Multicriteria Approach in Developing Pedestrian Network Data for Sustainable Urban Mobility

Sagar Sonone
Public Works Authority, Ashghal, Doha, Qatar
ssonone@ashghal.gov.qa

Narayanasamy Balamohan
Public Works Authority, Ashghal, Doha, Qatar
nmohan@ashghal.gov.qa

Abstract

Building a reliable Infrastructure is a continuous activity, improving the accessibility to the known areas and connecting the origin to destinations with various modes of transportation. Having safe and secure pedestrian movement ensures sustainable urban mobility. Therefore, the study includes an approach for multi-criteria evaluation to reach from origin to destination. Factors strongly correlating that will affect the walkability were considered, including climatic conditions, type of network (crossings, pedestrian bridges, shared use, footpath), land use etc. which will affect the distance and time of the walkability. After capturing & tracing all the footpath locations in GIS for the most populated areas, the percentage of land use provides insights into typical pedestrian movements for a specific period of the day. Pedestrian movement is categorised into various levels and focused on locations of interest where huge volume travels a particular area at the same time & travel distance, which leads to analysing required infrastructure considering safety and convenience aspect such as availability of sufficient footpath width, availability of streetlights, locating a bus stops/ public transport etc. as an initial experiment using the above criteria for a known location such as a metro station was considered which will result in building more confidence on the factors and their integrity. The study will aid as a tool in designing and constructing infrastructure projects which will ensure the maintenance of seamless pedestrian connectivity & incorporate necessary assets within the project. Better connectivity will encourage people to walk further, safely & use public transportation facilities more often.

Keywords: Walkability; Pedestrians network; Sustainable infrastructure; GIS; Urban connectivity

1 Introduction

The pedestrian network is the fundamental unit of urban space and becomes the most crucial supply-side part of the transportation network. In addition, the pedestrian network provides last-mile connectivity for people, specifically for public transportation users. Recent studies show that the extent of availability of pedestrian networks and cycle tracks influences urban mobility. Pedestrian infrastructure is considered the primary means of access to public spaces and the most complex transport network as it joins all transport modes.

In this modern information age, the accessibility of maps for trip planning has become much easier compared to a decade ago. With the easy availability of online maps and mobile maps apps like Google Map®, HERE®, Wain®, etc., becoming day-to-day commodities, the use of maps for navigation and exposure to a suitable pedestrian network encourages people to walk and highly influence the travel behaviour of the population.

2 Qatar Context and Background

Doha, the capital of the State of Qatar, is transforming from a major city to a metropolis. Pedestrian linkages and networks are a critical element of a metropolis urban form. In addition, during the last two decades, public infrastructure, specifically the roads and highway infrastructure, have grown in multiple folds, and pedestrian and network is part of any road and highway design aspects. Figure 1 shows pedestrian space in local road design.

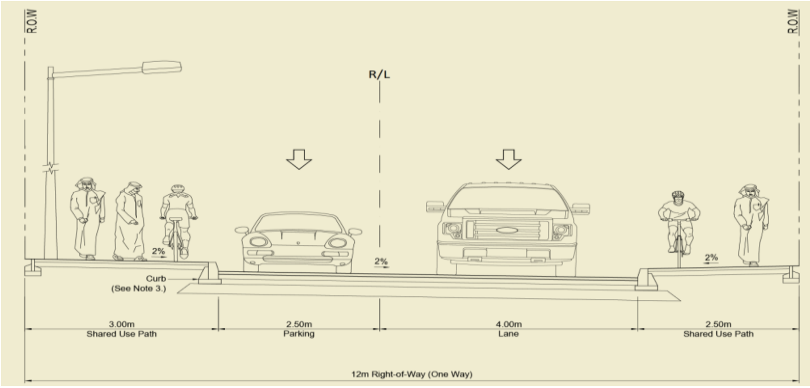

Fig. 1: Typical cross-section of the local road

As more than 90% of total pedestrian trips occur in the Doha Metropolitan Area (DMA), Qatar has prioritised pedestrian-friendly urban mobility. Thus a detailed study has been undertaken by MOTC to review Qatar's Pedestrian Environment as part of the Qatar Pedestrian Crossing Master Plan in 2017. The study employed PERS developed by TRL in the UK. Qatar 2050 Transportation Master Plan study identified about 263 km of dedicated off-road pedestrian footpaths: and 124 km of off-road cycle tracks with 53 km of shared-use pedestrian/ cyclist off-road routes.

Public Works Authority (Ashghal) is responsible for managing and maintaining the geographic information for road and highway infrastructure. Ashghal keeps the information both from an asset perspective and a network perspective. Ashghal maintains the schematic of road network data using a carriageway centreline representing the flow of traffic called a 'flowline.' Ashghal also developed a navigable network dataset derived from the flowline data set.

As the travel demand has a multi-purpose and inherently becomes a multi-model, the need for pedestrian network and cycle network track become highly warranted within the network perspective. A dedicated cycle lane has become part of the recent road and highway design. Currently, the dedicated cycle network covers about 930 km in Qatar, and Qatar gained a Guinness record for having the longest continuous cycle track of 32.89 km.

The pedestrian network information must be part of Ashghal's primary network dataset. As Qatar was hosting the FIFA World cup 2022 and expected more than two million visitors to visit during the event, the need for a pedestrian network of digital information was in high demand. The information facilitated visitors' smooth movement and prepared plans for safe and secure pedestrian walkways. To make the network more conducive for walking and to engage the FIFA fans to explore Qatar's Cultural Landmarks, various key areas were transformed entirely for pedestrian movement, and vehicle movement was restricted.

To develop a pedestrian network dataset in the shortest possible time, Ashghal has undertook a study to prioritise areas for capturing the geographic information of the pedestrian network. The key objective of the study is to (i) identify and prioritise the areas that needed a pedestrian network, (ii) set an approach for constraints for links and crosses, (iii) define the classification of a pedestrian network, and (iv) build the network. This paper shares how Ashghal prepared the pedestrian network in a limited time and with a focused approach.

3 Methodology

A systematic 4-step methodology, as shown in Figure 2, was adopted to identify the priority areas for developing the pedestrian network dataset. The study used a multi-criteria analysis technique, which is robust and widely used in many fields in selection & prioritisation processes based on multiple influenced criteria. As spatial dimension has become one of the critical factors in evaluating options, integrating Geospatial Information System (GIS) with multi-criteria analysis was considered appropriate.

Fig. 2: Study Methodology

Step 1: Undertake a study and identify the factors influencing the development of the pedestrian network. Per the previous study conducted by MoTC, Pedestrian Environment Review System identified 14 factors for the quality of an environment for pedestrians. The proximity to Bus Stops, Metro Stations significantly impacts pedestrian movement (Khaled Shaaban et al., 2018). Land Use density, diversity & design are critical dimensions for the walkability index. The number of intersections facilitating the road crossing for pedestrians is considered one of the essential evaluation factors in assessing the pedestrian network (Pereira, 2022).

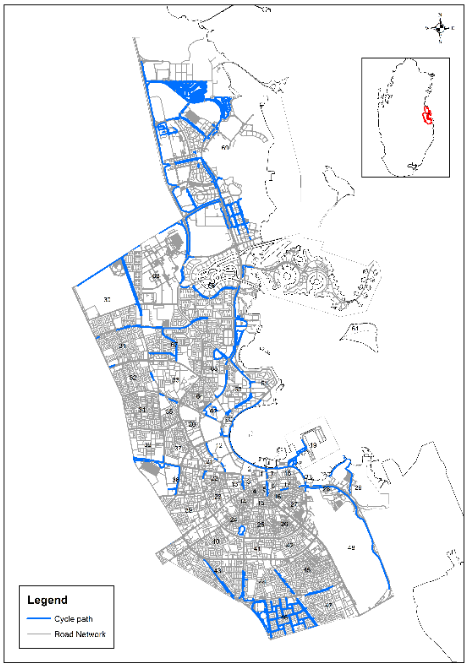

Fig. 3: Dedicated cycle tracks in urban zones

There is a high degree of preference for sharing pedestrians with available cycle track networks. It is also natural for a pedestrian to use the shared path that relies significantly on off-road routes for safety and security (Delaney, Hannah et al., 2016). Thus, while defining the criteria of zone selection, the cycle paths are not considered because the dedicated cycle lane in the urban zones contributes about 6% of the total road network, Figure 3.

Step 2: Previous studies provided various factors affecting pedestrian movement and the suitability of pedestrian networks. Though there are many factors identified, however by considering the following three factors for evaluating the quality of the pedestrian network in this study:

a. Accessibility - Proximity for Public Transport (Metro Stations & Bus Stops),

b. Land Use - Residential Areas, Offices/commercial, Point of Interest (PoI),

c. Street Connectivity – Intersections, Pedestrian structures.

The data required for this evaluation have been assessed, collected, and extracted. The following data in Table 1 represent criteria as the fundamental data unit for the assessment. The quality of the availability of the spatial data is assessed before its use to ensure the requirements can be quantifiable and spatial interpreted.

Table 1: Datasets and source

No.	Datasets	Source
1	Land use	CGIS / MME
2	Bus Stops	MoTC
3	Metro Stations	Q Rail
4	Road’s data	Ashghal
5	Zones	CGIS / MME

Step 3: In this step, the conventional strategy is to determine the weightage and scoring for priority decisions in the multi-criteria approach. The strategy is a simple subjective scoring reliant on the judgments of subject matter experts. The key benefit of this approach is that it can be guided & performed quickly. The weightage and ranking scores for the criteria are valued and presented in Table 2.

Table 2: Weightage and scoring attributes

Weightage	Criteria	Sub-Criteria	Measure	Score
50%	Accessibility to Public Transportation	Proximity to Metro	< = 300 m	1
			> 300 m	0
		Proximity to Bus Stop	< = 200 m	1
			> 200 m	0
30%	Land use	Residential & PoI	> 20 %	1
			< 20 %	0
		Offices / Commercial	> 50 %	1
			< 20 %	0
20%	Street Connectivity	Intersections, Pedestrian Structures	> 200 (Number of intersections per sq. km)	1
			50-200 (Number of intersections per sq. km)	0.5
			< 50 (Number of intersections per sq. km)	0

Step 4: Performing prioritisation analysis using GIS as a tool. ESRI ArcGIS 10.8 as a GIS platform. Performing three spatial analyses and thematic maps supports all the outcomes.

4 Assessment

Building a pedestrian network database along an ~18000 km road network requires evaluating a critical assessment of the priority through a thorough analysis of influential factors and criteria and assessing with a multi-criteria analysis based on the factors of usage & importance of the network in the given area/street. Considering the proximity to public transportation using the buffer analysis and nearest neighbourhood analysis using the Thessian polygon technique to determine prevailing service areas for bus stops and to identify the areas influenced by the spatial spread of land use categories by conducting buffer analysis. The street connectivity factor was analysed using the spatial density technique on street intersections and pedestrian structures.

4.1 Assessing Proximity to Public Transport

The study includes assessing the proximity of metro stations using a 300m Euclidean buffer analysis. The land use with this 300m buffer was analysed, and calculating the percentage of each land use type within this buffer gives an estimate of land use diversity. The pairwise influence of Metro stations and land use criteria were analysed based on the set weightage and Score. Overlaying Zones on these metro stations are provided with high priority scoring considering the percentage overlay of the buffer within the zones. Figure 4 illustrates the buffer's proximity and the land use percentage.

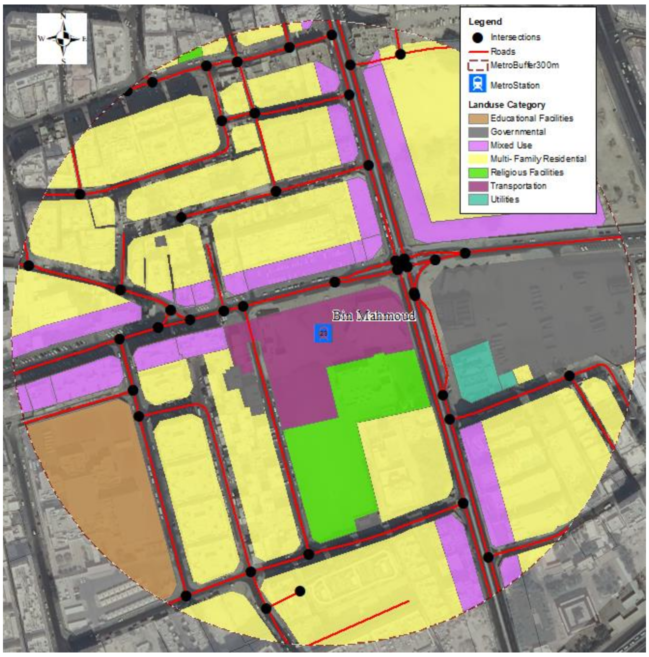

Fig. 4: Land Use within 300m of the proximity of the metro station

Generating Thiessen polygons using bus stop locations to address the proximity to public transportation for bus stops. The area of the polygon is the factor for the influence area of each bus stop. Smaller zones indicate closer proximity to bus stops and stronger influence for pedestrian users, deciding an appropriate area to signify the influence. It is assumed based on 15min walkable urban city concept. If a normal person walks 1.2km in 15 minutes, then any area less than 4.5 sqm would be highly influential. Considering Qatar's weather conditions during the peak summer, reducing the walking distance to 300m would cover approx. 0.3sqkm. Then all Thiessen polygon that meets this conditional is selected and merged to depict the map showing the influential area—considering the Zones with the maximum coverage of Thiessen polygons as thematically presented in Figure 5.

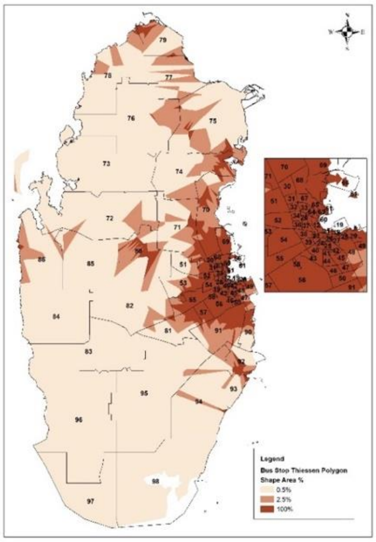

Fig. 5: Proximity of bus stop

4.2 Land Use: Assessing the Percentage of Land Use within Zones:

Land uses are differentiated into various categories. Reclassifying land use categories into four significant groups should simplify the analysis for this exercise as presented in Table 3. These groups will provide subjective weightage and scoring based on a judgmental valuation of pedestrian volume and movement for the zone.

Table 3: Land use categories collated into four significant groups

Residential	PoIs	Offices/Commercial	Other
• Multi- Family Residential • Single- Family residential	• Community and culture facilities • Educational Facilities • Health Facilities • Open Space Recreation (Indoor-Outdoor) • Religious Facilities • Tourism	• Governmental • Services/ Offices • Special Use • Commercial	• Agriculture and Green Areas • Heavy Impact industry • Logistics- Distribution- Warehouse • Low Impact industry • Medium Impact industry • Mixed Use • Sports Facilities • Transportation • Unknown/Undefined • Utilities • Vacant Land • Wholesale

4.3 Pedestrian Crossings

Pedestrian crossings on intersections & dedicated bridges serve as an effortless way to safely cross any significant junctions or roads. Typically, public movement around these areas is more than in other locations to cross any streets safely. Zones containing pedestrian bridges & a more significant number of intersections are likely to be used more by pedestrians. Pedestrian bridges & crossings positively correlate to the volume, and it becomes necessary to have enough space & need footpaths around it. Using a density range from 0.010 to 0.085 total of 53 zones are selected.

$$Zone\ Intersection\ Density = \frac{Number\ of\ intersections}{Total\ Zone\ Area\ (sq.km)}$$

Example: Zone 23- Bin Mahmoud total intersection is 396 for an area of 1161750 sq.m

Zone 23 intersection density = $\frac{396}{1161750}$ = 0.03408

5 Evaluating The Factors

Based on the assessment area, calculating the score for each criterion for each zone will help derive the final scoring of individual zones. Figure 6 illustrates the areas identified with the influential individual criteria.

Factor A = Accessibility Weightage x ∑ (metro proximity score, bus stop proximity score).

Factor B = Land Use weightage x Score for land use category.

Factor C = Street Connectivity weightage x Score for intersection density,

$$Total\ Score = Factor\ A + Factor\ B + Factor\ C$$

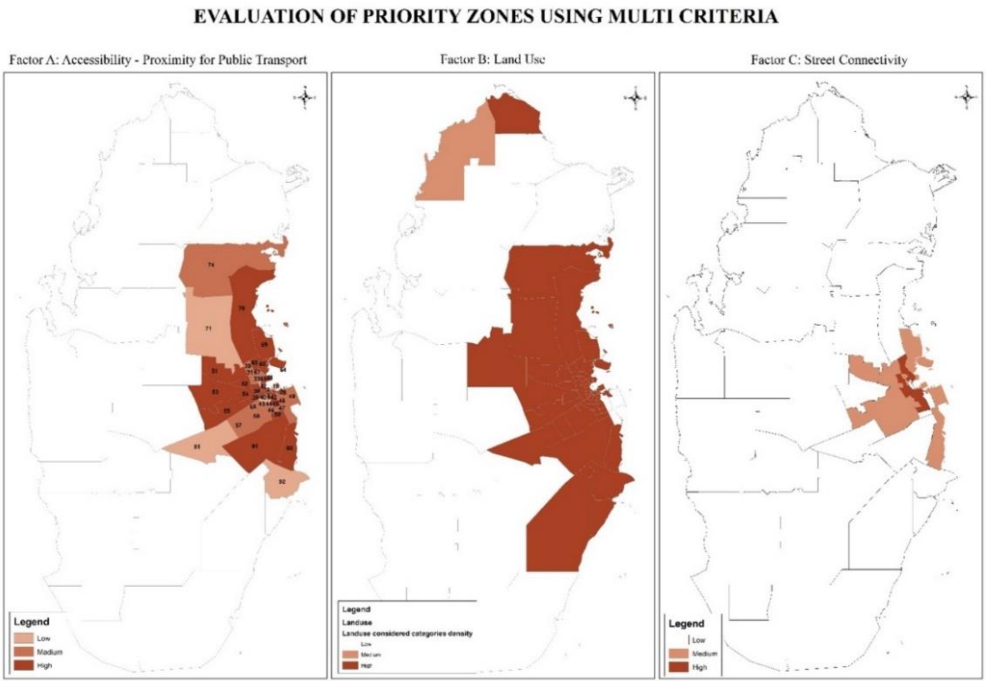

Fig. 6: Individual criteria evaluation

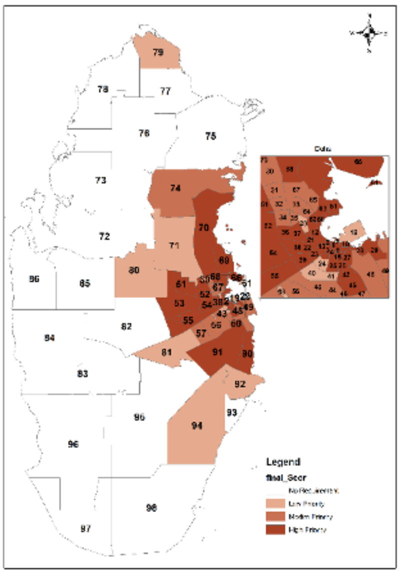

Fig. 7: Prioritised zone based on the combined normalised Score

The final scoring was evaluated based on the spatial addition of individual factor scores, normalised on the zone, and sorted based on the Score to prioritise the zones. Presenting the outcome of the assessment with priority zone is thematically in Figure 7. The combined scores are further normalised to classify the low, medium, and high-priority zones. The priorities of zones will assist in computing the lengths, further aiding in generating the prioritised pedestrian database, as presented in Table 4.

Table 4: Assessed priority zones and estimated length of pedestrian network data

No.	Priority Classification	Number of zones	Estimated Walkway Length(km)
1	High Priority	46	~ 8065
2	Medium Priority	25	~ 5280
3	Low Priority	3	~ 5071
4	No Requirement	17	-

6 Conclusion

The availability of pedestrian network information is necessary for the transportation network spatial dataset used for navigation and multi-model trip planning analysis. The main goal of this study is to support the data team in identifying and prioritising the zone where the pedestrian network data will be developed. This study considered three influential factors and applied multi-criteria analysis to determine the priority areas/zones. The assessment provides insights into the need for pedestrian network spatial information. Although the proposed method assigned the weight for all walkability elements based on subjective judgment, the above method can easily be modified by adding more or assigning different weights to different elements as needed. Combined values of evaluation scores of each criterion assist in identifying the priority areas for developing the pedestrian network dataset and implementing the necessary pedestrian safety infrastructure, maintaining the existing conditions of the assets, and promoting safe walking. This prioritisation and assessment of walkway length helped the data to estimate the resources required to develop the walkway database in a limited duration.

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