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Determining Pedestrian Level of Service for Selected Footpath Stripes 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 short distance trip. Since 19.6% of the trips are made by foot in Dhaka, it is necessary to ensure friendly walking environment in the footpath for the welfare of pedestrians of Dhaka. This study aims to make a comparative analysis of Pedestrian Level of Service (PLOS) of selected footpath stripes along Segun Bagicha road, Toynbee Circular road, Mirpur road and Baily road. Pedestrian Level of Service has been determined based on ten factors: path width, pedestrian volume, crossing facilities, availability of buffer, distance from vehicular traffic, surface quality, comfort, walking environment, existence of street light. Weight of each factor has been determined through Multi-criteria analysis approach, Analytical Hierarchy Process (AHP). Path width, Pedestrian volume and existence of buffer have been found to be first, second and third most important factors. PLOS has been determined based on indexed value of factors and weight of factors. All the sections were found to have poor PLOS. The findings of the study will be helpful for the transport policy makers to ameliorate the condition of these factors to ensure a better walking condition for pedestrians of selected footpath sections.

Introduction

Walking is the most accessible mode of transport. It is considered to be the most sustainable and environment friendly mode of transport across the globe. For this, it is very important for concerned city authority to ensure better environment for pedestrian movement along footpath and provide necessary facilities to ease their movement. 19.8% of total trips of Dhaka are made on feet (DHUTS, 2010:3-15). So, it is necessary for the city authority to ensure lively environment and provide required features for these pedestrians to make transportation system of Dhaka sustainable. But unfortunately, footpaths of Dhaka city are not congenial for 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 over bridges etc have made movement for the pedestrians difficult and negatively effecting

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Pedestrian Level of Service (RSTP, 2015:4-49-50, Health Bridge Foundation of Canada, n.d.: 4-8). In order to ameliorate PLOS, firstly, it is necessary to explore the condition of relevant factors influencing satisfaction of pedestrian and determine the overall condition of PLOS. This study is unique because no other studies have been conducted earlier to determine relative weight of factors influencing PLOS based on opinion of pedestrians. This study aims to determine PLOS of selected segment of footpaths of Dhaka city on the basis of ten factors using multi-criteria based decision making approach, Analytical Hierarchy Process. It provides indication of areas to be more focused on for future improvement as well as development of pedestrian facilities in the city.

Selected Stripes of Footpath

Dhaka city has huge road network used by the pedestrians. For the simplicity and time constrains this study selected four footpath segments of Dhaka city with potential land uses to generate huge pedestrian flow to carry out the study. Toyenbi Circular Road, Mirpur road, Shegun Bagicha and Baily road. 900 meter long road stripe from Mothijeel Junction Bus Stop to Intersection of DIT Avenue Road and Toyenbi Circular Road has been selected for study. Prominent educational institutions like Notre Dame College and University, Arambag Girls School is in close proximity to this stripe.For this study, 850 meter footpath along Nilkhet Bus Stop to City College Bus Stop along Mirpur road as study pathway stripe. Many people come to this place to buy clothes and daily necessary products. The famous Dhaka New Market is located on this site. A 850 meter road section between intersection of Segunbagicha Road and Bir Uttam Samsul Alam Sarak and intersection of Topkhana Road and Segun Bagicha Road is the third footpath under consideration. This road gives access to a Shilpakala Academy, Anti-Corruption Commission, Income Tax collection office, Office of Geological Survey of Bangladesh and other public and private offices. This 900 meter long road section along Baily Road starts from the intersection of Hare Road and Baily Roads and continues to the Baily Fiesta Shopping Mall. This road section has mixed land uses in the surrounding which includes residential land uses, banks, schools (Viqarunnesa Noon School and Shiddasheri Girls School).

Methodology

Level of service is one of the key concepts for measuring the performance of the transport infrastructures. Pedestrian Level of Service (PLOS) is an approach to quantify environmental quality of a pedestrian space and serve as a yardstick for defining standard for pedestrian facilities in footpath (Parida, Najamuddin and Parida, 2007:27; Papacostas and Prevedouros, 2006:136). With more focus across the world on green transport and active transport, it has become a very important issue to ensure 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 stripes.

This study has been conducted on the basis of primary data collected through 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 conducting reconnaissance survey, concept of PLOS were explained to pedestrian first and they were asked to mention the factors that they consider important

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 pedestrian mentioned a factor. From tallied data, top ten factors have been identified which pedestrian considers most important for ensuring better environment for pedestrian movement.

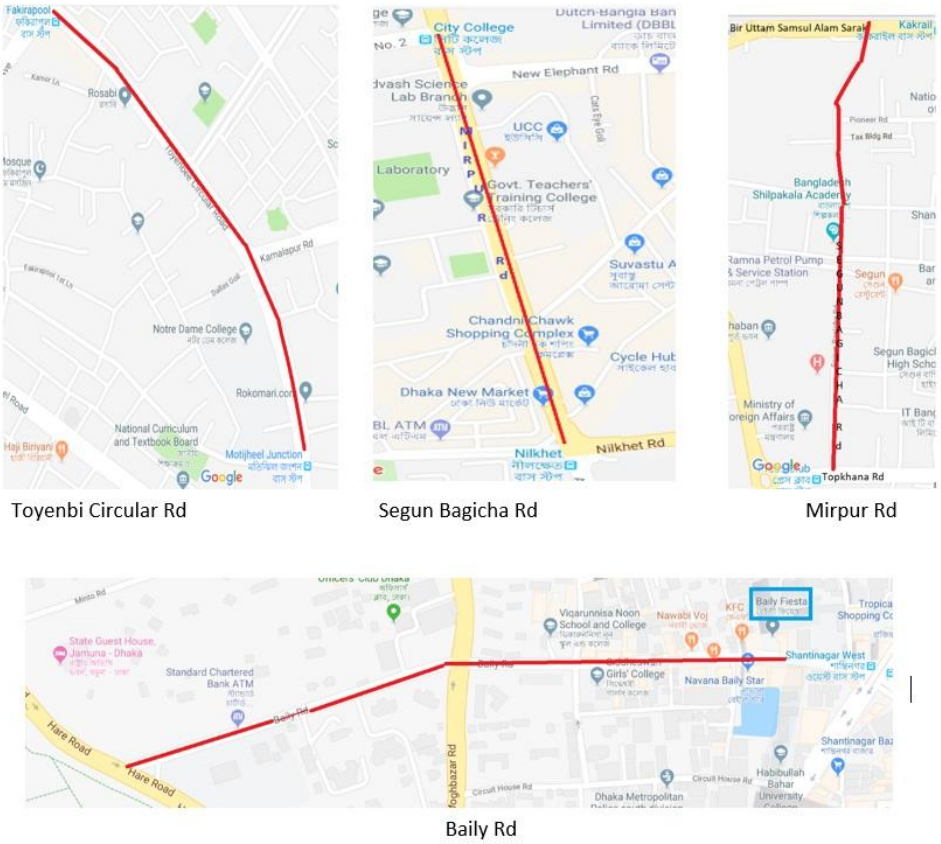

Figure 1: Selected road stripes of Toyenbi Circular road, Mirpur road, Shegun Bagicha and Baily road having area of 26240, 5051, 10496 and 20467 square feet respectively.

Total number of pedestrian has been surveyed is 240 with 60 from each of walk way segment to collect information on relative weight of factors in respect of others. Pedestrian were asked to provide rank about their level of satisfaction on factors in a scale of 1-5.

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 wheel chair users to manoeuvre wheel chair (Main Roads Western Australia, 2006:7; NYC, 2006:15). Path width has been determined through physical survey. It has been indexed as 0-2, 2-4, 4-6, 6-8 and 8-10 feet as point 1,2,3,4 and 5 respectively.

Appropriate Placement of Roadside Features: Appropriate Location of roadside features like benches, trees, bird bath etc on the footpath is necessary so that pedestrian can move on the footpath without receiving hindrances on their way (Mineta Transport Institute, 2012:26-27; Old Colony Planning Council, n.d.:9). Through questionnaire survey, value of this factor has been indexed as point 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 existence of foot over bridge, zebra crossing, median refugees, guard or police control crossing for the pedestrians (Main Roads Western Australia, 2006:3-5; MinetaTransport Institute, 2012:26-27; National Roads Authority, Ireland, 2001: 8-9). Point 1,2,3,4 and 5 has been allocated by surveyed pedestrian for the following situations: almost non-existent, 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 quality walking environment (Parida, Najamuddin and Parida, 2007:28; Banarjee, Maurya and Gammel, 2018: 25,32). Through questionnaire survey, value of this factor has been indexed as point 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 the vehicular way, the possibility of conflict of vehicles with pedestrian will increase and safety is likely to decrease. In this study, distance from the pedestrian way from the kerb has been considered as distance from vehicular traffic (Main Roads Western Australia, 2006:7; Singh and Jain, 2011: 119). 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 kerb as point 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, PLOS value will decline (Main Roads Western Australia, 2006:7; TRB, 2000:11-1—11.4). While conducting reconnaissance survey, it has been observed that pedestrian activity remains at higher level between 8.00 am to 8.00 p.m in weekdays. For this, pedestrian volume survey was conducted on between 8 a.m. to 8 p.m over 5 weekdays. Average pedestrian volume of 5 days was divided by area of footpath stripe of road to determine the pedestrian volume over each unit area of footpath. Pedestrian volume of 1.96-2.14, 1.67-1.95, 1.38-1.66, 1.09-1.37and 0.80-1.08 person/sqft/day has been indexed as point 1,2,3,4 and 5 respectively.

Comfort: Comfort has been attributed as existence of different landscaping elements placed on the footpath including benches, drinking fountain etc (Parida, Najamuddin and Parida, 2007:28; Banarjee, Maurya and Gammel, 2018:12). Through questionnaire survey, value of this factor has been indexed as point 1,2,3,4 and 5 for very poor, poor, moderate, good and very good respectively to know level of comfort ensured by existing facilities.

Existence of Buffer: Buffer like fences, bollards, tree are used to separate pedestrians from the vehicular traffic for their safety (FHWA, n.d.:13-3; Rahaman, n.d. : 5-8) According to opinion of pedestrians, point 1,2,3,4 and 5 has been assigned to buffers providing very poor, poor, moderate, satisfactory and highly satisfactory protection by buffers.

Availability of Street Light: Availability of street light is necessary to ease movement of pedestrians and ensure safety for them from being mugged or victim of other crimes at night. In this study, availability of street light has been quantified on the basis of frequency of street light on footpath (FWHA, n.d.:13-7; NLPIP, 2011:8). 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 pleasant look encourages people to use footpath. Besides, existence of trees or other plants keeps the temperature of atmosphere of footpath at a pleasant level. According opinion of pedestrians, point 1,2,3,4 and 5 has been assigned to very poor, poor, moderate, satisfactory and highly satisfactory walking environment.

Multi-criteria Decision Making Approach and Pedestrian Level of Service

As ten different factors (i.e. criteria) are required to bring under single platform to determine Pedestrian Level of Service, multi-criteria analysis approach has been followed in this study. Analytical Hierarchy Process (AHP) is a widely used multi criteria approach which is used to determine relative weight of each factor influencing particular phenomena (Saaty, 2008). Khan (n.d.) used AHP to determine acuteness of different problems faced by pedestrian while walking along footpath based on weight put to different problems by the pedestrian themselves. In this study, AHP has been applied to determine relative weight of considered factors to determine PLOS following weights put by the pedestrians. Indexed value of each factor has been multiplied by 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 determines Pedestrian Level of Service.

Combined weighted index $C=w1* x1+w2*x2+\ldots\ldots\ldots..+wn*xn$.....(1)

In the 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 total number of factors considered. PLOS is classified into four categories on the basis of combined weighted index. Values of combined weighted indexes of 0-1.25, 1.25-2.5, 2.5-3.75 and 3.75-5 are regarded as very poor, poor, good and very good respectively.

Data Analysis

In order to conduct AHP, a pair-wise matrix is developed with the help of the judgment values provided by the surveyed pedestrians showing significance of one factor over another on a scale of 1-9 (Saaty, 2008). Table 1 shows a sample pair wise matrix. In order to normalize the matrix, judgement 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 normalized score for each entry. Normalized score of each row is summed up to determine Row Total. Priority vector is determined by dividing row total by 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 consistency measure of each factor. In 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 240 samples separately. Geometric mean of 240 priority vectors has been determined to calculate overall weight of each factor influencing PLOS.

Table 1: Detailed calculation of AHP procedure for determining weight of each factor

PW	1	3	5	2	1	2	0.5	2	2	2	1.419	0.142	10.874
RdFt	0.333	1	0.5	0.333	0.5	0.5	0.143	0.5	0.5	0.25	0.34	0.034	10.54
Srf	0.2	1	1	0.5	0.5	1	0.2	0.5	0.5	0.5	0.417	0.042	10.82
Crs	0.5	3	2	1	1	0.5	0.5	2	4	4	1.299	0.13	11.342
Buf	0.5	2	2	1	1	3	0.333	2	1	1	0.939	0.094	10.956
WkEn	0.5	2	1	2	0.33	1	0.25	0.333	0.5	0.5	0.644	0.064	11.01
PV	2	7	5	2	3	4	1	4	3	5	2.537	0.254	10.834
Com	0.5	2	2	0.25	0.5	3	0.25	1	0.333	0.333	0.642	0.064	10.618
DsTr	0.5	2	2	0.25	1	2	0.333	3	1	1	0.862	0.086	10.794
Lig	0.5	4	2	0.25	1	2	0.2	3	1	1	0.901	0.09	10.717
CT	6.533	27	22.5	9.583	9.83	19	3.71	18.333	13.833	15.58			
Factors; PW=Path Width, Rdft= Appropriate Placement of Roadside Features, Srf=Surface Quality, Crs=Crossing 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												n max	10.851
												CI	0.095
CR= CI/RI	CI= Consistency index of pair wise matrix= (n_{max}–n) / (n-1)											RI	1.51
n_{max} = ∑CM/n	RI= Random consistency of pair wise matrix =1.98x (n–2) / n											CR	0.063

Source: Field survey, 2017

Table 2 reveals that path width the most significant factor influencing PLOS. Path width, pedestrian volume, existence of buffer, and availability of crossing opportunity have been identified as second, third, fourth significant factors respectively with a value greater than 0.10.

Table 2: Average Weight and Ranking of the factors influencing PLOS

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

Evaluation of the Factors Influencing Pedestrian Level of Service

Path Width: Among four selected road sections, Toyenbi Circular road and Mirpur road have footpath with relatively larger width than other two road sections with width of 10 feet and 8 feet respectively (Physical Survey, 2017). Section from the Baily road and Shegun Baghica road has a footpath width of 4 feet and 2 feet (Figure 1).

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 has average pedestrian volume of 4800, 2160, 3000 and 5400 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 has been more congested than other two footpath stripes.

Buffer from Road: No buffers were found on the Toyenbi Circular road, Segun Bagicha road, Baily road. A series of steel made bollards was 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 the vehicular traffic from pedestrian and ensure better safety for pedestrian.

Crossing Opportunity: In Mirpur road, zebra crossing and foot over bridge were found to provide pedestrian crossing facilities. In Tyoenbi Circular road, there was zebra crossing for pedestrian to cross the road. But other two road sections have over pass or zebra crossing. Pedestrian have to cross the road directly from footpath (Field Survey, 2017). Average value for existence of crossing facility has been found 2.1, 1.04, 1.09 and 2.9 for Toyenbi Ciruclar 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 footpath of Segun Bagicha road, the distance from kerb to footpath was between 0-0.5 meter. Whereas, other three pedestrian ways was within 0.5-1 meter. None of the roads have their footway in sufficient distance from the vehicular way which makes the experience of walking through these footpaths unpleasant.

Walking Environment: Average value for existence of walking environment has been found 3.1, 2.87, 3.6 and 1.9 for Toyenbi Ciruclar road, Shegun Baghicha road, Baily road and Mirpur road respectively. According to opinion of pedestrian, Toyenbi Ciruclar road and Baily road has better environment for walking.

Availability of Street Light: Availability of street light is necessary to ensure safety of pedestrian movement at night. The average distance between the street light has been found 24, 20, 16 and 28 meter for foot paths along Toyenbi Circular road, Segun Bagicha road, Baily road and Mirpur road respectively. As the average distance between two consecutive street lights are 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 footpath of Baily road was relatively crack free. So, pedestrian feels it less problematic to walk through this footpath. On the other hand, 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. Average value for surface quality has been found 2.6, 3.4, 3 and 3.04 for Toyenbee Ciruclar road, Shegun Baghicha road, Baily road and Mirpur road respectively.

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, pedestrian can get better comfort by sitting on these benches. Benches or other kind of facilities which may provide comfort or Comfort for walking are missing in footpaths of other three road sections. Average value for comfort has been found 1.3, 1.9, 3.1 and 1.02 for Toyenbee Ciruclar road, Shegun Baghicha road, Baily road and Mirpur road respectively.

Appropriate Placement of Roadside Features: It has been found that dustbins and trash receptacles are placed on the middle of each footpath stripe which is not only creating obstacles in pedestrian movement but also odours from these dustbins and trash receptacle have made the surrounding environment unsuitable for walking. As there is no designated place for vendors and hawkers, they have occupied the place in the middle of footpath and are creating obstacles in pedestrian movement in all the footpath stripes under consideration (Field Survey, 2017). Average value for appropriate placement of roadside features has been found 1.1, 1.05, 1.9 and 1.03 for Toyenbi Ciruclar road, Shegun Baghicha road, Baily road and Mirpur road respectively.

Pedestrian Level of Service

Combined weighted index "C" was calculated first before determining PLOS. It was calculated according to following equation.

$$C= 0.173* PW+0.151* PdFl+ 0.144* Buf+ 0.131*Crs + 0.086*DsTr+ 0.084* Lig +0.083*Com+0.082*WkEn+0.043*Srf+0.024* RdFt$$

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

Table 3: Situation Analysis of the Factors and determining Pedestrian Level of Service

Factors	Toyenbi Circular road	Segun Bagicha 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	

Conclusion

From the study, it has been observed that all the factors influencing PLOS are not equally important to ensure better walking condition. It has been found adequacy of path width is the most significant factor influencing PLOS. Pedestrian volume and existence of buffer are second and third important factors influencing PLOS. Adequate crossing opportunity and distance from vehicular way are also important factors. All the pedestrian walk way segments under consideration have unsatisfactory PLOS. But in respect of Dhaka city this situation is very pitiable as 19.6% 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 constraint, it may not be possible to ameliorate all the factors influencing PLOS. Government can prioritize to the factors on the basis of findings of this study. Concerned authority should take necessary steps to improve the PLOS for Dhaka. First priority should be given to expand the footpath as much as possible. The authority should also motivate land owners to left lands from their own plots to expand footpath which will enhance capacity of footpath to accommodate higher pedestrian volume avoiding congestion. Besides, providing adequate crossing opportunity and buffer are also necessary steps to improve PLOS.

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