ENGINEERING SOLUTIONS TO MINIMIZE DELAYS AND SAFETY RISK AT DEHIWALA FLYOVER

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Abstract: Traffic congestion is one of the most imperative problems in almost all countries. Flyovers are usually used all over the world to address the traffic congestion, especially at intersections. Advantages of grade separation are; less interruption to traffic flow, higher speed and reduces the scope for accidents. In Sri Lanka also flyovers are used to address the delays and the safety risk at highly congested intersections. Dehiwala intersection was also replaced by a flyover in order to eliminate the traffic congestion. However, congestion and accident trends have not been reduced yet. There are many factors that contribute to increased congestion levels especially during peak periods and the issues behind the increase in accidents at Dehiwala junction. Engineering solutions based on traffic and highway engineering principles can effectively be used to improve the traffic flow and reduce traffic accidents at this location. Accident data analysis, speed and travel time surveys were used to compare the conditions at present and before construction of the flyover. Moreover vehicle movement pattern, road geometry and adjacent land use activities can be used to evaluate the impact to the Dehiwala flyover. Geometry of the road need to be improved as it will not generate significant speed difference between two adjacent sections as well as not generate bottlenecks at the entrances of the flyover. Stopping of buses within 75m from the junction and vehicle parking within 50m range from the intersection need to be discouraged by using regulatory methods.

Keywords: Flyovers, Engineering solutions, minimize delays, safety risks, accidents.

1. Introduction

Traffic congestion is one of the most vigorous topics in traffic engineering, irrespective of whether in a developing or developed country. In all situations where capacity cannot be provided for the peak demands, waiting and delay are inevitable. Avoiding traffic congestion is an important aspect in traffic engineering. Economy of a country depends on the quality of the road networks.

Different traffic management approaches have been used for a long time, based on the appropriateness to reduce the issue. Grade separation is one final solution that allocates vertical space for each road at various heights in order to avoid disruption to the traffic flow at the junctions where two or more roads are crossing. In Sri Lanka, flyovers are recently introduced to reduce traffic congestion and accident tendency at road intersections. Dehiwala flyover is the second such flyover in Colombo. Prior to this solution Dehiwala junction has undergone a number of traffic management options varying from a roundabout to signalized roundabout and then a signalized intersection and finally a flyover. However, the congestion issues have not been properly solved.

Objectives of this study are to identify the factors contributing to increased congestion levels especially during peak periods and the factors contributing to increase in accidents at Dehiwala junction and propose engineering solutions based on traffic and highway engineering principles which can be used to improve the traffic flow and reduce traffic accidents. Conditions at present and before the introduction of the flyover can be compared by using accident data analysis, speed and travel

time surveys. Figure 1 shows the plan view of the junction. All dimensions in meters.

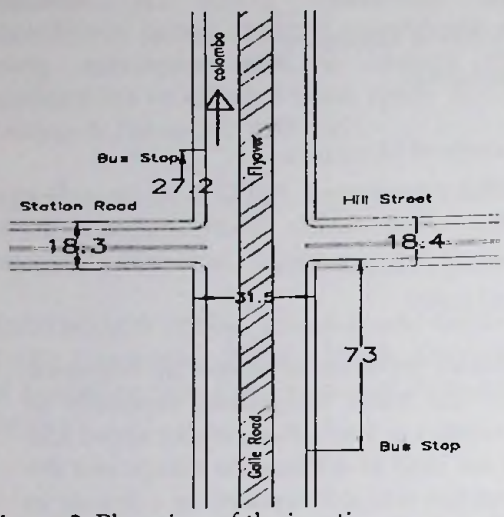

Figure 3: Plan view of the junction

2. Literature review

Peiris & Fernando (2011) have studied the appropriateness of a flyover as a traffic management measure. They found that 67% of accidents were occurring on the flyover. Buses and heavy vehicles contribute to 74% of accidents at the ends of the flyover. They have identified that the monthly average of recorded accidents in 2007 were 10 and average increased up to 36 by 2010. They have mentioned that the disadvantages of the flyover are comparatively higher than its expected benefits. Less co-ordination among relevant administrative bodies and the shared responsibility between road development agencies, management bodies as well as the local authority in pre and post assessment of the performance of flyover at the location was not done properly were some of the other observations by them. Peiris & Fernando (2011) have mentioned about a sudden speed drop at the flyover. They have identified that the obstructive design of the flyover at the approach level blocks the visual path of the users and the lack of overtaking opportunities exist under heavy traffic condition. Also the functional efficiency and the land use activity patterns were not considered at all in these mega projects as well as feasibility studies were not done. Eventually they have recommended that the land use compatibility be evaluated with the transport system before introducing costly traffic management tools such as flyovers. They have also suggested evaluation of the functions at the intersection such as transition, terminal, and the road geometry particularly the gradient and width critically before decision making on any flyover project.

Misaghi and Hassan (2005) conducted experiments on two-lane rural highway to research the relationship of geometric features and the operating speed consistency, discovering that driver's perception of the road rather than the designer's was the main factor on speed decision. Effect of visual range on driving speed on low-grade highway was studied by Wang, Fang and Wang (2013). It is normally believed that the better the visual range, the safer the driving environment becomes. However researchers have mentioned that this is not always the case. If the visual range is too large, it easily leads to a big speed difference between the adjacent parts. So the length of visual range should correspond with the design standard of the whole road. Moreover they mentioned that the significant speed difference is definitely unfavorable to road safety. Therefore, they have recommended limiting visual range of 80m to prevent speeding. Visual ranges of road sections which are adjacent to the flyover need to be compatible, as it helps to reduce the speed difference between flyover section and adjacent sections.

Meadows(2010) has cited that the inadequate width of both sides of the road and trading activities on the sidewalks are reasons for the issues. He has mentioned that the "Marine Drive" project from Moratuwa to Dehiwala would be a good solution for the existing issue. Zilioniene and Vorobjovas (2011) investigated the horizontal alignment of 30 regional roads, finding that sight distance, is one of the safety assessment indices, directly affected the acceleration and deceleration performance of vehicles on long tangent section.

Surrogate safety measure for evaluating rear-end collision risk related to kinematic waves near freeway recurrent bottlenecks was studied by the Li, et al., (2013). They mentioned that the likelihood of rear-end collisions is highest when traffic approaching from upstream is at capacity state while traffic down-stream is highly congested. Abdel and Pande (2005) mentioned that the speed difference between upstream and downstream locations and the average occupancy were

identified as contributing factors for collision risk.

Shankar, Mannering, & Barfield (1995) mentioned that the section with steeper maximum upgrade between any two sections will experience a greater number of rear-end and other same-direction accidents. In addition, rear-end accidents will increase substantially if the maximum grade exceeds 2% in that section. The impact of grades is reversed in the presence of downgrades. Much of the effect of the higher braking distance on downgrades appears to be offset by the visual impact of brake lights warning drivers of the potential slowing of vehicles ahead. In contrast, drivers are unlikely to use brakes on an upgrade which eliminates a critical warning sign of speed reductions. And also they have mentioned that the number of rainy days in the month decrease sideswipe and rear-end collisions and increased fixed object collisions.

3. Methodology

3.1. Methodology of study

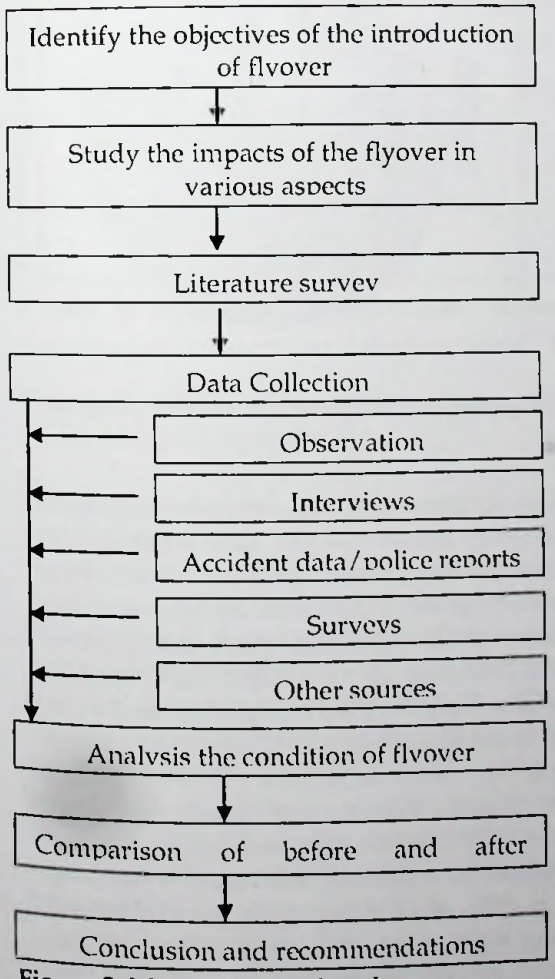

Figure 2: Methodology of study

3.2. Objectives of introduction of flyover

The purpose of construction of this fly-over is to eliminate the traffic delay in Galle Road (AA002) at the Dehiwala Junction. (Dehiwala flyover, 2011)

3.3. Impacts of the flyover

Accident tendency and congestion level has increased at the intersection. This was confirmed by the Dehiwala Traffic Police Division and they had to allocate more officers on duty near the flyover. Trading activities also have influenced and previous researches (Peiris & Fernando, 2011) have mentioned about it.

3.4. Data collection

The location was observed for a few hours during the peak periods of the week days and special features and issues of the flyover were identified. Intersection and entrance to the flyover from both ends were observed. About 1km distance along the A002 road was observed and vehicle and passenger movement patterns were recorded for supplementary studies. Dehiwala police station was visited and accidents records were referred. Police officers, road users, pedestrians, sellers and shop owners were interviewed. Accident data was obtained from the traffic police headquarters and Dehiwala police station. Newspaper articles, videos relevant to the Dehiwala flyover were also collected. Breaking of rules and mistakes were identified by examining recorded videos.

4. Observation and analysis

Gathered data were analyzed to identify the variation of the accident patterns, driver behavior, and pedestrian movement patterns in order to decide the justification of observations.

4.1. Driver's behavior patterns

Drivers keep a low speed on most sections of Galle Road except for those sections with good visual range where it is easy to lead drivers to raise speed to a high value. The situation becomes much worse when a bad vision alignment follows the good vision sections. This situation occurs near the Dehiwala flyover. Vehicles travelling on Galle Road, especially during night time, travel at higher

speeds. But due to the visual obstruction at the junction they are vulnerable to accidents. Especially travelers, who are not the daily commuters, can be victims of accidents. Most of the time they collide with other fixed objects.

During the night times, drivers follow the white line which separates the two lanes on left side of the road and without notice center median appears in front of them in such a way that there is hardly any time to avoid the collision. Most of the times three wheelers and motor cycles use sidewalk for travel. It is also observed that vehicles stop on the pedestrian crossing during red light. Pedestrians are compelled to deviate their path causing accidents. During the peak hours vehicles have to follow a stop and go type pattern. If they do not maintain adequate distance between two vehicles it collides with the rear end of another vehicle which is travelling ahead of it. When drivers need to go to shops, most of the times they tend to stop their vehicles on both sides of the road, underneath the flyover. It causes reduction of limited available width of the road. Due to that reason, a two lane road becomes a single lane road causing bottle necks.

4.2. Geometry and other features

Dehiwala junction is a heavily populated junction and which involves so many trading activities such as large shops, small hotels and traders on side walkways. There are many byroads directly connected to the A002 road.

Arrangement of the bus stop is another reason for increased congestion. Buses are stopping closer to the junction to get passengers. Passengers also stop at the intersection to get in to the buses instead of going to designated bus stop which is positioned about 40m away from the intersection. During the peak hours it generates long queues. Gradient of the flyover also cause to reduce the speed of the vehicles. Lack of overtaking opportunities and inadequate width of the road also induce traffic delays.

4.3. Accident Data analysis

Suitable area and the road section for analysis was selected such a way that it includes the Dehiwala flyover. According to the police map Node no 662802 contain the Dehiwala junction. Range of 3 km distance along the A002 road was selected to study the accident patterns. Following parameters were considered for the analysis. Severity, accident frequency vs. time, lighting condition and location were considered. Flyover was opened for public on 21st of October 2009. Before the construction of flyover and after the construction of flyover were considered to identify the safety situation in the area.

4.3.1. Accident frequency in each year

Accident tendency has gradually increased after the introduction of the flyover according to the figure 3. Difference between accident frequencies of the year 2009 and the year 2010 is substantial. Before construction of the flyover accident frequency per year was about 125. It has increased to 184 in the year 2010. Number of accidents that occurred during the year 2012 are almost double the number of accidents that occurred during 2008.

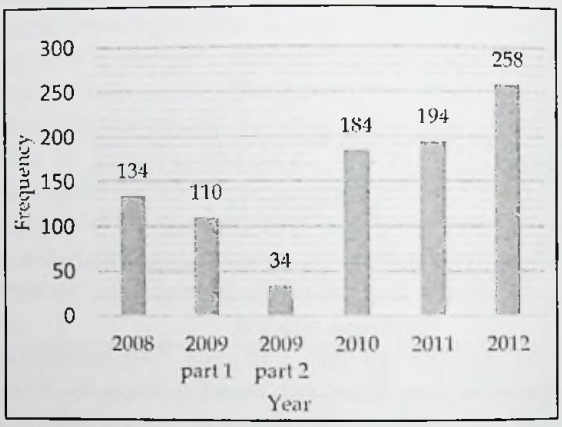

Figure 3: Total accident frequencies in each year

4.3.2. Accident frequencies in each hour of a day

Time of accidents and frequencies were plotted considering data before and after construction of the flyover. Same pattern of accident distributions were indicated by both graphs. Majority of accidents took place during peak hours. Normally 10 am to 2pm and 4 pm to 9pm are high accident frequency hours. A drop of accident frequencies can be identified during 3pm to 4pm (Figure 4). During that time period, number of road users is significantly less than the peak hours. It cause reduction of accidents. But most interesting fact is 79% of fatal accidents have occurred during night time after construction of the flyover. Before construction of flyover it was 67%.

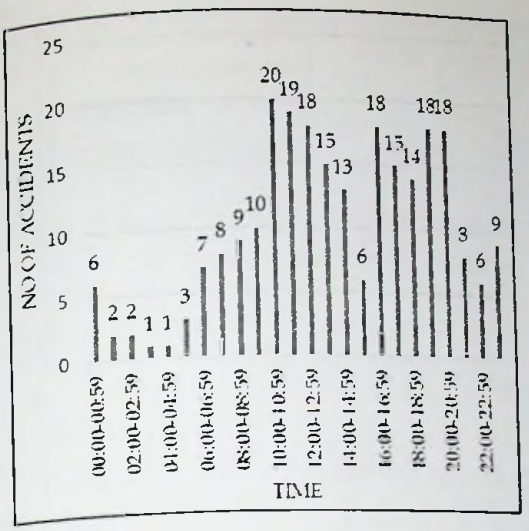

Figure 4: Accident frequency vs. time before construction of flyover

4.3.3. Percentage severity in each accident category

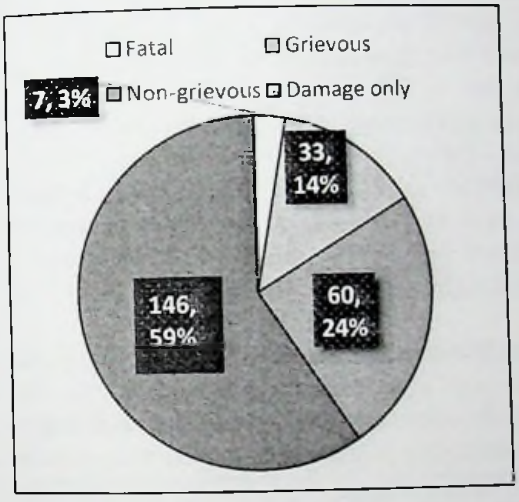

Figure 5: Severity vs. accident percentage before construction of flyover

Percentages of fatal, grievous, non-grievous and damage only accident percentages for period before 2010 are shown in Figure 5. Above statistics have been changed after introduction of the overpass to the junction. As shown in Figure 6 it can be seen that fatal accident percentage has increased. While grievous accident percentage has reduced after the introduction of the flyover at Dehiwala junction. Non grievous accident percentage also has reduced during latest years. But damage only accidents have increased significantly.

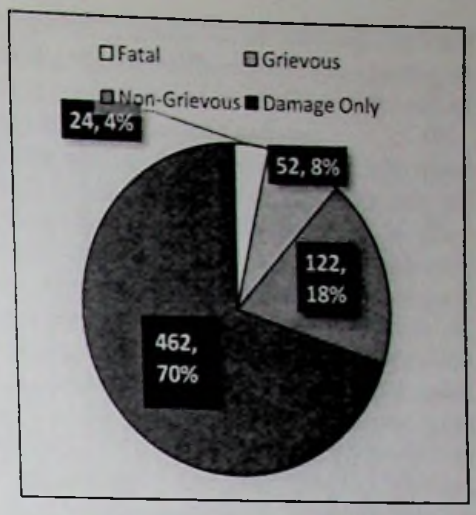

Figure 6: Severity vs. accident percentage after construction of flyover

4.3.4. Accident frequency along the road

Most of the accidents have concentrated to the vicinity of the flyover as shown in Figure 7. Range within the 500m either sides of the junction was the most crucial sections and large number of accidents has happened within this section. Same type of accident distribution can be seen before and after construction of the flyover. Most prominently, accident frequencies at that region have increased significantly after construction of flyover. Accident trend of other locations (at least 500m away from the junction) along the Galle road have not changed significantly after introduction of the flyover. Accident frequencies within the flyover have increased while accident frequencies of other locations away from the junction have remained almost same as before. The most critical location is the Dehiwala junction. In addition the location about 500m away from the junction towards south (Mount Lavinia) represent another critical place.

4.3.5. Accident type vs. frequency

"Rear-end crash hitting a vehicle in position for going straight ahead" is the most common type of accidents which have occurred at this area in every year irrespective of the construction of the flyover. "Overtaking to the right", "Over taking to the left", "Shifting lane or merging to the right", "Shifting lane or merging to the left", "With pedestrian entering the road section from the left sidewalk, shoulder etc.", types "With pedestrian entering the road from the left prior to intersection", "With pedestrian entering the

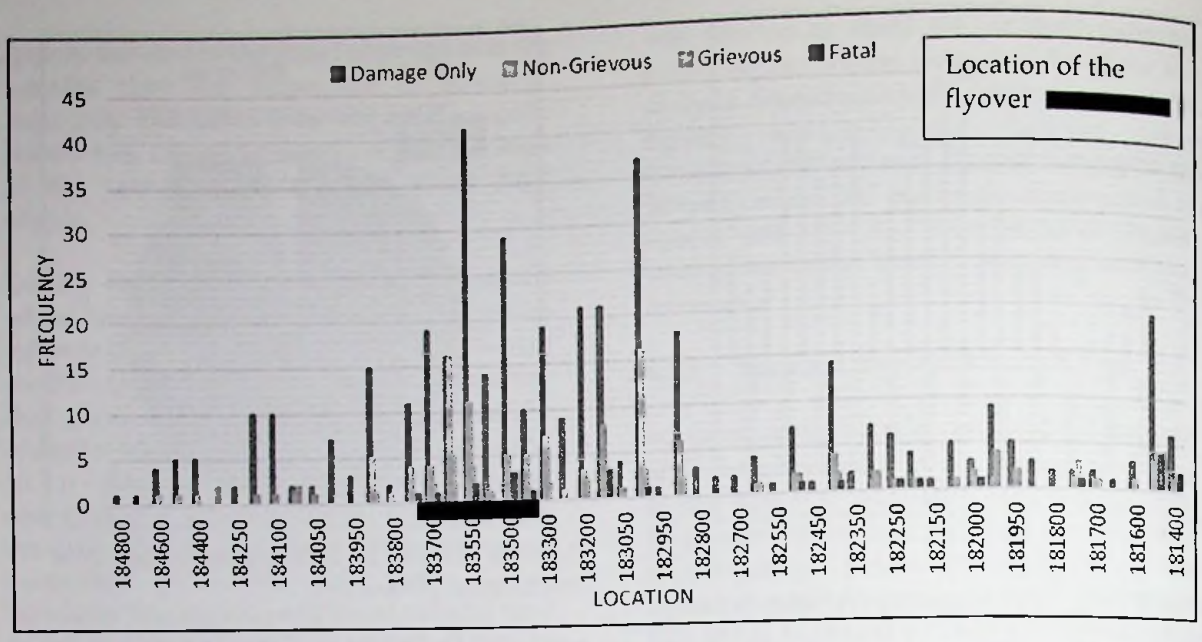

Figure 5: Severity vs. location after construction of flyover

road from the left after an intersection", "In conjunction with overtaking and "Other crashes with fixed object" are common accident types.

4.3.6. Location vs. severity

183500, 183550, 183100, 183000, 183400 and 183700 are the northing coordinates of the identified dangerous locations (Figure 7). Fatal accident frequencies have increased after the introduction of the flyover as a traffic management solution. Grievous accidents are also more likely to happen closer to the junction after construction of the flyover. Above described pattern can be identified in 2008 and 2009. But after the introduction of flyover number of accidents has increased. Most importantly damage only accident frequency has increased significantly within the region of 500m from the junction to the both directions. In 2008 and 2009 most number of accidents has happened between northing 183000 and 183550. In 2010 and 2011 similar distribution can be seen while frequency has significantly increased. But in the year 2012 majority of damage only accidents have happened between the northing 183200 and 183900. That means accident distribution has spread either side of the flyover.

4.3.7. Accident type vs. severity

Most of the fatal accidents happened due to accident types which involves pedestrians such as "With pedestrian entering the road section from the left sidewalk, shoulder etc.", "With pedestrian entering the road from the left prior to intersection" and "With passenger being hit when hanging outside vehicle" because pedestrians are more likely to be injured during an accident. Damage only accidents are generated by the other accidents types such as "Other head on crash", "Rear-end crash hitting a vehicle in position for going straight ahead"

4.3.8. Street lighting condition

Table 2: Severity and existed lighting condition

	lighting condition			
severity	daylight	night,no street lighting	night,improper street lighting	night,good street lighting
fatal	3	0	0	3
grievous	10	2	0	0
non grievous	32	8	0	0
damage only	146	43	1	0

In 2012, accident severity and the existed lighting conditions are shown in Table 1. According to Table 1 considerable number of accidents also occurred under no lighting condition. However, fatal accidents have occurred under good street lighting conditions at that night. Number of fatal accidents that occurred during night and day time is similar. Generally the number of vehicles travelling at night is less than the number of vehicles travelling at the day time. Hence accidents

possibility is higher during night relative to day time.

4.3.9. Days of week

Figure 7 illustrates the accident occurrences in each day of the week. Lesser number of accidents has occurred on Saturday and Sunday where traffic flow is relatively low. More accidents have happened on the Thursdays and Fridays as compared to other weekdays.

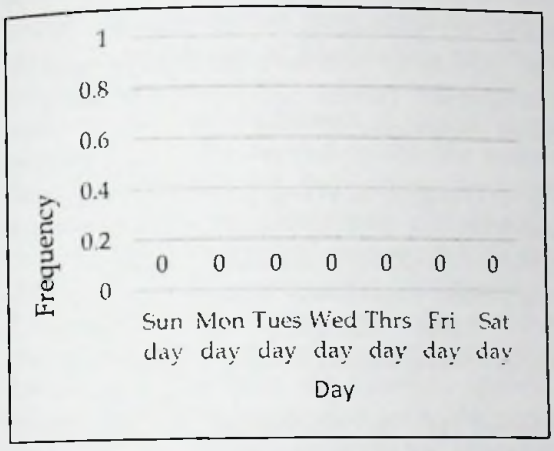

Figure 8: Day of the week vs. accident frequency

5. Conclusion

Safety of the road users has been significantly influenced by the flyover. Delays have been induced due to the high congestion especially during peak hours. Expected benefits have not been achieved yet from the flyover project.

5.1. Reasons for accidents and delays

Geometry of the road has induced significant impact to the traffic flow especially during peak hours. Most importantly bottle necks are created at the entrance of the flyover due to the existing shape of the road. Inadequate width of the road involves increasing the traffic congestion and the accident frequency. Lack of overtaking opportunities is another reason. Especially during congestion period smaller vehicles try to reduce travel time by even using sidewalks.

According to the Shankar, Mannering and Barfield (1995), rear-end accidents will increase substantially if the maximum grade exceeds 2% in a section. Gradient of Dehiwala flyover is also at a higher range. It causes the speed of vehicles to reduce while driving upward direction. Drivers are unlikely to use brakes on an upgrade, which cause to increase the risk of meeting with a rear end collision.

Drivers tend to speed up their vehicle when visual range is large. But situation can get worse if bad vision section follows a good veison section. Road sections which are adjacent to the Dehiwala flyover contain good vision sections specially during off peak times. Because of that, drivers increase their speed on that sections. But if they not reduce the speed significantly closer to the flyover, it can cause accidents. Because visual range of the flyover section is lower than the adjacent sections. Wang, Fang, & Wang in 2013 recommended to maintain speed diffrences within some range to avoid safety issues. Especially during the night times, drivers follow the white line which separates the two lanes on left side of the road. But due to the high speed of the vehicle and visual obstructions at the location, drivers can't identify the fixed objects such as center median, sign boards or concrete guard rail. Specifically non-daily commuters are facing huge problems due to lack of knowledge about the location and most of the time they become the victims.

People tend to stop their vehicles at both sides of the road, underneath the flyover, causing reduction of limited available width of the road. Due to that two-lane road becomes a single lane road causing bottle-necks. Further it reduces the visual range of the drivers and creates the uncertainty in their mind as side walkways are congested during the peak hours. Random crossing of pedestrians can also cause accidents. Some sign boards are missing at the junction. Because of that road users are unable to identify important features of the road. Further, bad lighting conditions at the entrances to flyover and visual interferences magnify the above issues.

Stopping of the busses closer to the junction and the parking of the vehicles near the intersection, increase the traffic congestion and the safety issues at the junction. This issue would have reduced to certain extent if busses are stopped at the established bus stop.

6. Recommendations

Geometry of the road has to be changed in such a way that it reduces the occurrence of bottlenecks at the entrances of the flyover. Alignment and the visual ranges of the road

sections need to be improved as those do not generate significant speed differences between adjacent road sections especially at the approaches to the flyover. Vehicle parking within 50m range from the intersection needs to be discouraged otherwise it causes to induce the uncertainty in the drivers mind and increase the visual obstructions to the drivers. And also it creates the bottle-necks at the junction. Since the bus traffic near intersections impede with the traffic flow, it is desirable that the bus stop should be positioned at least 75m away from the junction for passengers to disembark at safe places such as curbs or islands. (Kadiyali, 2007). And also rules and regulation need to be prepared for enforce the road users to follow that rules. Sign boards need to be provided at least from 500m away from the flyover indicating the existence of flyover, road crossings, and fixed objects. Further, adequate lighting needs to be provided at the approaches to the flyover. Curbs and required safety precautions have to be taken to increase the safety of the pedestrians. Appropriateness of the timing of the traffic signals should be checked. If timing of the signals are not appropriate it generates more delays, significant increase of accident frequencies (especially rear end collision), increase the use of less adequate routes as road users attempt to avoid the traffic control signals and drivers can tend to neglect the important traffic signals.

References

Abdel, A., & Pande, M. (2005). Identifying crash propensity using specific trafficspeed conditions. *Journal of Safety Research*, 97-108.

Dehiwala flyover. (2011, 07 27). Retrieved from Road development Authority : http://www.rda.gov.lk/supported/flyovers/dehiwala/dehiwala.html

Kadiyali, L. R. (2007). *Traffic engineering and transport planing.* Delhi: Kanna publishers.

Li, Z., Ahn, S., Ragland, D. R., Chung, K., Wang, W., & Yu, J. W. (2013). Surrogate safety measure for evaluating rear-end collision risk relatedto kinematic waves near freeway recurrent bottlenecks. *Accident Analysis and Prevention*, 52- 61.

Meadows, W. (2010, 02 19). *The awesome Dehiwala flyover.* Retrieved from Dailymirror: http://print2.dailymirror.lk/features/features/4090.html

Misaghi, P., & Hassan, Y. (2005). Modeling Operating Speed and Speed Differential on Two-Lane Rural Roads. *Journal of Transportation, 131*(6), 408-417.

Peiris, O. V., & Fernando, K. D. (2011). *An examination of the appropriatness of flyover as a traffic management measure to the road intersection of Sri Lanka.* Town and Country planning, University of Moratuwa.

Shankar, V., Mannering, F., & Barfield, W. (1995). Effects of roadway geomatrics and environmantal factors on rural freeway accident frequencies . 371-389.

Wang, P., Fang, S., & Wang, J. (2013). Effect of Visual Range on Driving Speed on Low-grade Highway. *13th COTA International Conference of Transportation Professionals (CICTP 2013)* (pp. 1175 - 1184). Shanghai, 201804, China: Procedia - Social and Behavioral Sciences.

Zilioniene, D., & Vorobjovas, V. (2011). Analysis of Driving Conditions on Low-volume Roads in Lithuania Assessing Geometry Parameters of. *8th International Conference Environmental Engineering,* (pp. 1254-1260). Vilnius, Lithuania.