European Transport \ Trasporti Europei n. 27 (2004): 57-68

Modeling Traffic Impact of Flyover at an Urban Intersection Under Mixed Traffic Environment

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Abstract

In order to ease transportation problems, many urban authorities in India have taken up initiative for construction of flyovers at major intersections. However, in most of the cases a comprehensive planning approach has not been adopted, either due to lack of fund or ignorance about the planning perspective of such proposals. The locations for flyovers have been decided based on present day operating conditions and the traffic impacts of such flyovers at adjacent intersections have not been analysed. In the present paper, the traffic impact of a flyover along with its adjacent intersection has been analysed, using a simulation model developed for mixed traffic operations and poor lane discipline prevailing in India. Through the case study presented in the paper, it has been demonstrated that an ill planned flyover only shifts the location of the problem without bringing any benefit to traffic. The potential use of simulation model for analyzing traffic impacts has been shown; and the need for such analysis for the planning of flyovers has been highlighted.

Keywords: Modelling traffic impact; Flyover; Urban intersection; Traffic environment.

1. Introduction

The increase in urban traffic congestion has become a serious concern to transportation professionals. Therefore, efforts have been made by researchers for obtaining rational quantification of congestion (Turner 1992; Thurgood 1995; Maitra, Sikdar & Dhingra 1999) and formulating appropriate measures for mitigation of congestion for urban roads (Pratsch 1986; Lindley 1989; Arnold 1993). Urban road network consists of large number of intersections at close proximity, which are potential sources of acute traffic congestion, especially during peak hours. Attempts have been made by researchers to improve traffic operations at urban intersections (Cronje 1983; Olszewski 1993; Chou, Chen & Li 2001). However, the scope of improvement of intersection at-grade or widening existing roads is very limited in urban areas. In order to minimise the surface level conflict and to provide a relief to mixed traffic, spatial separation in the form of flyovers is planned at major intersections in the congested cities of India. Flyovers at major urban intersections can be instrumental in reducing traffic congestion and delay. However, in most of the cases a comprehensive planning approach has not been adopted, either due to lack of fund or ignorance about the planning perspective of such proposals. The locations for flyovers have been decided based on present day operating conditions and the traffic impacts of such flyovers on adjacent intersections have not been analysed. A wrongly planned flyover may only shift the location of the traffic problem without offering remedies.

The objective of the paper is to analyse the traffic impact of such an independently designed flyover at an urban intersection. For the purpose of analysis, an intersection in Calcutta (Kolkata), where a flyover is being constructed, and another adjacent intersection in close proximity have been considered. The analysis shown in the paper can be used to answer queries like how effective it will be to construct flyovers at urban intersections or whether it will solve the congestion problem successfully etc.

Traffic in most of the developing countries is heterogeneous in nature. In order to achieve the above objective it is necessary to have a tool for analyzing mixed traffic operation at urban intersections. In recent years, the advent of high-speed computers has resulted in extensive use of computer simulations for analyzing transportation problems (Payne 1979; Leo and Pretty 1992; Wang and Prevedouros 1998; Chou, Chen & Li 2001; Wong et al. 2002; Olmos, Pierre & Boudreault 2003; Dion, Rakha & Kang 2004; Taniguchi and Shimamoto 2004; Hidas 2005). A Number of traffic simulation software like TRANSYT (Vincent, Mitchell & Robertson 1980), SATURN (Hall, Vliet & Willumsen 1980), CARSIM (Benekohal & Treiterer 1988), NETSIM (Rathi & Santiago 1990), etc., was developed for analyzing traffic operations. However, majority of works carried out by researchers considered homogeneous traffic stream and strict lane discipline. Therefore, in general, they are not directly applicable for heterogeneous traffic conditions and poor lane discipline prevailing in developing countries like India. Several researchers have also developed traffic simulation models considering mixed traffic operations (Arason & Jagdeesh 1995; Popat, Gupta & Khanna 1995; Hossain and McDonald 1997; Faghri and Egvhaziova 1999). These models have been extremely useful for addressing the issues related to mixed traffic operations. The potential use of computer simulation in formulating improvement measures under mixed traffic operations has been established through the development and application of these models. However, most of these simulation models were developed for specific purposes and are not generally available for use by others. In the present study, a simulation model has been developed for modeling traffic impact of flyover at an urban intersection in Calcutta (Kolkata).

A flyover was under construction at a major 4-arm intersection (i.e. Gariahat Intersection) in Calcutta (Kolkata). In the present paper, Gariahat intersection and the adjacent 5-arm Phari intersection have been considered for modeling the traffic impact of flyover at Gariahat. Due to the construction of flyover, the traffic flow at Gariahat and Phari intersections was disturbed and it was not possible to validate the simulation model for Gariahat or Phari intersection. Therefore, an adjacent intersection (i.e. Deshpriya Park) having similar road geometry and traffic environment to that of Gariahat Intersection, was considered for the validation of the simulation model. A sketch of intersections considered for validation and application of simulation model is shown in Fig. 1.

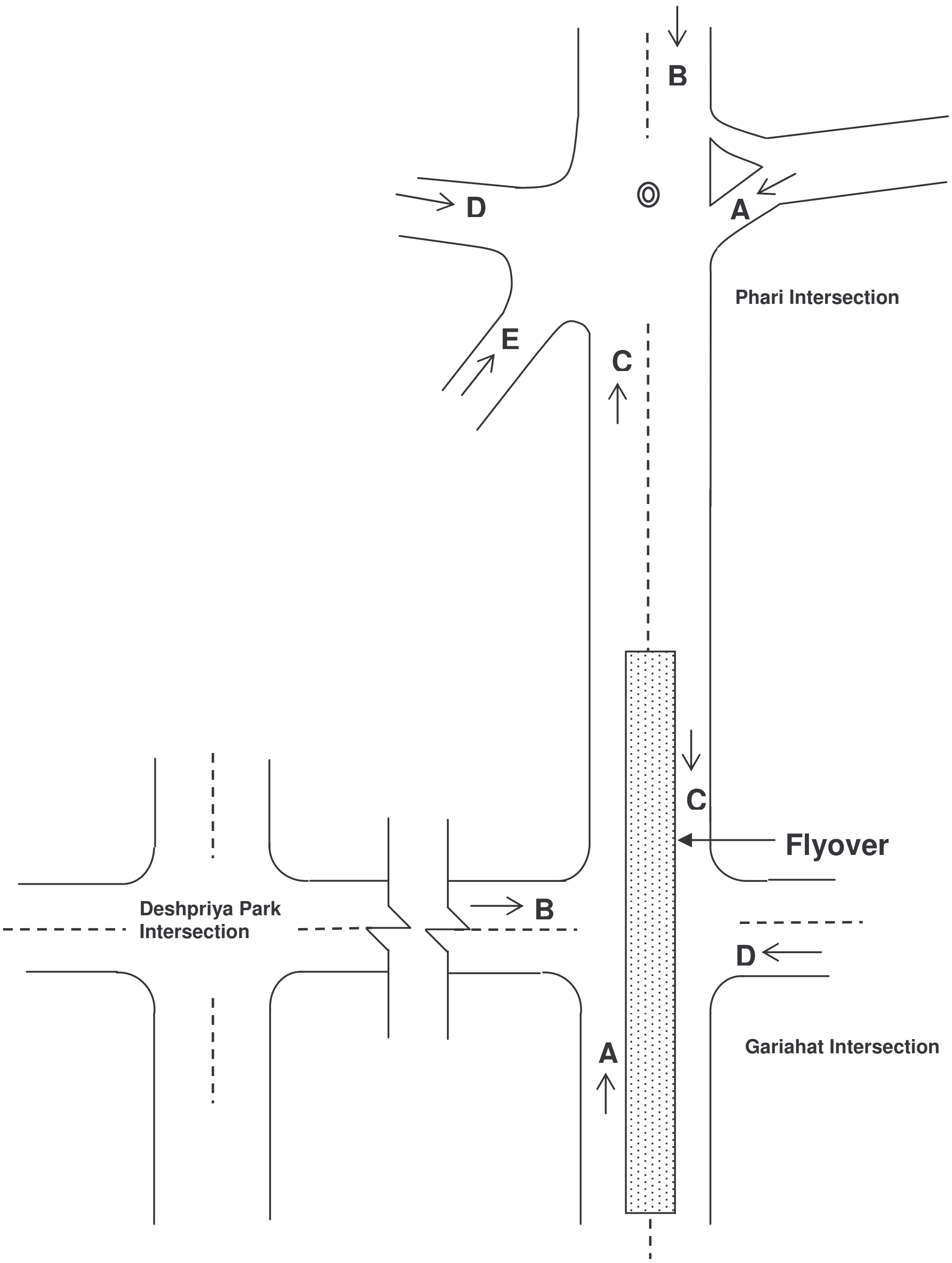

Figure 1. A sketch of Intersections Considered for Validation and Application of Simulation Model.

2. Development of a Traffic Simulation Model

An interval oriented traffic simulation model is developed considering the mixed traffic operations and poor lane discipline prevailing in Indian cities (Azmi 2002). The major inputs required by the model and the outputs obtained are given below. A brief description of the salient features and the parameters incorporated in the model is also included in the paper.

The major inputs required by the simulation model include, i) different types of vehicle and their dimensions, ii) volume of traffic in each approach of intersection, iii) composition and directional distribution of approaching traffic, iv) approach speed distributions and acceleration / deceleration characteristics for different types of vehicle, v) width of intersection approach and signal timings. The major outputs obtained from the model are overall delay and queue length.

Each approach of an intersection is simulated in the model. During the simulation process, the headway, type of vehicle, turn characteristic (i.e. left, straight or right going) and approach speed are generated by the model. Assuming a minimum headway of 0.5 second, the shifted negative exponential distribution is used to generate the time headways of vehicles. The type of vehicle and its turn characteristics are generated based on the cumulative probability distribution charts developed from the field observations, and acceleration/deceleration characteristics are assigned. In the process of generating approach speed of a vehicle, Box and Muller Technique is used to generate standard normal variants.

The action of a vehicle generated in the simulation model is guided by certain rules. A vehicle travels with its generated speed until there is a hindrance from another vehicle in front or the stop line appears along with red indication from the signal. A vehicle starts decelerating only when, the available sight distance is equal to the stopping sight distance. If there is no opportunity for overtaking then a vehicle decelerates to attain the speed of the slow moving vehicle in front and maintains a distance equals to the stopping sight distance. A stopped vehicle accelerates only when the available gap in front is at least equal to a predefined value. This predefined distance is a function of the type of vehicle and its value is given based on the field observations.

In the absence of strict lane discipline, vehicles tend to find gaps in the traffic stream and move forward to position them nearer to the stop line. This phenomenon is duly incorporated in the model by additional rules. It is assumed that right-turning vehicle can occupy either right lane or central lane to move as close as possible to the stop line. Similarly, left-turning vehicles can occupy either left lane or central lane; and straight going vehicle can occupy any lane to move as close as possible to the stop line. In the model, a scanner was used to scan the available gap in front of an approaching vehicle and compare the same with the effective width required by that vehicle type to move forward. The scanner also checked for the possible obstruction by any of the already positioned vehicles and accordingly the scanner width was reduced to the available width of the gap. The scanner and the vehicle following it continuously moved forward until the scanner width became lesser then the effective width of the vehicle.

Database

For the validation of the simulation model for Deshpriya Park intersection, all the required inputs were collected from the field and the model outputs were compared with field observations. Traffic at Deshpriya Park intersection was heterogeneous in nature and comprised of different modes like Two Wheelers, Three Wheelers (Autos), Cars, Buses and Minibuses. At the time of study, a two phase fixed time signal was in operation at the junction.

In order to obtain directional distribution of approaching traffic, a turning movement survey was conducted and vehicles were recorded in each five seconds interval. In order to understand the distribution of approach speed for different types of vehicle, spot speed data was collected by recording the time taken by individual vehicles to cover a short trap length of 37.7m. Queue length at the end of green to the start of next green was measured in terms of number of vehicles and also in meters. Pre-installed benchmarks at an interval of 10 meters were used to determine the length of queue in meters. The deceleration rates of different types of vehicle were recorded from the filed. Classified traffic volume count was also carried out during 8:00 A.M. to 1:00 P.M. The signal timings and existing road geometry of approach lanes e.g. approach width; number of lanes etc. was also recorded.

Validation of Model

For the validation of the simulation model, a number of simulation runs were taken using the inputs measured from the field during the peak hour of traffic flow. The outputs obtained from several model runs were compared with those observed in the field. The average queue length and average maximum queue length as obtained from several model runs during the peak hour, were compared with those observed in the field. A comparison of modeled and observed queue lengths is shown in *Table 1*. It may be noticed from *Table 1* that the modeled queue lengths are in agreement with the field observations. Similarly, the delays for different types of vehicle and average vehicular delay as obtained from different simulation runs were also compared with those observed in the field. A comparison of delays as obtained from model runs and as observed form field measurements is shown in *Table 2*. It is observed from *Table 2* that except for buses, the modeled delays for different types of vehicle are in agreement with those observed in the field.

Table 1: A Comparison of Modeled and Observed Queue Lengths.

Queue	Length of the Queue in 'm'	
	Model Average	Field Observation
Maximum	122.6	139.7
Average	61.8	64.8

Table 2: A Comparison of Modeled and Observed Delays.

Type of Vehicle	Modeled Delay (Sec)	Observed Delay (Sec)
Auto	16.4	17.5
Bus	29.6	36.8
Car	19.5	20.7
Minibus	22.5	23.9
Two Wheeler	15.6	16.3
Average	*19.5*	*21.5*

In order to capture more passengers, bus drivers were found to spend more time while crossing the Deshpriya Park intersection. Moreover, due to the unhealthy competition among private bus operators, buses were placed in such a way that no other bus could overtake a bus in front. This phenomenon was not considered in the model and therefore, the average delay for buses as obtained from the model were lower than that measured in the field. It is assumed that in extremely busy intersections like Gariahat and Phari, such unhealthy competitions among private bus operators can be avoided under stringent supervision from the city traffic police. Therefore, the simulation model was applied to analyse the impact of the construction of a flyover at Gariahat intersection.

3. Application

The validated simulation model was applied to analyse delays for Gariahat and Phari intersections for the peak hour of traffic flow. Before the construction of flyover a two-phase signal was in operation at Gariahat intersection, while a three-phase signal was in use at Phari intersection. *Table 3* shows the traffic volume for different approaches of Gariahat and Phari intersections, while the directional distribution of traffic for different approaches are given in *Table 4*.

Table 3: Approaching Traffic Volumes at Gariahat and Phari Intersections.

Intersection	Approach and its Width	Car	Two Wheeler	Bus	Mini Bus	Auto	Total
Gariahat	A (9.35m)	791	128	85	64	0	1068
	B (11.45m)	323	78	77	17	189	684
	C (12.25m)	886	155	128	115	0	1284
	D (11.45m)	382	62	153	19	234	850
Phari	A (6.70m)	868	243	34	50	105	1300
	B (6.90m)	1307	194	81	97	21	1700
	C (10.30m)	1148	232	51	82	14	1527
	D (8.45m)	465	92	7	22	0	586
	E (10.60m)	363	93	23	26	206	711

Table 4: Directional Distributions of Traffic at Gariahat and Phari Intersections.

Intersection	Approach	Percentage of Traffic		
		Left Turning	Straight	Right Turning
Gariahat	A	12	88	NA
	B	27	73	NA
	C	15	85	NA
	D	12	70	18
Phari	A	21	42	37
	B	27	73	NA
	C	24	70	6
	D	41	15	44
	E	18	45	37

3.1 Analysis of Delay before the Construction of Flyover at Gariahat Intersection

Several simulation runs were taken to model the delays for different types of vehicle at each approach of Gariahat and Phari intersections. The delays for different types of vehicle and the average vehicular delay (considering all types of vehicles together) at each approach of Gariahat intersection are shown in *Table 5*. Similarly, the delays for different types of vehicle and the average vehicular delay for each approach of Phari intersection are shown in *Table 6*.

Table 5: Delays at Gariahat Intersection before the Construction of Flyover.

Vehicle Type	Average Vehicular Delay in Sec for Approach			
	A	B	C	D
Car	38.8	34.6	41.4	27.6
Two Wheeler	23.8	28.6	27.5	14.4
Bus	40.2	46.3	49.5	30.9
Mini Bus	38.7	42.8	48.6	28.2
Auto	NA	35.6	NA	15.1
Average	*37.1*	*35.7*	*41.2*	*23.8*

Table 6: Delays at Phari Intersection before the Construction of Flyover at Gariahat.

Vehicle Type	Average Vehicular Delay in Sec for Approach				
	A	B	C	D	E
Car	38.1	51.5	44.9	78.1	34.6
Two Wheeler	31.9	47.4	25.7	74.2	9.4
Bus	41.9	61.5	53	92.3	35.8
Mini Bus	42.5	61.5	48.6	81.4	33.4
Auto	37.3	50.5	37.4	NA	27.7
Average	*37.1*	*52.1*	*42.4*	*77.8*	*29.3*

When all four approaches of Gariahat intersection were considered together, the average vehicular delay was estimated as 35.3 sec. Similarly, the average vehicular delay at Phari intersection was estimated as 46.0 sec. Based on the approaching traffic volume and average delay, the total vehicle-hour delay during the peak hour was estimated as 38.1 for Gariahat and 74.4 for Phari. It may be observed that average vehicular delay was more at Phari intersection as compared to that of Gariahat intersection. The traffic handled by Gariahat intersection during peak hour was 3886 vehicles as compared to 5824 vehicles by Phari intersection. The total vehicle-hour delay at Phari was more, as both average vehicular delay and the traffic volume were more as compared to those at Gariahat. Apparently, it would have been logical, from the above point of view to plan for a grade separation at Phari intersection rather than a flyover at Gariahat. However, the local authorities planned for a flyover at Gariahat intersection. The analysis of delay for both intersections after the construction of flyover at Gariahat intersection is given in the following section.

3.2 Analysis of Delay after the Construction of Flyover at Gariahat Intersection

After the construction of flyover at Gariahat, the entire straight going traffic from approach A and approach C will use the flyover (*Fig. 1)*. As the turning traffic from approaches A & C and the entire traffic from approaches B and D will continue to use the at-grade intersection, it will be necessary to redesign the signal for the at-grade traffic at Gariahat. The at-grade traffic movement after the construction of flyover at Gariahat intersection is summarised in *Table 7*. It may be mentioned that out of 3886 vehicles approaching Gariahat intersection, 2031 vehicles will use the flyover during the peak hour. A cycle time of 150 sec was estimated for the operation of at-grade traffic at Gariahat intersection and accordingly the delays at different approaches were estimated from model runs. *Table 8* summarises the average delays to at-grade traffic for different approaches of Gariahat intersection after the construction of flyover. A comparison of delays of different types of vehicle as shown in *Table 8* with the delays shown in *Table 5* clearly shows that there will be substantial benefit for the traffic that will continue to use the at-grade traffic signal at Gariahat.

Table 7: At Grade Traffic Volume at Gariahat Intersection after the Construction of Flyover.

Approach	Left Turning	Straight	Right Turning	Total
A	128	0	0	128
B	185	499	0	684
C	193	0	0	193
D	102	595	153	850

Table 8: Delays at Gariahat Intersection for at-grade Traffic after the Construction of Flyover.

Vehicle Type	Average Vehicular Delay in Sec for Approach			
	A	B	C	D
Car	9	22.7	13	19.4
Two Wheeler	3.1	12.5	4.1	9.6
Bus	27.5	31.5	24	24.5
Mini Bus	33.3	28.5	20.5	27.8
Auto	NA	24.1	NA	11.3
Average	*11.2*	*23.1*	*13.7*	*17.6*

When the total at-grade traffic on all approaches of Gariahat intersection were considered together, the average delay per vehicle was estimated as 18.7 sec. When entire traffic (i.e. traffic at-grade and traffic using flyover) was considered together the average delay per vehicle was estimated as 8.9 sec. A comparison of this average delay with the average vehicular delay of 35.3 sec. before the construction of flyover clearly indicates that there will be a reduction of average vehicular delay by 74.8% due to the construction of flyover at Gariahat intersection. This reduction in average vehicular delay is substantial for the traffic using Gariahat intersection during the peak hour of traffic flow. Probably, the local authorities realised this benefit and therefore, planned for the flyover at Gariahat without understanding the impact of this flyover on the adjacent Phari intersection. After the construction of flyover, the total vehicle-hour delay at Gariahat intersection was estimated as 9.7. This indicates a reduction of 28.4 vehicle-hour delay during the peak hour due to the construction of flyover.

For the Phari intersection, the pattern of traffic arrival for approach C (traffic approaching from Gariahat) will change after the construction of flyover at Gariahat. The inflow during the peak hour will increase substantially because of the uninterrupted flow of traffic approaching Phari using Gariahat flyover. Moreover, as only about 47.7% of the earlier total traffic will continue to use the traffic signal at Gariahat intersection, they will also be discharged with much lesser delay. Altogether, the inflow of traffic from Gariahat to Phari during the peak hour will be much higher after the construction of flyover at Gariahat. This change in the traffic arrival pattern was duly considered in the analysis and the average delays for different types of vehicles at approach C of Phari intersection were modeled. The estimated delays were 119.1 sec for Car, 65.0 sec for Two Wheeler, 125.0 sec for Bus, 102.3 sec for Minibus and 62.5 sec for Auto. When all vehicles of this approach (i.e. approach C) were considered together the average delay per vehicle was estimated as 110.3 sec. A comparison of this average vehicular delay with the average delay of 42.4 sec before the construction of flyover at Gariahat *(Table 6)* clearly shows that for approach C (at Phari), there will be more than 100% increase in delay because of the change in arrival pattern of traffic caused by the flyover at Gariahat. The delays for other approaches of Phari intersection are unlikely to be affected by the flyover at Gariahat. The signal timing could be readjusted to distribute some of the delay to the other arms though the average vehicular delay will not change significantly. Therefore, the modeled delays for other approaches as estimated earlier (*Table 6*), along with the newly estimated delay for approach C were used to estimate the average vehicular delay for Phari Intersection. The average vehicular delay for Phari was estimated as 70.4 sec. Similarly; the total vehicle-hour delay for Phari intersection was estimated as 132.6. It may be observed that both the average vehicular delay and the total vehicle-hour delay for Phari intersection will increase substantially after the construction of flyover at Gariahat intersection. A comparison of vehicle-hour delays for Gariahat and Phari intersections before and after the construction of flyover at Gariahat is shown in *Fig. 2.* If both Garihat and Phari intersections are considered together, the net change in vehicle hour-delay due the construction of flyover at Gariahat is also shown in *Fig. 2*. It may be observed from *Fig. 2* that after the construction of flyover at Gariahat, the increase in vehicle-hour delays for Phari intersection will be more than the reduction in vehicle-hour delays for Garihat intersection. As a result, if both Gariahat and Pharai intersections are considered together, there will be a net increase in vehicle-hour delay. The total increase in vehicle-hour delay for Phari intersection was estimated as 58.2. When both Gariahat and Phari intersections were considered together, the net increase in vehicle-hour delay was estimated as 29.8. *Fig. 2* clearly shows that the flyover at Gariahat will not solve the traffic problem. Rather, it will only shift the location of problem from Gariahat to Phari and also result into an increase in vehicle-hour delay.

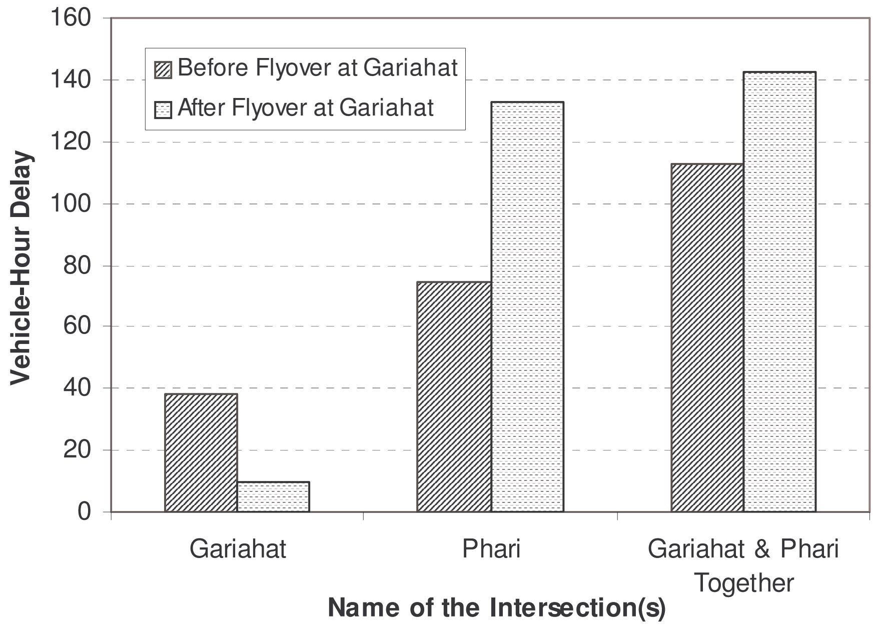

Figure 2: A Comparison of Delays due to the Construction of Flyover.

4. Conclusions

In order to mitigate road traffic congestion, several urban authorities in India have taken up initiatives for construction of flyovers at major intersections. However, a comprehensive planning approach is missing in most of the cases. The locations for flyovers have been decided based on present day operating conditions or some times even by the perceptions of the decision-making bodies without resorting to the analytical planning approach. The case study presented in the paper is an example of many such flyovers in Kolkata and other cities in India. It has been shown that instead of solving transportation problem, an ill planned flyover only shifts and / enhances the problem. It has been shown that how a simulation model can be used for assessing the traffic impact of a proposed flyover at an intersection, emphasising the need of a systematic approach and analysis at the planning stage.

In an urban network, one intersection may be more congested than other adjacent intersections. But, decision for construction of flyover at the most congested intersection should not be based on only the present day operating condition. This is because the less congested operating conditions for adjacent intersections can be simply due the bottleneck and constrained outflow from the existing congested intersection. If a flyover is planned and operating condition is improved, other adjacent intersections may become congested due to the change in traffic flow pattern. Therefore, during the planning of flyover, the traffic impact analysis should be carried out considering adjacent traffic intersections. It has been shown in the case study that how the average vehicular delay and total vehicle hour delay will increase for Phari intersection after the construction of the flyover at Gariahat intersection. Following similar method, the traffic impact on other adjacent intersections can also be modeled.

In the case study presented in the paper, only two intersections have been considered. However, the results indicate that it may be rational to consider one or more prioritised corridors in an urban area, and then analyse the traffic flow considering all intersections along each such selected corridor. Based on the traffic impact analysis considering adjacent intersections along the selected corridor, one or more flyovers may be recommended for improving operations of traffic at corridor level. This is contrary to the school of thoughts presently being followed by many urban authorities in India, where flyovers are constructed at a few congested intersections only based on present day operating conditions. As the selected intersections are spread over the whole city and do not serve as a part of any corridor, the construction of flyovers may only change the spatial nature of the traffic problem in the city without bringing the expected benefits.

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