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IMPACTS OF REPLACING A FOUR-PHASE SIGNAL INTERSECTION WITH A DIAMOND INTERCHANGE OF A SELECTED CORRIDOR IN DHAKA CITY USING MICROSCOPIC SIMULATION

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Abstract: As most of the existing intersections in Dhaka city have already exceeded the capacity, we need to find alternative solution to minimize the losses in traffic jam A proper traffic impact study needs to be conducted in order to know whether the alternative solution will mitigate the chronic congestion problem or not. A signalized intersection in Dhaka city, having diverse traffic and geometric characteristics is taken as our study area and data were gathered to calibrate and validate the model of that intersection created in microscopic simulation software VISSIM. Therefore, this study applies alternative option to the existing condition with the help of VISSIM. As an alternative solution, diamond interchange is used in this research. Diamond interchange uses less space than most types of freeway interchange and avoids traffic signal, which causes hours of operational delay. This research will look at reconstructing current four-phase non-lane based intersection in Dhaka city into a diamond interchange to see how it will perform to cope up with the current peak flow traffic of Dhaka city.

1. Introduction

There is a massive increase in the vehicular population day by day which has resulted in problems like congestion, pollution, accidents and wastage of fuel. The vehicle population is increasing day by day calling for proper planning of the road network. This requires a realistic model based on actual traffic conditions. On a typical four-leg intersection, one out of two intersecting roads has the higher traffic volume. This roadway is referred to as the major or arterial road. The second roadway, which services the lower traffic volume, is referred to as the minor or collector road. When the volume on either road nears capacity, queues begin to form, raising the potential for unsafe driving manoeuvres. For this reason, improving safety and operational efficiency at intersections on urban road intersections remain a constant goal (Naghawi 2014). For this purpose, microscopic simulations are widely used now a days to develop alternatives to alleviate traffic congestion after calibration and validation of large network, assessing alternatives on existing condition of traffic and evaluation of alternatives to choose the best alternative. Intersections are usually considered as the critical points within the network and the evaluation of their performance provides valuable understanding and useful indication about the performance of the system (Sunil 2013). In this paper our study area is a major and mostly congested four legged signalized intersection of Dhaka city, Bijoy Sarani. To evaluate its system performance microscopically a diamond interchange has been superimposed. The diverging diamond interchange (DDI) design is an innovative interchange design, which is gaining momentum in the developed and developing countries.

At these intersections or crossover nodes, the opposing traffic movement along an arterial crosses each other. This crossover enables drivers to drive on the opposite side of the roadway between the two interchange node points. Being on the opposite side of the roadway allows the left-turn movements, from the ramp to the arterial and from the arterial to the ramp, to operate free, without being impeded by opposing through movement.
Microscopic simulations are widely used in transportation operations and management analysis because "simulation is safer, less expensive and faster than field implementation and testing" (Park & Schneeberger, 2002). It is a useful tool to effectively analyze and evaluate proposed improvements and alternatives. Here, an attempt is made to model the study sections using VISSIM to analyze the driving behavior.

Therefore, the main objectives of this research are to identify and observe the unique features of mixed traffic and techniques to incorporate them in VISSIM, to visualize the traffic flow scenario in VISSIM, to validate key performance measures from another data set and to incorporate an alternative (Diamond Interchange) in VISSIM to compare traffic behavior from the existing condition of the study area. The parameters and quantitative measures obtained from the study could be used to make proper planning of the roadway. The study would also depict some parameters, which might be used to design and improvement of the roadway infrastructure. So, the research comprises of introduction, review of related previous papers and cross-referencing, methodology to simulate an intersection at our local environment, data collection prior to modeling, modeling diamond interchange, data analysis and finally a conclusion for the entire study and some suggestions and recommendations for future development.

2. Literature Review

Prajapati et.al.2007 conducted a study entitled “Simulation of Heterogeneous Traffic Intersection using VISSIM”. The study mainly concerned with the conceptual simulation model of highly heterogeneous traffic flow, delay and saturation at signalized intersections, various cycle time’s effect at intersection and to study the impact of provision of priority for BRTS at various frequencies. Study area of this research was Ahmedabad (India). The main objective of this study is to analyze the simulation model developed using VISSIM software and its application in transit signal priority for the existing BRTS in Ahmedabad. The study included collecting all data required to design optimum cycle lengths for a given phasing by using different available methods.

(Arasan and Vedagiri 2006) applied the simulation model to estimate the saturation flow rate of heterogeneous traffic. (Gowri and Sivanandan 2008) developed a simulation model and examined the effects of left turn channelization on vehicle waiting times. (Arasan and Arkatkar 2010) and (Arasan and Dhivya 2010) also have developed micro simulation models for midblock sections. (Radhakrishnan and Mathew 2011) developed a traffic simulation model integrating the concepts of cellular automata. Thus microscopic simulation models are used in recent times for numerous purposes. However, the effect of signal time or signal phase modification and or introduction of an interchange in a signalized intersection can alter many changes to traffic properties of that intersection which has not been extensively studied.

3. Methodology:

In Bangladesh, where traffic flow is non-lane based and Most of the drivers and pedestrians are ignorant of traffic rules and regulations and signal is hand operated by traffic police, creating simulation model is of great concern and involves much recalibration effort and significant model modifications. This thesis work is undertaken considering these local peculiarities. Therefore, the methodology includes representation of non-lane based traffic, identification of sensitive parameters, determining the parameter values by comparing the simulation model with the calibrated model, validating the model, incorporation of diamond interchange on the model and comparing the results of with or without the interchange. Due to VISSIM’s tightly integrated development environment makes it easy to pass freely among the stages of model construction, simulation, optimization and validation. VISSIM is used by thousands of engineers at commercial, government and academic institutions worldwide to solve real world problems in a variety of engineering disciplines. As a student version of VISSIM is available at BUET transport Lab, so VISSIM is used as the microsimulation tool for calibration and validation of a model. A proposed methodology of calibration process can be summarized as follows.

3.1 Defining Study Goals and Objectives:

To meet the goals and objectives of this research a decision has to be made to use traffic simulation software with careful consideration of the relative advantages and disadvantages of simulation modeling as compared to other non-simulation techniques.

3.2 Choosing Measures of Performance:

A measure must be selected to compare with field conditions in order to conduct the calibration process. The measure collected from the field to compare with the simulation result is called “Calibration Data”. Moreover, the choice of the appropriate set of calibration data is influenced by the study objectives, the capabilities of the model, and the available field data. The development of the list of required field data is also influenced by the choice of calibration data to be used. In this study, maximum queue length is considered as calibration data because of its easiness of collection, sensitivity to traffic condition, consistency with study objectives & capabilities of the model.

3.3 Establishing Evaluation Criteria:

One of the most difficult elements of traffic modeling is to establish the criteria by which the adequacy of simulation model results can be determined. The choice of the appropriate measure of performances to use and the establishment of an acceptable range of values for this measure is very much complex. When sufficient field data are available, it may be possible to quantify the mean and variance of the measure of performance and from these data, statistical confidence limits are established which can be used as calibration criteria. However, in practice, field data in sufficient quantity and of sufficient quality are rarely available. Consequently, in practice, calibration acceptance criteria tend to be subjective, rather than purely objective. This approach tends to result in the use of qualitative terms such as reasonable, adequate and representative, to describe the calibration results.

3.4 Determining Required Field Data:

It is important that a priority ranked list of required field data be established. In general, necessary data can be categorized into two parts: “fundamental data” and “calibration data”. First, fundamental data are the data required to build a base simulation network e.g. intersection geometry, signal timing, phasing, vehicle types, traffic composition etc. Second, calibration and validation data i.e., maximum queue lengths at any time interval at different day, are necessary to be used as a measure of the calibration and validation procedure successively.

3.5 Representation of Intersection in VISSIM:

The foremost aspect is to accurately represent the geometry defined by the number of approaches, width of each approach, and turning. The second aspect is the representation of the signal control system. This is comparatively difficult for non-lane based heterogeneous traffic of Dhaka city because of controlling signal system by enforcement i.e. traffic police. For our research, we observed 4 hour peak duration signal timing and took the average signal timing for our study area. Therefore, the representation includes the average cycle time, green time, and red time for each movement group, amber time, and phase sequence.

3.6 Identification of Sensitive Parameters:

A sensitivity analysis needs to be conducted to find out the influence of a parameter on the maximum queue lengths. The sensitivity of a parameter is generally assessed by incrementing its value by small units and the effect on the output is recorded; but as this procedure demands a large number of simulation runs we identify the sensitive parameters by changing each parameter value by a definite amount say 10 % while keeping all other parameters at their default values. The simulated maximum queue lengths are then compared with the maximum queue lengths obtained using default parameters. Thus, if changing the default values of a parameter significantly affects the maximum queue lengths, then that parameter is considered as an influencing parameter and is selected for calibration. This step is necessary to reduce the computation time by calibrating only the influencing parameters. However, as the study is executed for an urban intersection (Bijoy Sarani intersection, Dhaka) Wiedemann 1974 car following model is considered which is mainly suitable for urban traffic.

3.7 Validation:

A new data set corresponding at different time at different day should be used for validating the simulation model. But in the study area, the signal time controlled by traffic police, results in no fixed cycle time even no phase sequence at off-peak period. Thus, the data have to be collected almost at the same time but different day. The absolute error between queue length from the calibrated model and field is computed. The model can be confidently used if this error is within certain limit.

3.8 Drawing Diamond Interchange in VISSIM:

A diamond interchange has been drawn on VISSIM with two major arterial farmgate approach and Jahangir approach and with minor arterial of shangsad bhaban and Tejgaon link road approach as they exhibit less amount of traffic. The traffic volume collected from existing bijoy sarani intersection was also applied to this new interchange. Then the driving parameters were observed.

4. Data Collection and Model Development:

Regardless of the field of study or preference for defining data, accurate data collection is essential to maintaining the integrity of research. Both the selection of appropriate data collection methods and clearly delineated instructions for their correct use reduce the likelihood of errors occurring. To get comprehensive appropriate quality data set such as geometric layout of links and background map, signal timing, relative flow, proportion of motorized and non-motorized vehicles, desired speed, vehicle composition, vehicle model distribution, weight and power distribution, proportion of tuning vehicle and the measure of effectiveness data such as discharge profiles and queue length, carrying out data collection effectively and carefully is mandatory.

4.1 Data Collection:

To frame all the approaches of the intersection in a single one, a suitable platform with enough height was chosen, which was the rooftop of 8 storied adjacent building. The intersection was observed and traffic movement was recorded during peak times of the day. The intersection did not have fixed time signal and signal was controlled by traffic police according to the traffic flow. For the convenience and purpose of my research, Bijoy sarani intersection was chosen. For the collection of data, permission to use rooftop was taken formally from the building owner.

The traffic movement was recorder by video camera in the peak time of the day for the calibration purpose the traffic data from 6:00 pm-6:30 pm was used. The speed, dimensions of the vehicle, phase time, occupancy and queue length was measured directly from the field. We measured the geometric layout of the intersection directly from the field by odometer.

4.2 Extraction of Field Data:

Extraction of classified vehicle data from video records is a cumbersome task, also a time-consuming job. Vehicles that have been found in the study area are all motorized group. These are:

Car/jeep, Bus, Utility car, CNG, Leguna and Motorcycle. In Bijoy Sarani intersection having four links, each link can further be divided into four lanes (except Tejgaon link road which has three lanes), a vehicle can move into four directions from an approach, Through, Left, Right and U-turn.

That is why, to get the data from the video, the recording was slowed down to 0.25x normal speed of the video so that all vehicles can be easily counted. After even doing this, it takes to watch a single minute video for 10-15 minutes as the traffic system is non-lane based and heterogeneous and traffic moves haphazardly as soon as the signal goes on competing with each other to move faster than the other.

4.3 Model Development:

The traffic flow model in VISSIM is a discrete, stochastic, time step based microscopic model, with driver-vehicle-units as single entities. The model contains a psycho-physical car following model for longitudinal vehicle movement and a rule-based algorithm for lateral movement. The model is based on the continued work of Wiedemann. Model development in VISSIM includes geometric representation, vehicle reprentation, vehicle composition, signal control, evaluation and simulation. A satellite image of the intersection is imported into VISSIM and is used to construct the intersection geometry and all the physical measurements were matched.

Figure 1: Typical representation of Road Network in VISSIM

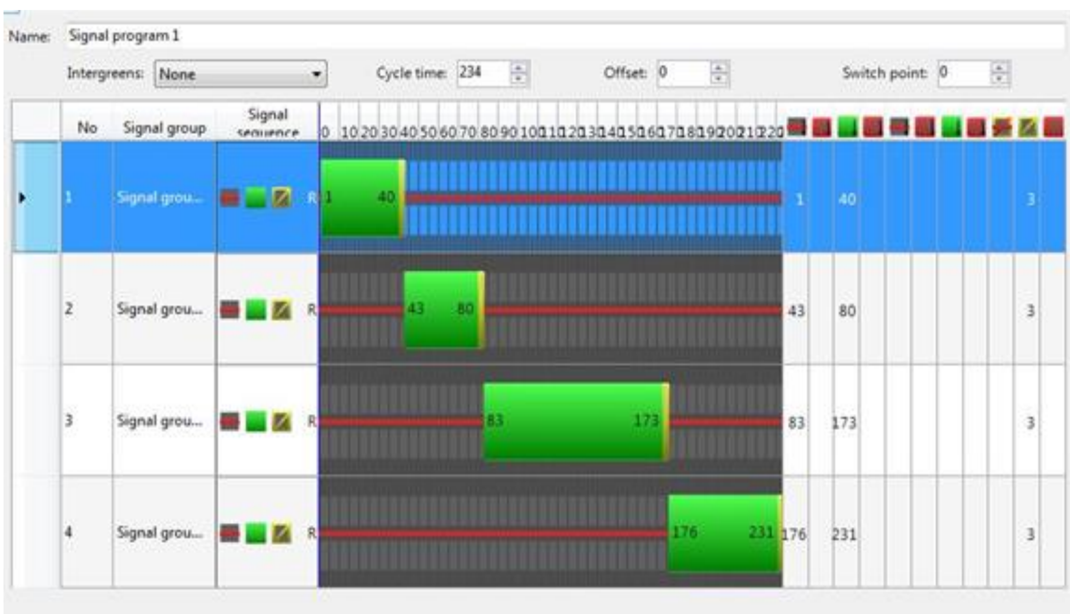

Figure 2: Signal Phases Used in this Model

After the calibration and validation of the generated model is done, the alignment is redesigned and modified with a diamond interchange. The existing model with prevailing four phase signal system is checked for introduction of Diamond interchange. For phase design, saturation flows at all the approaches and lost times are determined first. Subsequently, Travel time and delay of all phases are calculated. Various traffic parameters are analyzed according to the changes. Alternatives are compared and discussed whether the modification or measure will be suitable and efficient in terms of performance increase of the Bijoy Sarani intersection.

5. Data Analysis:

Collected field data was analyzed to find out the traffic composition of the study area and observe the traffic characteristic, such as speed of the traffics existed in the study area. A qualitative analysis was made regarding the study area to summarize the findings of points describing behavior of traffic, which would be considered in calibration of the simulation model for non-lane based traffic flow. A quantitative analysis was also done in the study area to estimate the traffic composition as well as flow composition in different routes.

5.1 Visualization of Model:

A model cannot be demanded as calibrated if the animations are not realistic. In this study a visualization check was conducted with the animation tool that VISSIM provides and no abnormal traffic movements were observed. The animation was similar to the traffic flow that was observed from the field as shown in following Figure.

Figure 3: Visualizing calibrated model with the field scenario

5.2 Calibration of Model:

As stated in methodology, the parameters that can affect delay are identified as Wiedemann 74 car-following parameters. These are ax_average, the average standstill distance; bx_add and bx_mult; and the additive and multiplicative factors respectively of safety distance. Already simulations have been conducted using the default values for parameters. So, the value of each of the parameters is now incremented by 10%, while keeping default values for all other parameters. Simulations are performed with different random seeds to reduce the effect of stochasticity. Queue lengths are obtained by simulation and the imprecision is then computed graphically. This trial is continuing until queue lengths obtained from field and simulation model match graphically with time. As manual method has been conducted in this study, trials were stopped when the two graphs match enough.

Table 1: Wiedemann 74 parameters

Parameter	Default value	Calibrated value
Average standstill distance	2.00	2.30
Additive part of safety distance	3.00	2.10
Multiplic. Part of safety distance	3.00	2.50

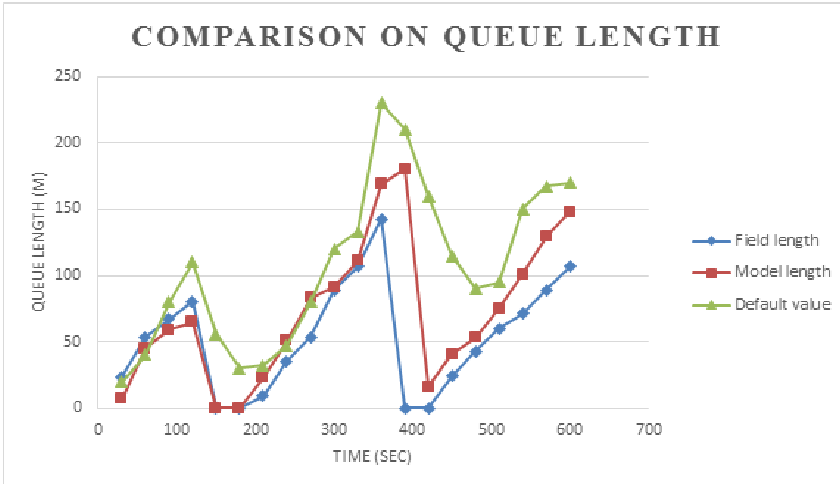

Figure 4: Comparison on Queue Lengths from Field, Calibrated Model and Uncalibrated Model.

5.3 Validation of Model:

For validating the model, the input volume, composition and maximum queue length data were collected on a different day. These data were used for validation process with calibrated value of Wiedemann 74 parameters. The maximum queue length observed in the field was compared with the maximum queue length value of validated model.

Figure 5: Validation of Model

It is observed that there is an anomaly between field data and validated data. This is because in the study area, there is no fixed cycle time and police tends to keep the signal green manually by hand until the queue length tends to be zero.

5.4 Incorporation of Diamond Interchange and Comparison of Simulated Results:

A diamond interchange was drawn on the intersection and the traffic volume and composition was maintained same as on existing situation of Bijoy Sarani. Then Travel time and Delay was compared with the existing condition.

Fig 6: Diamond interchange model

Table 2: Typical comparison of travel time for the generated model

Origin-Destination	**Distance in meter**	**Existing four phase signal**	**Diamond Interchange**
Farmgate to Jahangir gate	678.4	92.3	84.70
Farmgate to Tejgaon link road	846	369.00	318.60
Tejgaon link road to Jahangir gate	965	255.00	220.50
Link road to Shangshadbhaban	839	146.30	144.50

Table 3: Typical Comparison of delay for the generated model

Direction	Existing four phase signal			Diamond Interchange		
	Delay in sec	Stopd in sec	Stops	Delay	Stopd	Stops
Farmgate to Jahangir gate	9.20	5.50	0.36	6.50	3.50	0.22
Farmgate to Tejgaon link road	252.10	192.20	9.44	201.20	182.70	8.28
Tejgaon link road to Jahangir gate	112.30	92.20	1.63	104.20	95.30	1.53
Link road to Shangshadbhaban	118.90	102.70	1.97	104.40	89.00	2.02

Table 4: Typical Comparison of network performance for the generated model

Term	Existing four phase signal	Diamond Interchange
Average delay time per vehicle in sec	34.65	29.48
Average speed in km/hr	27.81	30.25
Total delay time in hr	79.69	59.14
Total travel time in hr	234.55	212.95

The comparison of various data extracted by simulation among alternatives (existing two phase, modified two phase and four-phase signal system) discussed, it is obvious that four-phase system will not be suitable at all and it will worsen the present condition. Most of the parameters suggest that modified two-phase system will be more effective in elevating the performance of the studied intersection.

6. Conclusion:

In this paper, calibration and validation methodology of microsimulation model of a selected corridor of Dhaka city for heterogeneous traffic is proposed. Although the calibrated model had some anomaly from the real scenario, more accurate model can be developed with extensive data for both high and low traffic volume and by considering some local context (e.g. physical and mental condition of drivers, condition of roads etc.). The notable features of the paper include representation of non-lane-based traffic, identification of sensitive parameters, setting their ranges heuristically, and determining the parameter values by iterations and after calibration and validation drawing diamond interchange with existing traffic condition. VISSIM 5.30 (student version) is used in this study as a micro-simulation tool to apply the methodology in the context of signalized intersection. Using the proposed traffic representation and tuning the calibration parameters, VISSIM is able to model signalized intersections having heterogeneous traffic reasonably well. As per study, it is evident that the modification of existing four-phase signal system can be a great alternative to facilitate better performance to the intersection. Existing Four-phase signal system is no longer suitable as far as the study results suggest. Incorporation of Diamond Interchange eliminates congestion problem to a great extent and flourish other parameters such as lesser travel time and queue length etc. The model can be tested for other traffic parameter changes as well. However, it is obvious that alternative such as a Diamond Interchange can be feasible option to lessen congestion problem of Dhaka city. This technique to improve intersection proficiency can be implemented to any North American intersection. Although the driving behavior parameters need to be adjusted due to the fact that there generally exists lane based homogenous or heterogeneous flow. Congestion in intersections is a waste of money and resources. The studied strategy can be applied to fabricate efficacious intersection that would lead to an efficient urban traffic system.

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