Improvements in pedestrian facilities at Maharagama to mitigate the traffic congestion

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Abstract— *Traffic congestion at the busy intersections during peak hours is very high and the wastage of time, fuel and other resources of road users is a critical issue. This congestion cost in Sri Lanka is estimated around Rs. 12 billion per annum. High Level Road (A04) which is a main corridor out of the seven major transport corridors, pass through Maharagama junction. Due to infringement and inadequacy of pedestrian walkways and facilities, encroaching of pedestrians into the carriageway disturbing vehicle movement is a main reason for the traffic congestion. Therefore, a number of road traffic accidents occur daily. This paper illustrates the overall study carried out to determine a solution for safe movement of pedestrians in Maharagama city. The study was started by identifying the problem and continued with data collection conducting a vehicle count survey and a pedestrian survey. As the most feasible solution for the congestion, a pedestrian overpass was selected and justified using a decision matrix. The network and the stations for overpass system were decided considering the commercial centres, public related service centres and locations where high pedestrian movement is present. As the secondary data, 1: 10,000 digital data obtained from Survey Department including the land use in the area were considered. In designing the structure, the ultimate loading conditions, deflection, vibrational effects, materials needed for construction, aesthetic appearance and power needed for the system were considered. Width of the overpass was decided by considering the Level of Service (LOS) for the pedestrians. Expected outcomes of the project are: improvement of vehicle flow, reduction of delay, reduction of road accidents and improvement of pedestrian safety at Maharagama.*

Keywords— ***Pedestrian Overpass, Level of Service, Traffic Congestion***

I. INTRODUCTION

Pedestrian crossing is a place which is designed to guide and assist the pedestrian to cross a road safely. Pedestrian crossings can be at-grade or grade separated. In certain locations where pedestrian and vehicle movement is high, at-grade pedestrian crossings cannot be used because it would further increase the traffic congestion at that point. At such locations grade separated crossings are used.

Maharagama city is a highly-urbanized suburb in Colombo Metropolitan Region, located about 15 km from the commercial capital. National Youth Services Council, National Cancer Hospital, National Ayurvedic Hospital, Maharagama Railway Station and Maharagama Bus Stop are some of the important places in and around the study area.

Few of the main problems for the congestion in the city are random pedestrian movements across the carriageway and the infringement and inadequacy of pedestrian facilities. This has caused mainly because street vendors have encroached the pedestrian walkways and road planners have neglected the pedestrian facilities in the design stage. The city is in a rapid development and the urban traffic congestion has become a serious problem in the area. It incurs both tangible and intangible costs to all road users as well as to the whole society.

II. LITERATURE REVIEW

As observed in many urban areas, adequate pedestrian accesses have been forbidden due to various reasons. Unavailability of pedestrian facilities and infringement of the provided facilities by different parties are the most remarkable scenarios. Therefore, pedestrians have been forced to use the carriageway when there is inadequate supply. Kumara et al. (2014) state that when a vehicle travels at its cruise speed, and if the speed is interrupted due to interruptions due to pedestrian crossings, it decelerates to a minimum speed or which can be even a complete stop. Subsequently, the vehicle has to accelerate back to its original cruise speed. Therefore, when a vehicle undergoes a speed change cycle, it increases the Vehicle Operating Cost (VOC).

Proper design of pedestrian facilities can be contributed to increase overall efficiency of the transportation system. Liyanage (2010) has found the traffic volume, flow characteristics, vehicular speed and level of service of each route in Maharagama city center. He states that in the area the vehicle speed at the peak time varies from 13km/h to 33km/h, and the large pedestrian movement is at the Maharagama junction. That is because passengers have to cross at least one main crossing to walk to take the next bus.

Number of surveys have been done to find the types of problems, pedestrians face on the road. Some of them are lack of or inadequate capacity of pavements, obstructions on footways: roadworks rubbish bins and sacks, poor footway maintenance and buildings. Therefore, people waste their time on the road which could be used more productively. Amarasinghe et al. (2012), express that one of the major problems for congestion at Maharagama town is excessive pedestrian movement taking place due to number of wayside textile traders occupying town area as their business grounds. Also, this business community disturbs the walkways and pedestrians have forced to use the carriageways.

Renfro (2007) points out that an overpass pedestrian system can improve the traffic situation and realize the separation of people and vehicles. He further states that the system should be built based on existing public facilities and should optimize the local environment, guide pedestrians walking habits and create a smooth traffic safety. Pedestrian overcrossings serve many users, including bicyclists, walkers, joggers, inline skaters, and pedestrians with strollers, wheelchair users, and others. These facilities can represent one of the most important elements of a community's non-motorized transportation network.

III. METHODOLOGY

Transport system prevailing in the Colombo Metropolitan area has failed to cater the mobility needs of people due to many reasons. Inadequate pedestrian walkways and random pedestrian crossings disturbing the vehicle flow are few of them. In identifying this problem in the study area, the level of service of the vehicle flow was calculated as the initial step of the project. A traffic survey was used to calculate the level of service of vehicles in the High-Level Road and Old Road during peak hours. 0700h–0900h in the morning, 1200h–1400h in the afternoon and 1700h–1900h in the evening were taken as peak hours for the survey.

After conducting interviews with pedestrians, businessmen and traffic police officers, locations where high pedestrian utilization occur were identified and their ideas were taken to find out the best solution for this problem. Using the gathered information, 5 major areas of extremely high pedestrian movement were selected (Figure 1).

Figure 1. Locations with a high pedestrian movement in the Maharagama City

Next, the capacities of pedestrians were determined at each point during different time slots and selected the places where highest pedestrian flow occur. After analyzing the survey results it was found that the points B, C and E had the highest pedestrian movement and those locations were selected to build a passenger crossing facility to mitigate the traffic congestion.

Some possible improvements identified to mitigate this problem were: an improved signalized traffic lights system, an underpass and an overpass. To select the best solution out of the three solutions, a decision matrix was formulated comparing different aspects such as cost, environmental impacts, effectiveness, safety, aesthetic appearance, construction feasibility and maintenance giving variable priority rating to each above aspect. And a quality rating was given on a scale from 1 to 5 where 1 is poor and 5 is excellent. From the decision matrix (Table 1), it was decided that a networked overpass will be the best solution out of the above solutions.

Table 1. Decision matrix for deciding the best solution

	Traffic lights		**Underpass**		**Overpass**	
Cost (0.2)	5	1	1	0.2	2	0.4
Environmental impacts (0.2)	3	0.6	2	0.4	4	0.8
Effectiveness (0.2)	1	0.2	5	1	5	1
Safety (0.2)	1	0.2	3	0.6	5	1
Construction feasibility (0.1)	5	0.5	1	0.1	3	0.3
Aesthetic (0.05)	3	0.15	4	0.2	2	0.1
Maintenance (0.05)	4	0.2	2	0.1	3	0.15
Total		2.85		2.6		3.8

When selecting the locations for access points for the networked overpass system, aspects such as land use, shortest path, connections to commercial and other important locations, utilization of existing infrastructure and access facilities were considered. Through a decision matrix, a lattice shell type truss bridge was selected as the type of the bridge (Table 2). Factors such as structural feasibility, the initial cost, ease of construction, maintenance cost and the aesthetic condition were considered and priority(P) was scaled from 1 to 5 where 1 is very low and 5 is very high and the quality (Q) was scaled from 1 to 5 where 1 is very poor and 5 is very good to develop the decision matrix. Because of the less aesthetic appearance of the truss bridges, it was designed as a lattice shell type structure while restoring the concept of truss bridges.

Table 2. Decision matrix for Selection of bridge type

Bridge Type	Structural feasibility		Initial cost		Ease of construction		Maintenance cost		Aesthetic condition		Total Rating
	P	Q	P	Q	P	Q	P	Q	P	Q	
Cable Stayed	5	4	4	2	4	2	3	2	3	5	57
Truss	5	5	4	5	4	4	3	4	3	2	79
Suspension	5	2	4	3	4	3	3	2	3	5	55
Arch	5	3	4	4	4	3	3	4	3	4	67

Another decision matrix (Table 3) was developed to select the building material of the bridge. Considered aspects were given a priority rating(P) from 1 to 5 where 1 is low and 5 is extremely high and a quality rating(Q) on a scale 1 to 5, where 1 is poor and 5 is excellent. Steel, concrete and wood were the materials considered and steel was selected as the most viable material.

Table 3. Decision matrix for Selection of Material

Materials	Initial Cost		Service life		Ease of construction		Maintenance cost		Aesthetic Condition		Env.l impacts		ToTAl
	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q	
Timber	5	4	4	1	4	2	3	1	2	3	1	5	46
Concrete	5	2	4	4	4	3	3	4	2	2	1	3	57
Steel	5	3	4	3	4	4	3	3	2	5	1	4	66

The energy requirement for the overpass network is governed by the energy required to run the escalators, lamps in the overpass and lamps at stations. To create a sustainable structure and to compliment the green building initiatives, the bridge was designed to have solar panels mounted along the roof to generate the required power for lighting. Lighting calculations were performed according to the IEC 62305 standards and factors such as lighting area, lux level needed, lumen output of fittings was considered.

The suitable width for the overpass network was obtained by considering the pedestrian level of service and life span for the structure was taken as 30 years. According to the American Association of State Highway and Transportation Officials (AASHTO) guidelines a vertical clearance of 5.1 m was maintained in between road level and the soffit level of the bridge for the safe movement of vehicles. Handrails which help people steady themselves while moving were designed to have a height of 1.0 m. Use of pedestrian barriers is essential to prevent the pedestrians from directly crossing the High Level and the Old road at the Maharagama junction. It also helps to force pedestrians to use the overpass system. In fact, side barriers 1.14m height and 3.5m of steel trails were used for the design. Escalators were used at every access point to attract pedestrians to the system since pedestrian dislike climbing stairs. Figure 2 shows the use of side barriers, hand rails and escalators in the design.

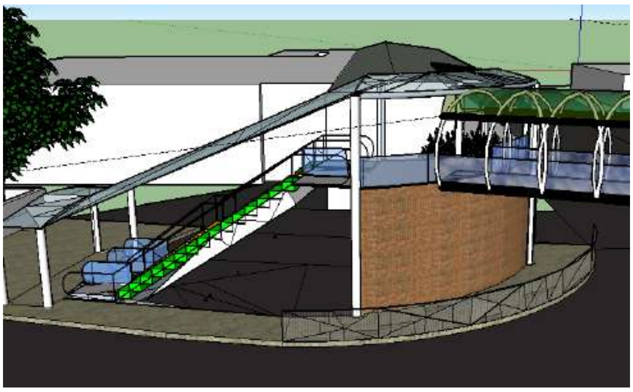

Figure 2. Escalator, side barriers and hand rails used at an access point

The structure was designed for the critical path which is the longest path in the overpass network. All steel sections which used for the design are hollow circular sections and diagonal members are two radii circular hollow sections. Bridge was designed so that it can be pre-fabricated and assembled at the site. Sections were designed according to BS 5950 and software's such as AutoCAD 2013, SAP 2000 and Prokon 2.4 were used for the structural design and analysis. A typical cross section of the bridge is given below in the Figure 3.

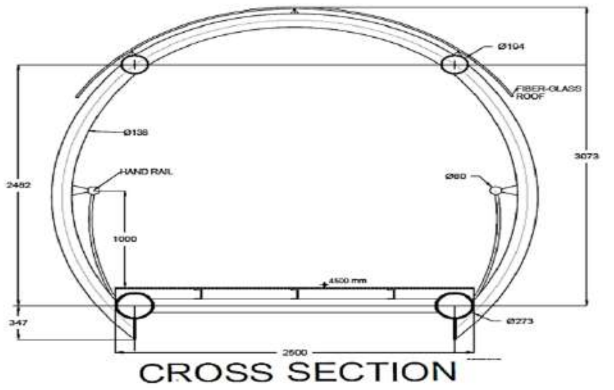

Figure 3. Typical cross section of the bridge

The distance and total time taken (including waiting time) to move from one access point to another access point were found and the time saving occur when using the overpass was determined. Finally, the economic, social and environmental impacts that can cause due to the structure were determined.

IV. RESULTS AND DISCUSSION

The pedestrian overpasses have a positive impact and have great potential of reducing number of pedestrian fatalities. At present, the role of existing pedestrian overpasses is not being fully implemented, because over 60% of pedestrians choose not to use pedestrian bridges for various reasons. Females use it more than males and children more than adults do. Reasons for not using an overpass include the discomfort, extra walking distance, high stairs, health reasons, or fear of safety. In order to mitigate these issues in this design, escalators were used in every access point. Also, to prevent random movements across the carriage way, side barriers were proposed. Foot bridges should be neat and clean and usable. Hawkers, beggars, banners, garbage should be removed.

It was observed that Maharagama area is congested during peak hours due to number of reasons. From the traffic surveys conducted it was identified that the level of service at the single lane (towards Kottawa) in the High-Level Road is D, level of service at the other lanes (towards Nugegoda) in the High-Level Road is B and level of service at Old Road is C. The area has a compound annual growth rate of 2.1%, and with the drastically increasing trend of the number of private vehicles, the problem will be much critical in near future. For the 2.5m width considered for the bridge, at the end of its life span the pedestrian level of service was obtained as C.

From the decision matrices formulated, it was decided that a networked overpass will be the best solution considering cost, environment impacts, effectiveness, safety, construction feasibility, aesthetic appearance, and maintenance out of the other solutions identified. Based upon the extensive research put forth and through the decision matrices formulated, the most suitable type of bridge to meet the needs of this structure was found to be a lattice shell type steel structure which is aesthetically pleasing.

Six major access points, (A, B, C, D, E and F) were selected for the proposed network of the overpass where access point A is close to the Market, access point B is the "Savina" building near the clock tower, access point C is near the Youth Center, access point D is between High-Level Road and Old Road, access point E is near the "Osusala" at the Old Road and access point F is at the Maharagama Railway Station. It is given below in the Figure 4 and 5.

Figure 4. Proposed stations of the networked overpass

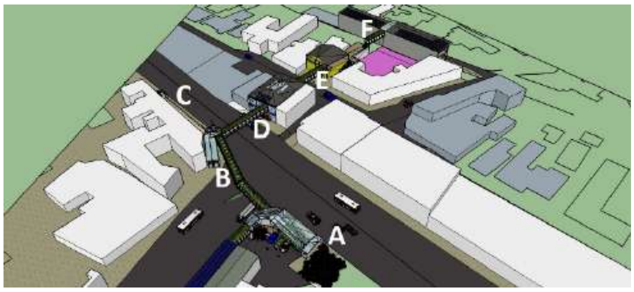

Figure 5. Proposed layout of the networked overpass

Access point A is the existing market building and it has enough space for the construction. This point will provide better access to Dehiwala, Moratuwa, Piliyandala bus routes and it will reduce the congestion in the High-Level Rad and Dehiwala-Maharagama Road. Access point B has enough space for construction and it will avoid random pedestrian movements across the High-Level Road. Access point C will provide better access to Youth Center and it will reduce the congestion at point D. Point D interconnects the pedestrian movements across High-Level Road and Old Road. Availability of a bare land gives enough space for the construction. Access point E provides direct access to Old Road and it will reduce the congestion of Old Road. Access point F which is the existing Railway Station has direct access to Pamunuwa Road. Availability of bare lands makes it easy for the construction of the bridge and with the proposed electrification of the railway track, demand at this point will be high.

The maximum span of the bridge between 2 nodes is 26m, and this path was taken for the structural design of the sections. The respective spans between 2 nodes in the overpass network is given in the following Table 4.

Table 4. Distance between nodes

Path	Span(m)
Access Point A- Clock Tower	18
Clock Tower- Access Point B	26
Access Point B- Access Point C	20
Access Point B- Access Point D	24.2
Access Point D- Access Point E	19
Access Point E- Access Point F	13

The total time saving occur when using the overpass is significant. The blue line given in the Figure 6 below gives the current pedestrian path connecting the access points and Table 5 gives the time saving between each access points in the proposed overpass.

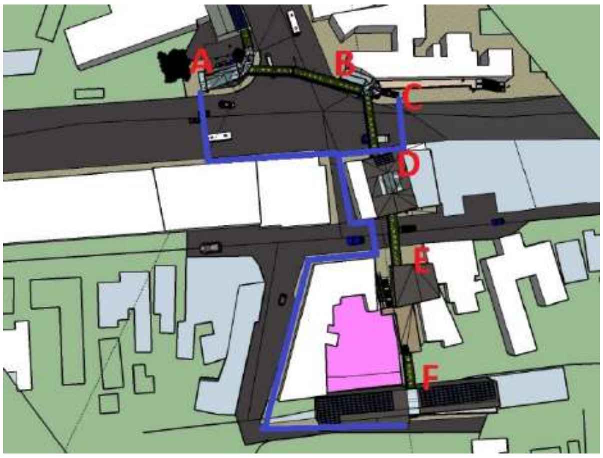

Figure 6. Existing pedestrian path and the path of the networked overpass

Table 5. Time Saving between access points

Acc. Pt 1	Acc. Pt 2	Path	Distance(m)	Total Travel time(min)	Time Saving
A	B	Existing	35	2.5	30%
		Proposed	46	1.7	
A	D	Existing	87	3.2	41%
		Proposed	60	1.9	
A	E	Existing	129	5.8	55%
		Proposed	109	2.6	
A	F	Existing	283	7.9	59%
		Proposed	153	3.2	
B	D	Existing	24	2.3	35%
		Proposed	30	1.5	
B	E	Existing	76	5.1	63%
		Existing	64	1.9	
B	F	Proposed	223	7.1	65%
		Overpass	108	2.5	
D	E	Blue	43	2.6	46%
		Overpass	27	1.4	
D	F	Blue	196	6.7	69%
		Overpass	77	2.1	
E	F	Blue	153	2.125	20%
		Overpass	50	1.7	

The total energy requirement for the whole overpass network was obtained as 474 kWh and it was decided to obtain the energy required for lighting using solar panels and to get the energy from the national grid to run the 8 number of escalators.

The main purpose of the designed pedestrian overpass is to reduce the traffic congestion by avoiding the pedestrian movement across the High-Level road and Old road, which disturb the continuous flow of the vehicles. This would mainly save the precious time of the road users and reduces the stressful driving experience of the motorists especially during peak hours. Therefore, the reduction of congestion in Maharagama due to the pedestrian overpass would be a great relief for the road users. One of the adverse social impacts of the pedestrian overpass would be that the beggars would tend to encroach in the overpass and the overpass would be a means of shelter for them. Legal actions need to be properly conducted to avoid this anti-social behavior of the beggars. For the construction of the designed pedestrian overpass, certain lands and buildings will have to be occupied. The building owners would not be willing to contribute their buildings for the construction, mainly because these buildings are used for their business work. Therefore, adequate compensation need to be paid for them. Also, relocation of their business places into the access points in the overpass system can be done.

IV. CONCLUSION AND RECOMMENDATIONS

It was observed that Maharagama area is congested during the peak periods due to number of reasons. One of the major reasons is the uncontrolled pedestrian movements where the walkway facilities have been used for unauthorized commercial activities. Also, failure to provide efficient public transport facilities lead to aggravate the traffic congestion encouraging unnecessary pedestrian movements. The ultimate goal of this project is to reduce the congestion due to pedestrian movements in the study area. In doing so three possible solutions were studied and selected best option as pedestrian overpass. Based upon the extensive research put forth by the design group, the most suitable type of bridge to meet the needs of this structure was identified as a lattice shell type design. Study was composed of field surveys to identify the best location for the facility, determination of Level of Service of the roads, analysis of topography of the study area, design of the overpasses satisfying the international standards. In the Maharagama study area it was found out 5 places with extremely high pedestrian movements and crossings. Data collecting was carried out in two ways namely Study Desk and Site Reconnaissance method. Then the designing and analysis of the overpass was conducted by software such as SAP 2000, Autocad 2013 and Prokon 2.4 using the data gathered from the surveys fulfilling the relevant guidelines and codes of international standards. After developing this facility, vehicle flow rate in the roads will increase saving fuel, time and reducing the impact to the environment. Also, accidents causing for road users will reduce drastically while having a stress-free ride for motorists.

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