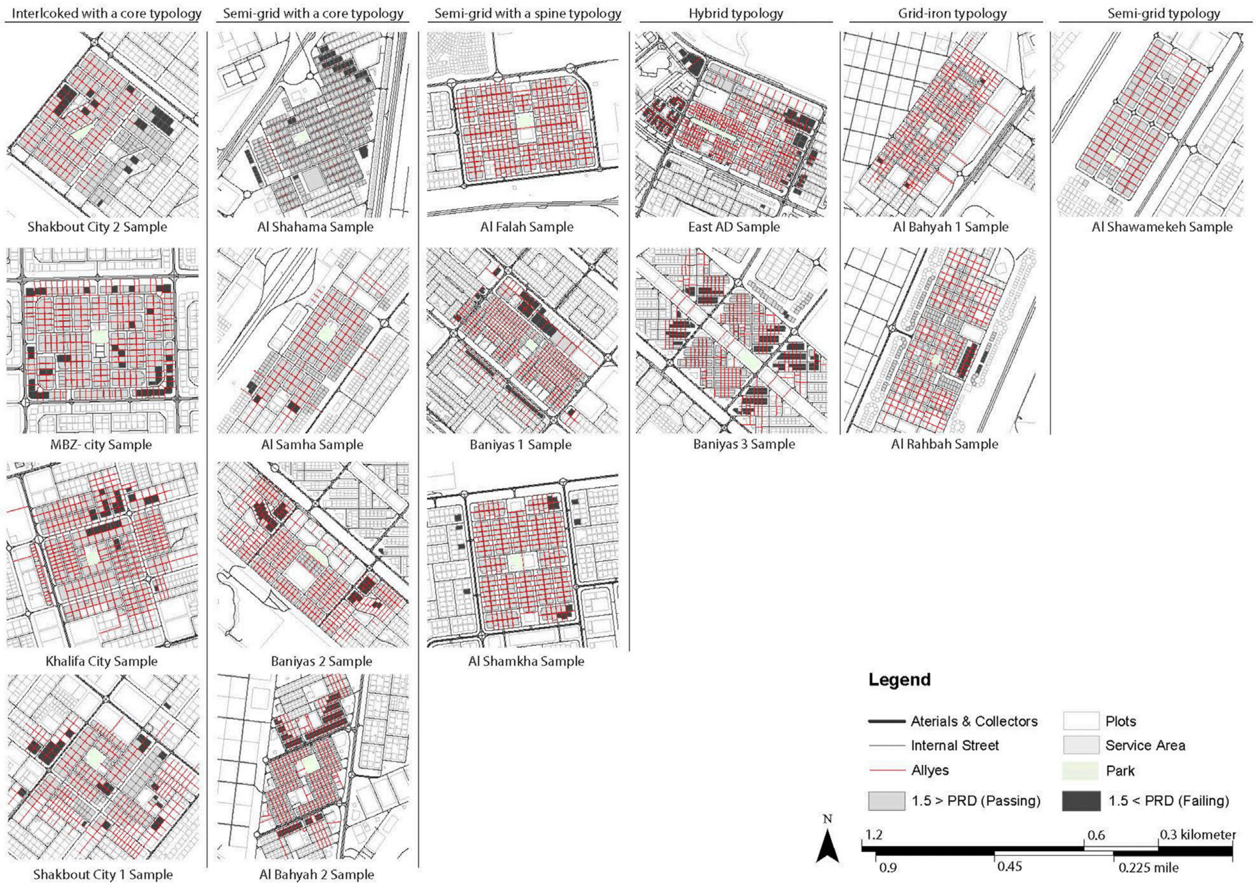

FIGURE 5
Samples showing Pedestrian Route Directness (PRD) analyses results for the streets and alleyways network.

significantly impacting the availability of redundant routes, resulting in median RC values of 5 or lower for those samples. However, RI values (between 1.32 and 1.89) indicate that for the few plots that have alternative routes, their cumulative lengths are within minimum deviation from the shortest routes, or 1.89 longer than the shortest route at most.

Two additional samples are considered to have inefficient typologies. The East-AD sample with its hybrid typology of semi-grid and T-type intersections, which is also internally divided into compartments by collectors. Despite having the highest intersection density and the lowest average block size, its average PRD value is at 1.95, suggesting very low network efficiency. This is attributed to the impeded route continuity due to the heterogeneous street pattern, within the sample, and the inclusion of arterials/collectors (at 32% of the total network length). However, the typology provides a median of 19 redundant routes to parks, the highest among the studied samples, with total distances expanding to almost 3 times the shortest route length. The other sample is Baniyas-3 with a diagonal semi-gird street pattern and a central spine. The average PRD value of this sample is above the test threshold at 1.96, suggesting an inefficient network. Distances to the local park is less direct due to the diagonal street pattern; this also impacts the availability of redundant routes to a median of (RC = 2) per residential plot.

4.2 Network scenario: Streets and alleyways

Connectivity results for the streets and alleways network scenario are depicted in (Figure 5), which indicates the passing and failing plots in each sample in terms of the PRD measure, in (Figure 6) which indicates the plots with route redundancy in each sample in terms of the RI measure. For most samples, the inclusion of alleyways improves network connectivity in terms of route directness and route redundancy. Alleyways are found to reduce the average shortest route distances, the spacing between frequent intersections, and the average block size. Their greater impact is found to be in increasing the networks densities and intersections, resulting in significantly higher count of redundant routes. The improved average PRD values are attributed therefore to the improved route continuity since routes to parks can be navigated *via* alleyways at shorter distances (Figure 7). In this network scenario, Al-Shawamekh typology is converted from a semi-grid typology into a gridded one, and it is reporting the lowest average PRD value at 1.24, suggesting a highly efficient network in terms of route directness. RC median value is at 9 redundant routes, per residential plot, and the RI value is at 3.52. The count of redundant routes, however, has dropped from a median of 12 to 9; this is attributed to the fact that alleyways have replaced street segments found in shortest routes, which resulted in relatively shorter routes

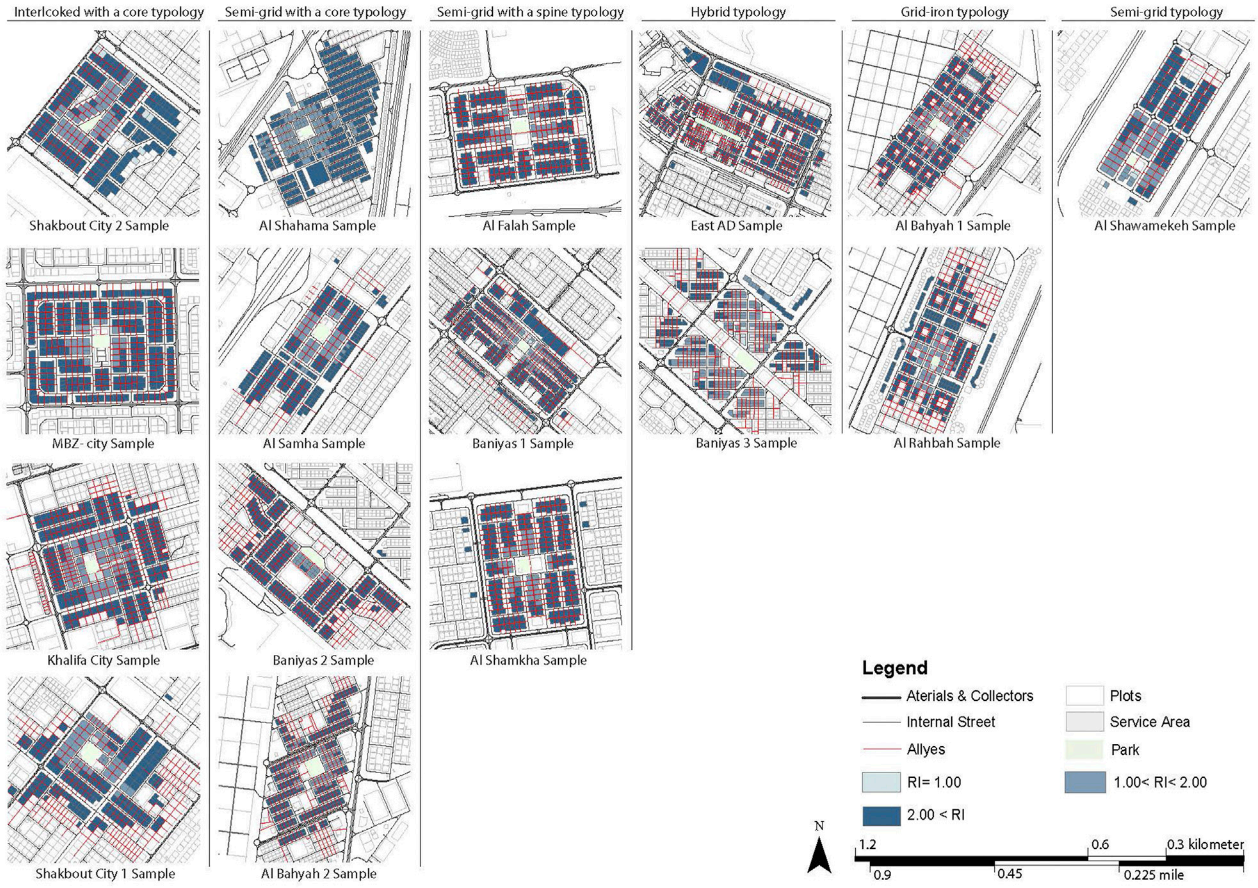

FIGURE 6
Samples showing Route Redundancy Index (RI) analyses results for the streets and alleyways network.

and have, therefore, reduced the allowed distance deviation. Samples belonging to the grid-iron typology, Al-Rahba and Al-Bahya, have also reported an improved average PRD values below 1.35. This is because alleyways increased the networks density. The increased intersection density and the reduced spacing between frequent regular intersections are contributing to those samples having the highest reported median count of redundant routes at (30 for Al-Rahba and 39 for Al-Bahya), with an RI values of 3.52 and 4.61 respectively. An abundance of alternative routes exists with total lengths that expands 4.6 times at most, suggesting that most of these routes have an acceptable deviation from the shortest route.

The typology group with the semi-grid and a spine, which includes: Al-Falah, Baniyas, and Al-Shamkha also reported improved average PRD values. For example, Al-Shamkha average PRD value improved from 1.49 to 1.33; this is attributed to parts of the street network being replaced with alleyways which provide efficient shorter connections to parks entrances. The median redundant routs count for samples in this typology is ranging between 24 and 27, suggesting that alleyways have significantly improved route choice, hence connectivity between residential plots and the local parks. The next typology with improved network connectivity, upon the inclusion of alleyways, is the interlocked street pattern with a core. The average PRD values of samples belonging to this typology are all below the 1.5 test threshold (between 1.37 and 1.41). For example, PRD values for Khalifa-city sample improved from 2.00 to 1.40. The inclusion of alleyways has reduced the average block size from 7 to 1 ha or lower, increased the network density from 0.14 to 0.36 km/ha, and the 4-way intersection percentage from 0.04% to 42.97%. All of this group's samples reported a median of RC values between 18 and 26, and RI values are between 3.00 and 3.32 except for MBZ-city sample which has an average RI value of 4.77. MBZ-city's high redundancy index is attributed to its low 4-way intersection density in comparison with other samples from this typology, thus redundant routes are likely to have greater deviations from the shortest route. The East-AD sample with its hybrid typology also showed an improved average PRD value; this is because alleyways mitigated the impact of the compromised route continuity caused by the arterials/collectors, included, within the park's service area. The median count of redundant routes in this sample is the highest at 119, yet the cumulative length of the alternative routes is on average 3.51 folds longer than the shortest distance suggesting that most of those alternative routes have reasonable deviations from the shortest routes. This is attributed to the significant increase in intersection and network densities (from 2.63 to 5.18 intersection/ha).

FIGURE 7
MBZ-city sample showing the conversion of the network layout into a gridded one. **(A)** Network scenario streets only. **(B)** Network scenario streets and alleyways.

The inclusion of alleyways in the semi-grid with a core typology samples have resulted in an improved average PRD values for all the samples except Al-Bahya-2. Al-Shahama, Al-Samha, and Baniays-2 samples reported average PRD values of 1.37 or lower, while the average PRD of Al-Bahya-2 has slightly improved from 1.76 to 1.62, a value that is still above the 1.5 test threshold. In Al-Bahya-2, route directness for some plots is impacted by the network hierarchical configuration, where the inclusion of arterials/collectors extends the travel distance and impedes route continuity. This is unlike Baniyas-2 sample, where peripheral plots are connected with alleyways that have direct interface points with arterials/collectors, thus providing more direct continuous routes (see Figure 8). Alleyways in Baniyas-3 sample, with its diagonal parallels typology, resulted in minimum improvement. The reported average PRD value of this sample is still above 1.5 (PRD = 1.58). This is attributed to the compromised route continuity resulting from the diagonal pattern of the block and network configuration. The diagonal network and block configuration increase travel distances relevant to the Euclidean distance. The inclusion of alleyway, however, has significantly enhanced route choice (from a median of 2–29), and the average RI value (at 3.60) suggest that most of

FIGURE 8
Baniyas-2 sample with uninterrupted route continuity against Al-Bahya-2 sample with route continuity impeded by the network hierarchy. **(A)** Baniyas-2 sample with alleyways forming continuous uninterrupted routes to the park. **(B)** Al-Bahya-2 sample with alleyways continuity interrupted by the network hierarchy.

these routes have reasonable distance deviations from the shortest routes.

5 Discussion

Considering the COVID-19 ramifications on daily life activities, connectivity to parks has been forwarded in literature and planning policies as a key quality in post-pandemic neighborhood design. This research assesses Abu-Dhabi neighborhoods as case studies to investigate the impact of network connectivity on walkability to parks within a catchment area of a 1-km network distance, from the parks' centroids. Connectivity is used to assess the network efficiency in terms of route directness and route choice. Route directness is evaluated using Pedestrian Route Directness (PRD), and the route choice is evaluated using two measures: Redundancy Count (RC), which returns the count of alternative routes that are longer than the shortest path by 20% at most, and Redundancy Index (RI), which provides insights on the distance deviations of alternative routes from the shortest route. Findings reveal that, within the catchment area, certain street network typologies and attributes provide more direct routes to parks in comparison with others. For example, samples with the grid-iron and semi-grid layouts are found to have the most efficient networks in terms of route directness, having the lowest average PRD values, when only street networks are considered. On the other hand, and considering only streets networks as well, samples with typologies of semi-grid with a core and interlocked with a core reported higher averages of PRD values. However, those typologies showed more route redundancy, higher median values of redundant routes count, than the samples associated with efficient route directness typologies.

When alleyways are included in the network, route directness and redundancy were observed to increase in all typologies. However, the reported improvement in both the average PRD values and the count of redundant routes in efficient typologies such as grid-iron, semi-grid, and semi-grid with a spine, was less than the reported improvement in the inefficient typologies, which include the semi-grid with a core, interlocked pattern with a core, and hybrids of fragmented and diagonal typologies. This can be explained by the fact that alleyways in typologies that are conducive to walking are less likely to form additional shorter connections, unlike inefficient typologies in which the impact of alleyways is more pronounced. The contribution of alleys with regard to network efficiency is attributed to the transformation of some networks to gridded layouts. Baniyas street's network layout sample, for example, has been transformed from a semi-grid with a service spine into a gridded one, evident from the increase in intersection density (from 0.55 to 2.44 intersection/ha), percentages of 4-way intersections (from 0.04% to 67.72%), resulting in an improved average PRD value (from 1.42 to 1.30). An example of improved values in an efficient typology is the semi-grid with a spine typology, where prior to the inclusion of alleyways, the average PRD values were between 1.42 and 1.49, and the median RC count was at 1. After the inclusion of alleyways, the average PRD values improved to become between 1.30 and 1.33, and the reported median RC counts are between 24 and 27. For inefficient typologies, samples belonging to the interlocked with a core have all reported average PRD values well above 1.5 except one, and median RC values were between 1 and 5. After the inclusion of alleyways, all the samples reported average PRD values between 1.37 and 1.41, and median values are between 18 and 26.

Key findings suggest that gridded and semi-gridded typologies tend to have more direct routes than fragmented or diagonal typologies. Higher intersection densities also increase routes redundancy/choice but are likely to extend travel distances. Typologies with more direct routes to parks provide residential plots with routes that can be traversed at short distances relevant to their location. Their low redundant routes count is attributed to the lower network and intersection densities associated with samples found in such typologies. Residential plots in typologies with less direct networks have higher network and intersection densities and are connected with parks *via* multiple routes. This suggests that, although increased intersections offer the opportunity of multiple routes, that connect the origin with the destination, they are likely to increase the route complexity and therefore the traveled distance. This was observed in multiple studies (Golledge, 1995; Sevtsuk et al., 2021) that associated increase in both the perceived and the actual traveled distance with increased route complexity/turns. It should be noted that this association between route directness and redundancy depends on the typology itself. For example, Al-Shawamekh sample with its semi-grid typology shows both high route directness and redundancy count. Although it has similar network and intersection densities to those samples of efficient networks, its semi-grid typology mitigates the low intersections and the long block faces. Conversely, Baniyas-3 sample, shows both low route directness and redundancy due its diagonal network configuration, despite its relatively high intersection density.

These results show that routes to parks are likely to be impacted by different network's attributes, including: densities of the network itself and its intersections, the average distance between intersections, and the type of streets included in the network. Most notably, typologies seem to exert stronger impact even when sufficient intersections and routes are present within the network. Ensuring appropriate connectivity levels, in terms of both route directness and availability of redundant routes, depends largely on successful implementation of alleyways to overcome route continuity deficiencies resulting from inefficient typologies or network configurations. Current planning policies in Abu-Dhabi would need to consider post-pandemic emergent living preferences with regard to how neighborhood parks can be accessed. The Abu-Dhabi public realm design manual, 2021, prioritizes increasing parks availability in line with the city's 2030 vision. The manual specifies that at the neighborhood level, a minimum area of 2-ha should be designated as a park with a catchment radius of 700-m. Although the manual provides detailed planning and design policies that addresses the park itself and the necessity of having direct connection with pedestrian/cycling routes, it does not take into consideration different neighborhood typologies with regard to network design, hierarchical configuration, as well as alleys distribution and contribution to the network. In particular, the manual is very descriptive in nature, providing design ideals without delving into the design and attributes of the network system. For example, the manual does not consider street typologies in terms of average travel distance, frequency of intersections or routes' diversity. Additionally, throughout the manual, parks entry guidelines mandate the necessity of ensuring direct connection with uninterrupted pedestrian/cycling routes. However, the guidelines do not take into consideration whether residential plots, within the park's catchment area, can access alleyways/pedestrian routes. Therefore, a more comprehensive approach to designing and planning for greater connectivity to neighborhood parks should consider average travel time and the availability of route options to pedestrians, as well as more pedestrian cross points along arterial/collectors. Other guidelines should evaluate the qualitative aspects of pedestrian routes in terms of infrastructure adequacy, suitability of accommodating longer connected walks, and availability of shading and landscape along the path.

6 Conclusion

Regarded as key destinations during the pandemic, neighborhoods' parks had an impactful positive role on the physical and mental wellbeing of residents during the extended lockdown duration. Access to parks was forwarded, therefore, by many policymakers and scholars as a necessity for post-pandemic neighborhood planning and design. This renewed the debate over how different physical features of the built environment support active mobility to parks and open public spaces. Network systems (streets + alleys) are central to this debate where active travel takes place. On this vein, this article evaluated connectivity efficiency of the network systems of Abu-Dhabi neighborhoods. Connectivity, a concept frequently used in urban practice and literature, addresses street networks in terms of the sufficiency of multiple connections between an origin and destinations, and the efficiency of such connection with regard to the traveled distance. Using three measures of network connectivity, 16 samples grouped into 6 different typologies were evaluated. The three measures are: The Pedestrian Route Directness PRD, which assesses whether routes to a park can be traveled at short distances; the route Redundancy Count, which evaluates whether the typology support travel through multiple routes with minimum distance devotion from the absolute shortest route; and the Redundancy Index, which evaluates the efficiency of the alternative routes. Typologies of gridded, semi-gridded, and semi-gridded with a spine networks were found to provide more direct routes, but lower redundant connections to parks unless supplemented with alleyways/pedestrian routes. Conversely, typologies of service core with a semi-grid or an interlocked network, and hybrid typologies of fragmented and diagonal networks were found to support access to parks *via* multiple but less direct routes; therefore, alleyways implementation in such typologies should address network's deficiencies. Overall, typologies with gridded, semi-gridded layouts with consistent street patterns, the ensures route continuity, reported significantly higher connectivity values than typologies with less consistent, fragmented layouts. An example of this is the East-AD sample which, despite having the highest intersection density before and after the inclusion of alleyways, its average PRD values remain among the highest, indicating lower network efficiency.

The study also recommended that current planning and design guidelines, in Abu-Dhabi, should adopt evidence-based and applied methods in drafting planning policies, assessing existing conditions, and revitalizing existing issues in the urban fabric, rather than providing descriptive narratives and idealistic text. The lack of pedestrian data availability is a limitation in this study; future studies, therefore, should consider such data along with other micro-scale route's attributes such as the quality of sidewalks, availability of greenery/shading and mixed land-uses along the routes.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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