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Evaluation of Pedestrian Level of Service of Selected Footpath Segments of Dhaka City using Multi-criteria Decision Making Approach

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Abstract

Walking is considered to be the most important mode of travel across the world, particularly for a shortdistance trip. Since 19.6

Index terms— pedestrian level of service, accessibility, analytical hierarchical process, connectivity, pedestrian flow rate.

1 Introduction

alking is the most accessible mode of transport. It is considered to be the most sustainable and environment-friendly mode of transport across the globe. A better walking environment can enhance the livability of a city, ensure better access to public transport and helps to combat climate change **??**Bhuiya, Morshed, and Rahman, 2013;UN, 2016). For this, concerned city authority needs to ensure a better environment for pedestrian movement along the footpath and provide necessary facilities to ease their movement. 19.8% of the total trips of Dhaka are made W on feet (DHUTS, 2010). So, the city authority must ensure a vibrant environment and provide the required features for these pedestrians to make the transportation system of Dhaka sustainable. But unfortunately, the footpaths of Dhaka city are not congenial for the movement of pedestrians. Lack of crossing facilities, installation of temporary vendor shops, parking of motorized vehicles, storing of construction material, piling of waste, poor surface condition of footpath and foot overbridges, etc have made movement for the pedestrians difficult and negatively effecting Pedestrian Level of Service (PLOS) (RSTP,2015; Health Bridge Foundation of Canada, n.d).

To ameliorate PLOS, firstly, it is necessary to explore the condition of relevant factors influencing the satisfaction of pedestrians and determine the overall condition PLOS. This study is unique because no other studies have been conducted earlier to determine the relative weight of factors influencing PLOS based on the opinion of pedestrians. Then, PLOS of selected segments of the footpaths of Dhaka city will be evaluated based on ten factors using multi-criteria-based decision-making approach Analytical Hierarchy Process. It will further indicate areas to be more focused on future improvement as well as the development of pedestrian facilities in the city.

2 II.

3 Selected Segments of Footpath

Dhaka city has a huge road network used by pedestrians. For the simplicity and time constraints, this study selected four footpath segments of Dhaka city with potential land uses to generate significant pedestrian flow to carry out the study.

4 Methodology

The level of service is one of the key concepts for measuring the performance of transport infrastructures. Pedestrian Level of Service (PLOS) is an approach to quantify the environmental quality of pedestrian space and serve as a yardstick for defining standard for pedestrian facilities in footpath (Parida, Najamuddin and Parida, 2007: 27; **??**apacostas and Prevedouros, 2006: 136). With more focus across the world on green transport and active transport, it has become a crucial issue to ensure the desired PLOS for developing a sustainable transportation system (Littman, 2003). For this, this study has aimed to explore PLOS of four selected footpath sections of Dhaka and suggest policy measures for the PLOS of those footpath segments.

This study has been conducted based on primary data collected through the physical survey, questionnaire survey and field observation. Initially, a reconnaissance survey was conducted to the pedestrians to identify the most important factors influencing PLOS. While carrying out the reconnaissance survey, the concept of PLOS was explained to pedestrians first and they were asked to mention the factors that they consider significant to ensure better PLOS in an open-ended manner. From the findings of the reconnaissance survey, factors mentioned by pedestrians have been tallied based on numbers of pedestrians mentioned a factor. From tallied data, the top ten factors have been identified which pedestrian considers most important for ensuring a better environment for pedestrian movement.

A total number of the pedestrian has been surveyed is 240 with, 60 from each walkway segment to collect information on the relative weight of factors in respect of others. Pedestrians were asked to provide rank about their level of satisfaction about factors on a scale of 1-5.

5 a) Factors Influencing Pedestrian Level of Service

Path width: With the increase in path width, there will be more space for pedestrian movement avoiding congestion and better accessibility for wheelchair users to maneuver wheelchair (Main Roads Western Australia, 2006: 7; NYC, 2006: 15, Bhuiya, 2018). Path width has been determined through the physical survey. It has been indexed as 0-2, 2-4,4-6,6-8 and 8-10 feet as points 1,2,3,4 and 5 respectively.

6 Appropriate

Placement of Roadside Features: Appropriate Location of roadside features like benches, trees, birdbath, etc on the footpath is necessary so that pedestrians can move on the footpath without receiving hindrances on their way (Mineta Transport Institute, 2012; Old Colony Planning Council, n.d.). Through the questionnaire survey, the value of this factor has been indexed as points 1,2,3,4 and 5 for very poor, poor, moderate, good and very good respectively.

Crossing Opportunity: In this study, availability of crossing opportunity has been referred by the existence of foot over bridge, zebra crossing, median refugees, guard or police control crossing for the pedestrians (Main Roads Western Australia, 2006; Mineta Transport Institute, 2012; National Roads Authority, Ireland, 2001). Point 1,2,3,4 and 5 have been allocated by surveyed pedestrians for the following situations: almost nonexistent, some provided but poorly located, some provided and are reasonably well located but more are needed, adequate crossing facilities, reasonably well located and dedicated pedestrian crossing facilities are provided at adequate frequency, respectively.

Surface Quality: A crack-free, well-textured surface without undulation is necessary for the quality walking environment (Parida, Najamuddin and Parida, 2007:28; Banarjee, Maurya and Gammel, 2018: 25, 32). Through the questionnaire survey, the value of this factor has been indexed as points 1,2,3,4 and 5 for very poor, poor, moderate, good and very good, respectively.

Distance from Vehicular Traffic: With the increase in distance from vehicular way, the possibility of a conflict of vehicles with pedestrians will increase and safety is likely to decrease. In this study, distance from the pedestrian way from the curb has been considered as the distance from vehicular traffic (Main Roads Western Australia, 2006; Singh and Jain, 2011). It has been indexed as less than 0.5, 0.5-1, 1-1.5, 1.5-2 and greater than 2 km distance from the curb as points 1,2,3,4 and 5, respectively.

Pedestrian Volume: With the increase in pedestrian volume per unit area, a footpath will get more congested. As a result, the PLOS value will decline (Main Roads Western Australia, 2006; TRB, 2000). While conducting the reconnaissance survey, it has been observed that pedestrian activity remains at a higher level between 8.00 am to 8.00 p.mon weekdays. For this, pedestrian volume survey was conducted between 8 a.m. to 8 p.m over 5 weekdays. The average pedestrian volume of 5 days was divided by area of footpath segments of the road to determine the pedestrian volume over each unit area of the footpath. Pedestrian volume of 1.96-2.14, 1.67-1.95, 1.38-1.66, 1.09-1.37 and 0.80-1.08 person/sqft/day has been indexed as point 1,2,3,4 and 5, respectively.

Comfort: Comfort has been attributed to the existence of different landscaping elements placed on the footpath including benches, drinking fountain etc (Parida, Najamuddin and Parida; Banarjee, Maurya and Gammel, 2018). Through the questionnaire survey, the value of this factor has been indexed as points 1,2,3,4 and 5 for very poor, poor, moderate, good and very good, respectively to know the level of comfort ensured by existing facilities.

Existence of Buffer: Buffer like fences, bollards, trees are used to separate pedestrians from vehicular traffic for their safety (FHWA, n.d; Rahaman, n.d.) According to the opinion of pedestrians, points 1,2,3,4 and 5 have been assigned to buffers providing very poor, poor, moderate, satisfactory and highly satisfactory protection by buffers.

7 Availability of Street Light:

Availability of street light is necessary to ease the movement of pedestrians and ensure safety for them from being mugged or victim of other crimes at night. In this study, the availability of street light has been quantified based on the frequency of street light on the footpath (FWHA, n.d.; NLPIP, 2011). Average distance between two consecutive street lights 25-27.5, 22.5-25, 20-22.5, 17.5-20 and 15-17.5 meter has been provided point 1,2,3,4 and 5, respectively.

Walking Environment: Neat and clean footpath with an aesthetically pleasing look encourages people to use the footpath. Besides, the existence of trees or other plants keeps the temperature of the atmosphere of the footpath at a pleasant level. According to the opinion of pedestrians, point 1,2,3,4 and 5, has been assigned to very poor, poor, moderate, satisfactory and highly satisfactory walking environment.

8 b) Multi-criteria Decision Making Approach and

Pedestrian Level of Service As ten different factors (i.e. criteria) will be required to bring under a single platform to determine the Pedestrian Level of Service, multi-criteria analysis approach has been followed in this study. Analytical Hierarchy Process is a widely used multi criteria approach that is used to determine the relative weight of each factor influencing particular phenomena (Saaty, 2008). Khan (n.d.) used AHP to determine the acuteness of different problems faced by pedestrians while walking along footpath based on weight put to different problems by the pedestrian themselves. In this study, AHP has been applied to determine the relative weight of considered factors to determine PLOS following weights put by the pedestrians. The indexed value of each factor has been multiplied by the respective weight determined through AHP. Thus weighted index value has been calculated and all weighted indexed values have been summed up to determine Combined Weighted Index (C). This combined weighted index value will be the Pedestrian Level of Service. In equation (1), w1,w2 defines the weight of the first, second???.n th factor, x1, x2 defines the indexed value of first, second???.n th factor and "n" is the total number of factors considered. PLOS will be classified into four categories based on the combined weighted index. Value of combined weighted index.0-1.25, 1.25-2.5, 2.5-3.75 and 3.75-5 will be regard be as very poor, poor, good and very good respectively.

9 c) Data Analysis

To conduct AHP, a pair-wise matrix is developed with the help of the judgment values provided by the surveyed pedestrians showing the significance of one factor over another on a scale of 1-9 (Saaty, 2008). Table 1 shows a sample pairwise matrix. To normalize the matrix, judgment values have been summed in each column to determine column total and each entry of the column is divided by the Column Total to determine the normalized score for each entry. The normalized score of each row is summed up to determine Row Total. Priority vector is determined by dividing row total by the number of factors. To obtain the consistency index of the judgments, each column of the pair-wise comparison matrix is multiplied by their corresponding priority vector to determine the consistency measure of each factor. In the next step, a Consistency Ratio (CR) has been determined to evaluate whether the level of consistency of the pairwise comparison matrix is reasonable or not. If CR ? 0.1, the level of inconsistency is acceptable and tolerable. Otherwise, the degree of inconsistency is high and the decision-makers might have to re-estimate the elements of comparison matrix for better consistency (Saaty, 2008). Overall priority is measured by determining the geometric mean of the priority vector. Priority vector has been derived for each factor for each of the 240 samples separately. The geometric mean of 240 priority vectors has been determined to calculate the overall weight of each factor influencing PLOS. Table 2 reveals that path width the most significant factor influencing PLOS. Path width, pedestrian volume, the existence of buffer, availability of crossing opportunity has been identified as second, third, fourth significant factor respectively with a value greater than 0.10. Buffer from Road: No buffers were found on the Toyenbi Circular Road, Segun Bagicha Road, Baily Road. A series of steel made bollards were found along the footpath of Mirpur but not across the whole footpath. For this, the buffer of Mirpur road was not able to completely segregate vehicular traffic from pedestrians and ensure better safety for pedestrians.

Crossing Opportunity: In Mirpur Road, zebra crossing and foot over-bridge was found to provide pedestrian crossing facilities. In Tyoenbi Circular Road, there was zebra crossing for the pedestrian to cross the road. But the other two road sections have over-pass or zebra crossing. Pedestrians have to cross the road directly from footpath (Field Survey, 2017). The average value for the existence of crossing facility has been found 2.1, 1.04, 1.09 and 2.9 for Toyenbi Circular Road, Shegun Baghicha Road, Baily Road, and Mirpur Road respectively.

Distance from Vehicular Traffic: All the four considered footpaths were in very close proximity to vehicular way.

For the footpath of Segun Bagicha road, the distance from curb to footpath was between 0-0.5 meters. Whereas, the other three pedestrian ways were within 0.5-1 meter. None of the roads have their footway insufficient distance from the vehicular way which makes the experience of walking through these footpaths unpleasant.

Walking Environment: The average value for the existence of walking environment has been found 3.1, 2.87, 3.6 and 1.9 for Toyenbi Circular Road, Shegun Baghicha Road, Baily Road, and Mirpur Road respectively. According tothe opinion of pedestrian, Toyenbi Circular Road, and Baily Road has a better environment for walking.

Availability of Street Light: Availability of street light is necessary to ensure the safety of pedestrian movement at night. The average distance between the street light has been found 24, 20, 16 and 28 meters for footpaths along Toyenbi Circular Road, Segun Bagicha Road, Baily Road, and Mirpur Road respectively. As the average distance between two consecutive street lights is relatively low for Baily Road, it has more street lights than others. More street lights are likely to contribute more to the enhancement of safety as well as PLOS for the pedestrian pathway of Baily Road.

Surface Quality: From the field observation, it has been identified that the footpath of Baily Road was relatively crack free. So, pedestrian feels it less problematic to walk through this footpath. On the other hand, the footpath of Toyenbi Circular Road has too many cracks in it which makes it difficult for the pedestrians to walk through it and decrease its PLOS. The average value for Comfort: Availability of benches, drinking fountains, public toilets, etc are very rare in Dhaka city. Only benches were found along the footpath of Baily road. For this, pedestrians can get better comfort by sitting on these benches. Benches or other kinds of facilities which may provide comfort or Comfort for walking are missing in the footpaths of the other three road sections.

The average value for comfort has been found 1. Pedestrian Level of Service for each of the footpaths has been shown in Table 3. None of the footpaths along the considered roads have been found to have a satisfactory PLOS. Each of the footpath segments has been found to have poor PLOS. Among the four footpath segments, the condition of Baily Road is relatively better in terms value of PLOS. IV.

10 Conclusion

Taking appropriate measures to improve the pedestrian level of service is necessary to motivate people to walk more and encourage them to go to the bus stop by walking and reduce dependence on other transport ??Bhuiya et al, 2013). By providing better environment for pedestrian movement, people can be encouraged to walk instead using motorized vehicles and reduce carbon emission which is very significant for Dhaka in the context temperature rise in recent years and mitigate possible impact of climate change in Dhaka ??Mohiuddin, Bhuiya and Mahmud,2014).From the study, it has been found out that all the factors influencing PLOS are not equally important to ensure better walking conditions. It has been found adequacy of path width is the most significant factor influencing PLOS. Pedestrian volume and the existence of buffer are the second and third important factors influencing PLOS. Adequate crossing opportunity and distance from vehicular ways are also important factors. All the pedestrian walkway segments under consideration have unsatisfactory PLOS. But in respect of Dhaka city, this situation is very pitiable as 19.6% of trips of Dhaka City are made by foot. It is a crying need to improve the condition of pedestrian pathways of Dhaka. Due to resource constraints, it may not be possible to ameliorate all the factors influencing PLOS. The government can prioritize the factors based on the findings of this study. The concerned authority should take the necessary steps to improve the PLOS for Dhaka. The priority should be given to expanding the footpath as much as possible. The concerned authority should motivate landowners to left lands from their plots to expand footpath which will enhance the capacity of the footpath to accommodate higher pedestrian volume avoiding congestion. Besides, providing adequate crossing opportunities and buffer are also necessary steps to improve PLOS ??Rahaman, n.d.).

1


Figure 1: Fig 1 :

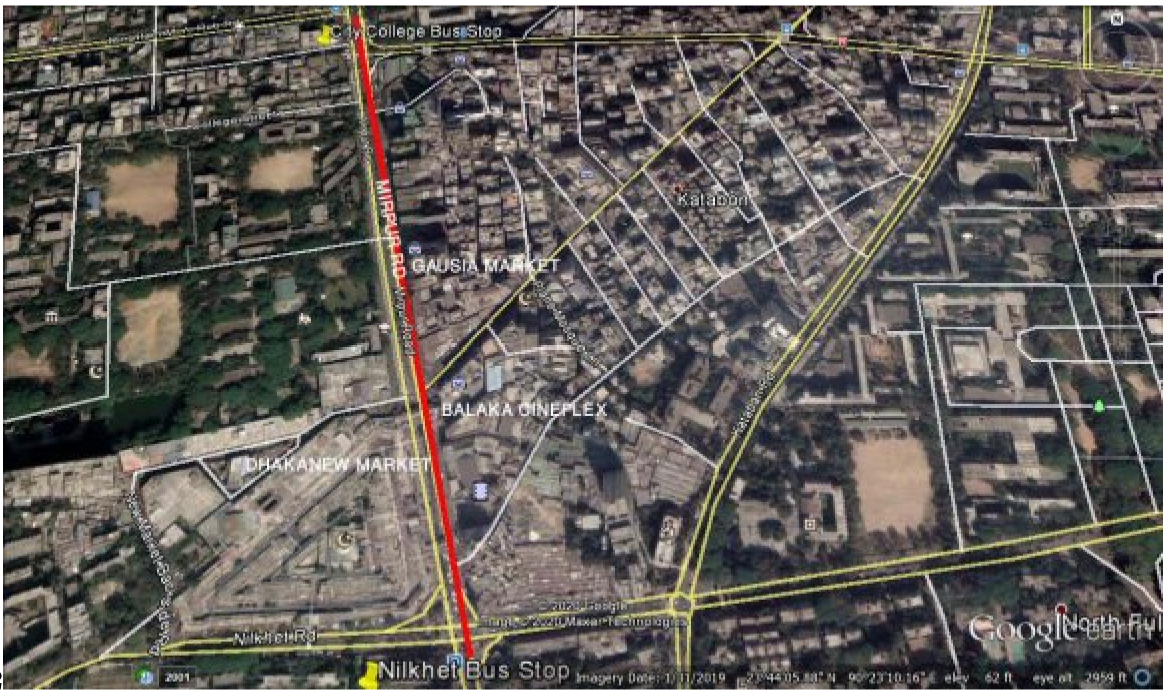
2


Figure 2: Fig. 2 :

34

Figure 3: Fig. 3 :Fig. 4 :

Figure 4:

Figure 5:

1

Factors	PW	RdFt	Srf	Crs	Buf	WkEn	PV	Com	DsTr
PW	1	3	5	2	1	2	0.5	2	2
RdFt	0.333	1	0.5	0.333	0.5	0.5	0.143	0.5	0.5
Srf	0.2	1	1	0.5	0.5	1	0.2	0.5	0.5
Crs	0.5	3	2	1	1	0.5	0.5	2	4
Buf	0.5	2	2	1	1	3	0.333	2	1
WkEn	0.5	2	1	2	0.33	1	0.25	0.333	0.5
PV	2	7	5	2	3	4	1	4	3
Com	0.5	2	2	0.25	0.5	3	0.25	1	0.333
DsTr	0.5	2	2	0.25	1	2	0.333	3	1
Lig	0.5	4	2	0.25	1	2	0.2	3	1
CT	6.533	27	22.5	9.583	9.83	19	3.71	18.333	13.833

Factors; PW=Path Width, Rdft= Appropriate Placement of Roadside Features, Srf=Surface Quality, Crs=C

Opportunity, WkEn=Walking Environment, DsTr=Distance from Vehicular Traffic, PV=Pedestrian Volume
Com=Comfort, Buf=Existence of Buffer, Light=Availability of Street Light,
CT=Column Total,
RT=Row Total,
PV=Priority Vector,
CM=Consistency Measure CR= CI/RI CI= Consistency index of pair wise matrix= (n max -n) / (
n max =?CM/n RI= Random consistency of pair wise matrix =1.98x (n-2) /

[Note: Source: Field Survey, 2017]

Figure 6: Table 1 :

2

Factor	Overall Weight	Rank
Path Width	0.173	1
Pedestrian Volume	0.151	2
Existence of Buffer	0.144	3
Crossing opportunity	0.131	4
Distance from Vehicular Traffic	0.086	5
Availability of Street Light	0.084	6
Comfort	0.083	7
Walking Environment	0.082	8
Surface Quality	0.043	9
Appropriate Placement of Roadside Features	0.024	10
	Source: Field Survey, 2017	

d) Evaluation of the Factors Influencing Pedestrian Level of Service

Path Width: Pedestrian Volume: It has been identified through pedestrian flow count from field survey that Toyenbi Circular Road, Segun Bagicha Road, Baily Road, and Mirpur Road have an average pedestrian volume of 4800, 2160, 3000 and 5400 pedestrians respectively between 8.00 am-8.00 pm of a day. Pedestrian Volume per square feet of footpath has been found 1.89, 0.85, 1.14 and 2.11person/sqft/day respectively. It implies that Baily Road and Toyenbi Circular Road have been more congested than the other two footpath segments.

Figure 7: Table 2 :

3

Factors	Toyenbi Circular Road	SegunBagicha Road	Baily Road	Mirpur Road	Weight
Appropriate Placement of Roadside Features	1.1	1.05	1.9	1.03	0.024
Path Width	5	1	2	4	0.173
Pedestrian Volume	2	5	4	1	0.151
Existence of Buffer	0	0	0	2.5	0.144
Crossing Opportunity	2.1	1.4	1.09	2.3	0.131
Distance from Vehicular Traffic	1	2	1	1	0.086
Walking Environment	3.1	2.87	3.6	1.9	0.082
Availability of Street Light	2	4	5	1	0.084
Comfort	1.3	1.9	3.1	1.02	0.083
Surface Quality	2.6	3.4	3	3.05	0.043
Pedestrian Level of Service	2.1964	2.18384	2.3258	2.0706	

Figure 8: Table 3 :

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