A Study on Existing Sidewalks to Interpret the Condition of Pedestrian Facilities using the Concept of Level of Service (LOS) in Urban Suburbs of Sri Lanka

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Abstract— This study is aimed at assessing the impact of pedestrians' behaviour and existing sidewalk facilities on Level of Service (LOS) for pedestrians in urban suburbs of Sri Lanka. For this study, two urban suburbs, Kaduwela and Athurugiriya junctions were selected. They are considered to be two main suburbs in Colombo district. During this study, sidewalks in six road links in these two city centers associated with roads AB4, AB10, B174 and B240 were selected to determine Level of Service (LOS) for pedestrians based on existing sidewalk facilities and pedestrians' behaviour. Thus, data such as pedestrian count and walking speeds, vehicular flowrate, walkway space and width, roadway condition and etc. were collected on weekdays and weekends for a period of one month prior to data analysis. Collected data was analyzed based on the methodology proposed in the Highway capacity manual to determine the existing Level of Service which is dependent on Pedestrian flow rate, vehicular flow rate, average speed and sidewalk space for selected road links. This study demonstrates that from the selected six road links, two in Athurugiriya and one from Kaduwela were classified under LOS standard of A, one road link from Kaduwela city center was classified as LOS standard of B. while, one each from both city centers were classified under LOS standard of D. Hence, recommendations were discussed to enhance sidewalk, provide sidewalk safety fences and prohibit unauthorized settlements in sidewalk for improving Level of Service (LOS) for pedestrians using sidewalks in urban suburbs of Sri Lanka.

Key words: Pedestrian Facilities; Level of Service (LOS); Sidewalks; Pedestrian Safety

I. INTRODUCTION

Walking, much like most common human behaviour, is dominantly influenced cultural perceptions, individual preferences, characteristics and environmental conditions [1]. Hence, pedestrians are counted as a major element in the road and walking is considered as an essential mode of transport in most city centers of Colombo. Pedestrian travel offers lot of fringe benefits to society and the individual. Regulatory parties and health officers around the world are promoting policies to enhance the pedestrian travel by developing necessary infrastructure [2]. Since, pedestrians' travels are governed by several factors such as individual physical and mental health conditions, preferences, and quality of infrastructure, lack of facilities, obstructions in sidewalks and time of travel. However, Studies that are focused on pedestrian planning based on pedestrian traffic flow and sidewalks has been carried out in the past. Based on these studies, guidelines have been proposed in terms of Level-of-Service (LOS) standards for sidewalks considering factors such as space module per pedestrian, flow rate and average speed [3]. With regard to standards given in LOS, provision of pedestrian facilities such as crossings, shoulders and widening of sidewalks are probable remedial actions for improving existing LOS conditions because it is important to encourage walking as a mode of travel as per regulatory bodies.

Objective of this research is to study on existing sidewalk facilities for pedestrians in selected city centers for chosen sidewalks with LOS conditions which depends on sidewalk width, pedestrian flow rate and average speed. Also to suggest probable ways of improving existing LOS conditions in sidewalks for selected road links.

II. LITERATURE REVIEW

A. Level of Service & its Conditions

Level of Service (LOS) is a concept defined as qualitative measure to describe operational conditions of vehicular and pedestrian traffic. Pedestrian flow rate, vehicular flow rate and sidewalk space are used to evaluate LOS of different road links with existing traffic levels and compared with theoretically estimated LOS levels. Different LOS conditions are defined and HCM specifications for LOS standards are shown in Table 1 [4], [5].

LOS	Space (ft^2/p)	Flow rate (p/min/ft.)	Speed (ft./s)	V/C ratio
A	> 60	≤ 5	> 4.25	≤ 0.21
B	> 40 - 60	> 5 - 7	> 4.17 - 4.25	> 0.21 - 0.31
C	> 24 - 40	> 7 - 10	> 4.00 - 4.17	> 0.31 - 0.44
D	> 15 - 24	> 10 -15	> 3.75 - 4.00	> 0.44 - 0.65
E	> 8 - 15	> 15 - 23	> 2.50 - 3.75	> 0.65 - 1.00
F	≤ 8	Variable	≤ 2.50	Variable

Table 1: HCM Specifications for Los Standards

III. METHODOLOGY

A. Study Area

For this study two main city centers, "Kaduwela" and "Athurugiriya" in Colombo districts were selected based on the facts that these two city centers are identified as suburbs of Colombo and very high pedestrian flows are visible throughout the day. Also, proper pedestrian facilities are not available in sidewalks of these city centers. Identified road links for the study in these two city centers are shown in Fig. 1 and Fig. 2.

Fig. 1: Identified Road Links at Athurugiriya Junction

Fig. 2: Identified Road Links at Kaduwela Junction

For the selected two city centers, 6 road links were selected based on the necessity of walkway facilities and density of pedestrians and their locations are defined as tabulated in TABLE 2

Road link	Name of the road	Location
1	Kotte-Bope road (B240)	In front of fish market
2	Kotte-Bope road (B240)	In front of Mega city shopping mall
3	Kaduwela-Athurugiriya road (B174)	In front of People's bank
4	Low level road (AB10)	In front of DSI shop
5	Low level road (AB10)	In front of Bus stand
6	New Kandy road (AB4)	In front of Kaduwela supermarket

Table 2 - Locations of the Selected Road Links

B. *Data Collection*

Manual pedestrian counts were taken in each road links for a time period 15 minutes in peak hours. For the reliability of the data pedestrian counts were conducted several times with the given time slot and average was taken. Data was collected on weekdays and weekends for a period of one month at given time slots in Table 3. These times slots were selected on the basis of school and office opening and closing hours. No observations were made during rain. For the reliability of the observations, occasional observations and pedestrian counts were made independent from the main data collection. Negligible differences were observed between data sets and inter-rater reliability was established based on this. Also average width of the sidewalks, effective width of sidewalks, time taken to walkthrough each sidewalk, positions of the light posts, condition of walkway surface, availability of street vendors were also identified.

Session	Time interval
Morning	07.15 a.m. to 7.45 a.m.
Afternoon	1.45 p.m. to 14.15 p.m.
Evening	4.30 p.m. to 5.00 p.m.

Table 2: Selected Time Intervals at Different Sessions of a Particular Day

IV. Observations & Results

A. *Pedestrian Survey & Sidewalk Dimensions*

During the pedestrian count survey following averaged results of total pedestrians were obtained based on observations made at Athurugiriya city center and Kaduwela city center. They are shown in Table 5 and Table 6 respectively. While, details of selected sidewalks are tabulated in Table 7 and Table 8 correspondingly.

Session	Time period	Pedestrian count		
		Road link 1	Road link 2	Road link 3
1	07.30h-07.45h	181	198	122
	07.45h-08.00h	165	203	137
2	13.30h-13.45h	196	253	146
	13.45h-14.00h	221	284	192
3	16.30h-16.45h	218	311	216
	16.45h-17.00h	248	292	233
Total		1229	1541	1046
Sidewalk width (m)		1.87	0.95	1.87
Time elapsed to walk through the road link (sec)		16.6	23.6	16.6

Table 3: Pedestrian Count Records at Athurugiriya Junction

Session	Time period	Pedestrian count		
		Road link 1	Road link 2	Road link 3
1	07.30h-07.45h	224	210	242
	07.45h-08.00h	249	296	280
2	13.30h-13.45h	260	258	195
	13.45h-14.00h	288	314	237
3	16.30h-16.45h	320	335	346
	16.45h-17.00h	342	402	338
Total		1423	1815	1583
Sidewalk width (m)		1.82	1.92	1.12
Time elapsed to walk through the road link (sec)		15	18	24.3

Table 4: Pedestrian Count Records at Kaduwela Junction

B. *Effective Walkway Width*

Effective widths of the sidewalks were calculated considering the total width of the sidewalk and obstacle width. Where

obstacle width was assumed to be 0.3 to 0.5m per obstacle. During the study light poles, borders, curbs, sundry vendors, unauthorized parking of vehicles were considered as walkway obstacles. Effective walkway width (W_E) was calculated using Equation 4.1 given below. Results for the computed walkway width for considered road links are shown in Table 6 [6], [7].

$$W_E = \text{average walkway width} - \text{Obstacle width} \quad (4.1)$$

Road link	Average walkway width (m)	Obstacle width (m)	Effective width	
			(m)	(ft.)
1	1.87	0.3	1.57	5.15
2	0.95	0.3	0.65	1.81
3	1.87	0.5	1.37	4.49
4	1.82	0	1.82	5.97
5	1.92	0.5	1.42	3.84
6	1.12	0.3	0.82	2.69

Table 5: Effective Walkway Widths of Road Links

C. Pedestrian Speeds & Flow Rates

Effective widths Pedestrian speeds were determined by average time elapsed measured for pedestrian to pass through each 30m long sidewalk and obtained results are given in Table 7. While pedestrian flow rate (Q_P) has been defined as number of pedestrians passing a point per unit time, expressed as pedestrians per 15 minutes or pedestrians per minute. Equation 4.2 was used to determine pedestrian flow rate using Pedestrian count in each road link (within 15 min time interval) ($N_{p,15}$) and W_E, and results are tabulated in Table 8 [8], [9]

Road link	Time elapsed to complete the road link (sec)				sidewalk length (ft.)	speed (ft./s)
	1	2	3	Avg.		
1	16	16	18	16.6	65.6	3.936
2	26	22	23	23.6	65.6	2.771
3	18	16	16	16.6	65.6	3.936
4	14	15	16	15.0	65.6	4.373
5	18	19	17	18.0	65.6	3.644
6	22	26	25	24.3	65.6	2.695

Table 6: Results for the Pedestrian Speeds

$$Q_P\left(\frac{\frac{p}{m}}{min}\right) = \frac{N_{P,15}}{15 \times W_E\ (ft.)} \quad (4.2)$$

Road link	Pedestrian count (Sessions)				Sidewalk effective width (ft.)	Flow rate (p/m/min)
	1	2	3	Average Peak volume		
1	173	209	230	230	5.15	2.97
2	201	269	342	342	1.81	12.53
3	130	169	225	225	4.49	3.34
4	237	253	261	261	5.97	2.91
5	274	295	216	295	3.84	5.12
6	331	369	315	369	2.01	12.29

Table 7: Results for Pedestrian Flow Rates

D. Current Level of Service (LOS) Standards

Based on the pedestrian speeds and flowrates given in the Table 7 and Table 8, Level of Service (LOS) was determined considering the specifications given in Table 1 and LOS standard for each of the road links are tabulated in Table 9 [4].

Road link	Pedestrian flow rate (p/m/min)	Pedestrian speed (ft./s)	LOS category
1	2.97	3.94	A
2	12.53	2.78	D
3	3.34	3.94	A
4	2.91	4.37	A
5	5.12	3.64	B
6	12.29	2.69	D

Table 8: Existing Los Levels for Selected Road Links

V. DISCUSSION

As found in the Results, Road links 1, 2 and 4 has a higher Level of Service (LOS – Grade A). Which can be identified as the best condition for pedestrian sidewalks. But LOS – Grade B has been obtained for road link 5 and it seems that adequate facilities has been provided for pedestrians to choose their walking speeds freely to bypass other pedestrians and avoid crossing conflicts. But, at this level pedestrian tends to be aware of other pedestrians and begin to response to their presence when electing a walking path.

Road links 2 and 6 have fairly low LOS grades which are not adequate for pedestrian movements. Hence these road links are identified to have very low pedestrian flow rates and speeds as shown earlier in respective tables. Possible causes for these could be identified as low effective width and use of existing pedestrian walkway spaces for commercial activities and unauthorized vehicle parking, Use of walkways as a storage facility by street vendors. Due to these, Phenomena such as facing highly probable conflicts during crossing or reverse flow and frequent speed and position changes could occur at this stage. Also, Pedestrians tend to face the risk of meeting with roadside accidents and impact on traffic congestions get enhanced. Out of road links 2 and 6, latter is at critical condition with weekly fair is located facing considered road link and effective width has been reduced to average value of 2 feet. Common scenario visible at this road link during fair days is that pedestrians tend to wait at road links for shopping purposes resulting in traffic congestion at walkways. Therefore, for these links, although a reasonable pedestrian flow is provided through LOS, friction and interaction between pedestrians is likely to happen. Hence, road links 2 and 6 are recommended for an expansion of sidewalk width to meet given LOS standards of Grade B as per Table 10.

Road link	Current LOS standards	Current effective width (m)	Recommended LOS standard	Required effective width (m)	Expansion width (m)
2	D	1.81	B	3.8	1.99
6	D	2.01	B	3.8	1.79

Table 9: Required Effective Width of the Sidewalks

Also during the study, it was identified that none of the considered sidewalks are protected with safety fence as shown in Fig. 3 and Fig. 4. Where, safety fence is a major component in pedestrian facilities providing safety for the pedestrians from roadside accidents and limiting unauthorized roadside parking along sidewalks. Hence provision of fences would reduce the possibility of pedestrians entering carriage way in the road. Therefore, provision of safety fences for road links 2,5 and 6 probably would help to enhance the Level of service with these links are expected to have very high pedestrian capacity during peak hours.

However, this study was based on methodology introduced in Highway Capacity Manual since it is considered to be concise and simple for implementation. But this method considers pedestrian speed as a minor factor, whereas flow rate as the major factor in determination of LOS conditions. Another drawback of using this method is that flowrate does not account for possible bi-directional or multi-directional effects and flow rate is only calculated using the sum of two directional counts. Where, friction introduced by opposing pedestrian flow is not accounted for computations.

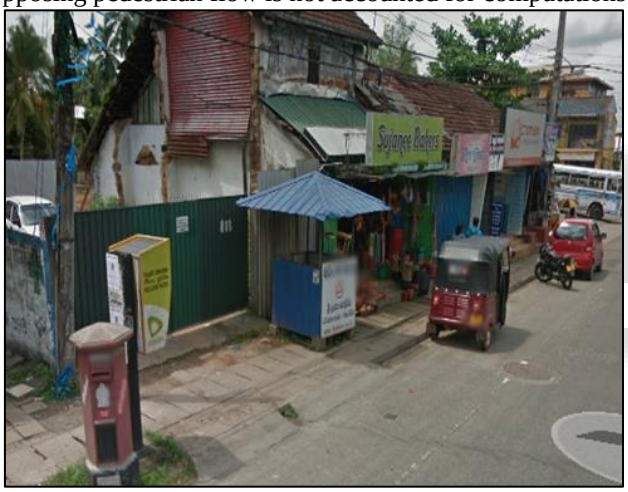

Fig. 1: Unprotected Sidewalks at Athurugiriya Junction

Fig. 4: Unprotected Sidewalks at Kaduwela Junction

VI. Conclusion

From the observations and results, it can be concluded that most of the road links considered for the study, which are located in Kaduwela and Athurugiriya city centers are generally congested during peak hours and suitable Level of Service (LOS) conditions are not maintained properly as illustrated in results due to numerous reasons. They are uncontrolled pedestrian movements, inadequate sidewalk width and possession of sidewalks for vending purposes. Moreover, in general, pedestrian LOS has not developed focusing Colombo city. Thus, steps such as expansion of existing pedestrian sidewalks, regulating street vendors and providing walkway fences are suggested to enhance the Level of Service (LOS) standards.

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