A Microsimulation Based Approach to Investigate Intersection Performance: A Case Study on Bhulta Intersection of Dhaka

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Abstract

Transportation planning plays a crucial role in ensuring safe and convenient movement for both vehicular modes and passengers. Dhaka is confronted with a big challenge for transportation to cope up with its lower travel speed, higher number of stops, greater delay, conflicts among through and right turning traffic etc. In this context, this study focuses on the evaluation of intersection performance using microsimulation modelling. Directional traffic count data of Bhulta intersection as a case study was used to create the base year (2017) scenario of the existing situation. Currently, this intersection faces severe performance shortages due to movement of both motorized and non-motorized vehicles. A base model was created using simulation software (Cube Dynasim) and validated against the real-world value of directional traffic count data and approach travel speed data. Various geometrical changes made to the intersection layouts and flow data for both base year (2017) and future year (2032) were put into each of the different geometric layouts: multilane without signal, multilane with signal, roundabout, right auxiliary lane and overpass. For each of the different geometrical layouts, two indicators (intersection delay and number of stops per vehicle) were measured and analysed to find out critical issues regarding their variations. In case of all of the intersection layouts, intersection delay increases with an increase in traffic volume. Bhulta intersection has shown to perform very poorly in comparison with the proposed geometric layouts. Higher intersection delay and higher number of stops per vehicle were found to create severe performance shortages for the existing layout. Among all the proposed geometric layouts, overpass has found to be the best intersection performance. It has also been found that roundabout delivers the best performance among at-grade intersections by providing lower intersection delay and number of stops. Right auxiliary lane provides comparatively better scenario in peak hour among at-grade intersections. Also, multilane without signal scenario performs better than multilane with signal scenario.

Keywords: Intersection delay, Number of stops per vehicle, Microsimulation modelling, Intersection performance

1. INTRODUCTION

Traffic operations in the congested sections of roadways are very complex since different drivers employ different techniques to travel through such sections while interacting with other drivers (Ahmed, 1999). The use of microscopic traffic simulation plays major roles in the analysis and evaluation of transport systems. Micro-simulation models are dynamic and stochastic modelling techniques that simulate the movement of individual vehicles based on car-following, lane changing and gap acceptance algorithms. The advantage of this type of modelling is the build-up and dissipation of queues and their effect on surrounding congestion. Therefore, microscopic traffic simulators can be considered as the best tool for analyzing transport systems (Barcelo & Garcia, 2003).

Traffic conflicts between vehicular movements are created when two or more roads cross each other. Such conflicts may cause delay and congestion (Prasetijo & Ahmad, 2012). Signalized intersections have a significant impact on the capacity of modelled traffic networks as they are often the focus of high volume conflicting traffic movements (NSW, 2013).

As safety and quality of travel on arterial networks tie closely to the capacity and performance of the intersections, this study aims at determining the condition of the intersection performance by making various geometric changes (Multilane, Roundabout, Overpass etc.) in the existing road network and by considering various factors (Demography, urbanization, economic growth, vehicle operating costs, GDP, induced traffic due to new road facilities nearby, vehicle ownership levels and availability of alternative transport modes etc.) that affects future traffic flow.

For the purpose of the study, Bhulta intersection on Dhaka By-pass road was selected as the study area. It was selected for the fact that it is one of the major intersection of Dhaka By-pass road. It is a key arterial route which connects the northern and north-eastern part of the country with the southern and eastern region by-passing Dhaka city. It is estimated that every day around 10,000 motorized vehicles use the Dhaka By-pass road and the numbers are continuing to increase. Consequently, the 2 lane road cannot cater for such increased traffic and there is a need to separate out the local traffic from the trans-regional traffic and create a dedicated expressway (Public Private Partnership Authority, 2017).

To create the micro-simulation model of the Bhulta intersection, Cube Dynasim software was used. Cube Dynasim is an event-based software with stochastic and dynamics outputs. It has tools which can be used to model the real transport system including the application of Intelligent Transport System (ITS) facility (Long Yue, 2015).

2. METHODOLOGY

Bhulta intersection of Dhaka- Bypass was selected as the study area due to availability of necessary data (directional traffic count data and approach travel speed). Data were mainly collected from Secondary sources. Secondary data regarding directional traffic count were collected from UDC Construction Limited. GIS map of the study area was collected from RAJUK in September 2017.

3. MICROSIMULATION MODEL

Microsimulation model captures drivers' acceleration behavior which can be classified into Car-following models and General acceleration models. The car-following model captures acceleration behavior in the car-following regime. In this regime, the drivers are close to their leaders and follow their leaders. Ahmed et al. (1996) developed a framework for a general lane changing model that captures lane changing behavior under both the Mandatory Lane Changing (MLC) and Discretionary Lane Changing (DLC) situations. Lane change is modelled as a sequence of four stages: decision to consider a lane change, choice of a target lane, acceptance of gaps in the target lane, and doing the lane change maneuver. Various gap acceptance models were developed in the early '70s based on the assumption of critical gap length. Herman and Weiss (1961) assumed the critical gap to be exponentially distributed, Drew et al. (1967) assumed a lognormal distribution and Miller (1972) assumed a normal distribution.

After micro-simulation for present scenario was finished, results (Directional traffic count and approach speed) which were used for the base model validation were extracted using the output tool. They were calibrated by identifying parameters that affect calibration process significantly. For validation of the directional traffic count and approach travel speed, Root Mean Squared Percentage Error (RMSPE) method and Percent Error method were used respectively. After the base model of present scenario along with the existing geometric layout of the intersection was validated, various geometric changes were made to the intersection layouts in Autocad, which were later imported into Cube Dynasim. At last, micro-simulation models for both the base year (2017) and future scenario (2032) were created using the simulation scenario tool of Cube Dynasim.

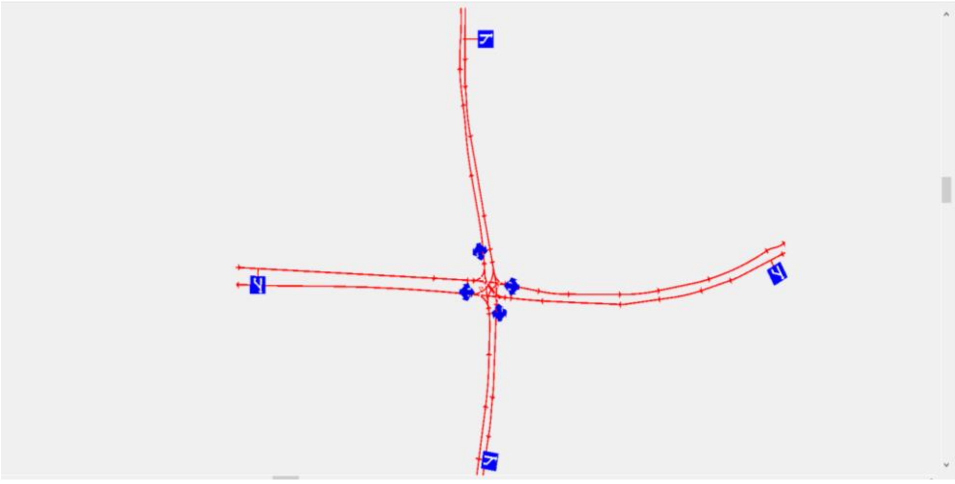

Figure 1: Creation of base model of Bhulta intersection in Cube Dynasim

After preparation of simulation models for both present and future scenario, results were extracted using the output tool. The following formula which was stated in HCM 2000, was used to derive intersection delay:

Intersection delay , $d_I\left(\frac{s}{veh}\right) = \frac{\Sigma d_A . V_A}{\Sigma V_A}$

Where,

d_A= Delay by approach (s/veh)

V_A= Approach flow rate (veh/h)

(HCM 2000: Highway Capacity Manual, 2000)

For this study, Bhulta intersection on Dhaka By-pass Road was selected as the study area. Bhulta intersection is located about 16 km East of Dhaka, the country's capital town. It connects the Dhaka By-pass road and Dhaka-Sylhet highway. The Dhaka By-pass Road starts from Naujuri, where Dhaka bypass Road N105 diverges from the National Highway N4 and Ends at Madanpur where the bypass road N105 merges with the National Highway N1. Bhulta intersection is a four-legged intersection. It is the connecting point of the two highways: Bhulta-Rupganj and Bhulta-Araihazar. For the purpose of this study, a 250-meter radius of buffer was taken centering the intersection for creating the simulation models. The reason behind choosing this specific value of radius was that there were no other major intersections within this radius.

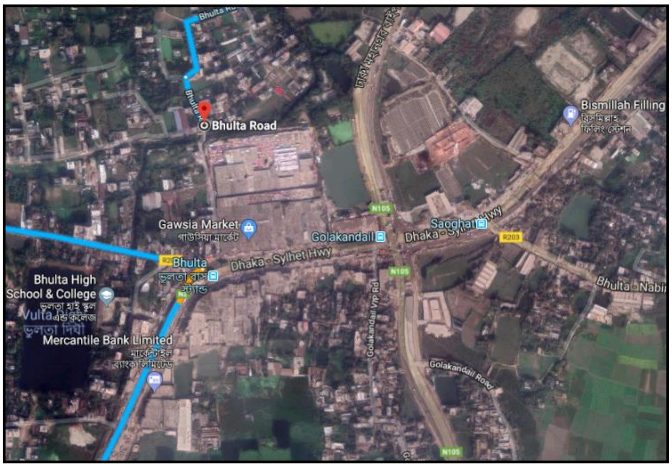

Figure 2: Bhulta intersection

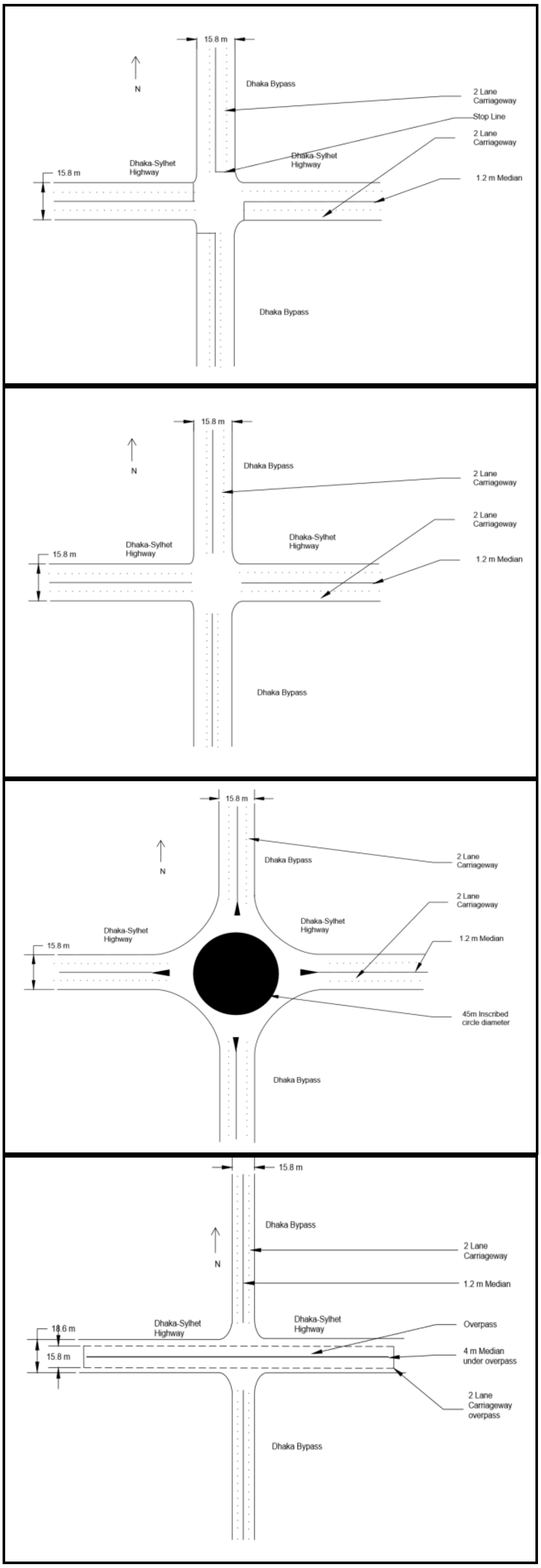

Figure 3: Schematic diagrams of the proposed geometric layouts

4. RESULTS AND DISCUSSION

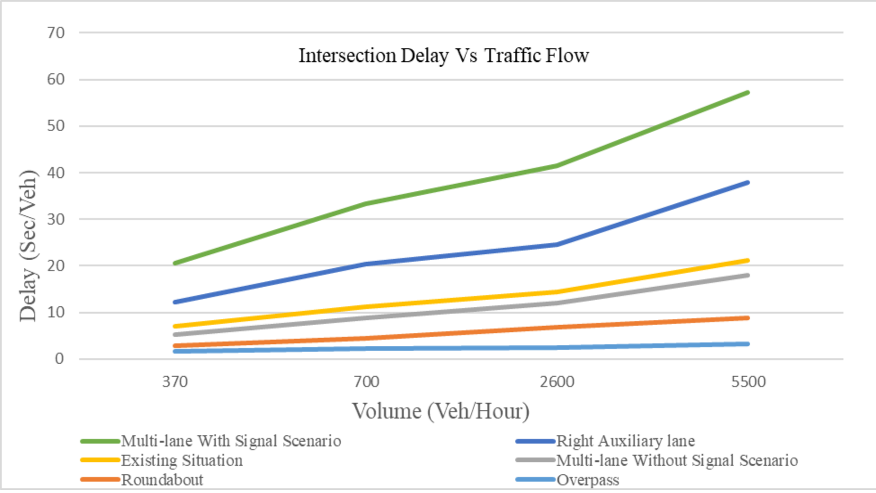

Figure 4: Relationship Between Intersection Delay and Traffic Volume for all of the Intersection Geometric Layouts

Here, all the traffic flow of peak and off peak hours in both the two time periods (2017 and 2032) were taken to see the relationship between traffic flow and intersection delay. A common scenario can be concluded from the Figure 2 that all of the intersection geometric layouts are showing an increasing trend in intersection delay with the increase of traffic flow. But different intersection geometric layouts are responding differently. From the Figure 2 it can be seen that Overpass, Roundabout, Multi-lane without Signal Scenario provide better performance than Existing geometric layout in terms of intersection delay at both high and low volume. But Multi-lane with Signal Scenario and Right Auxiliary Lane are performing worse than Existing geometric layout at both low and high volume. Overpass has the best performance among all the proposed layouts as the intersection delay remains the lowest with the ever increasing traffic flow. Among all of the cases in both 2017 and 2032, Multilane with Signal performs less than all other proposed geometric layouts. Relationship between intersection delay and traffic flow can be clearly understand from the Table 1 by measuring sensitivity of intersection delay to traffic flow. It can be seen that all the slopes are positive which refers to the fact that intersection delay is rising along with the increase in traffic volume. The higher the value of the slopes, the more the intersection layout is sensitive. From Table 1 it can be seen that existing layout has the highest sensitivity (2.47) for intersection delay with respect to traffic flow, which means intersection delay is likely to increase more with increasing traffic flow. Among all the intersection geometric layouts, Overpass has the least value of sensitivity (0.31) which means the intersection delay will rise slowly over the years with the ever increasing traffic flow. Among all of the at-grade intersection layout Roundabout has the least value of sensitivity (0.83).

Table 1: Sensitivity of Intersection Delay to Traffic Flow

Intersection Geometrical Layout	**Sensitivity of intersection delay to traffic flow**
Existing Situation	2.47
Multilane Without Signal Scenario	1.30
Multilane With Signal Scenario	2.10
Roundabout	0.83
Overpass	0.31
Right Auxiliary Lane	2.25

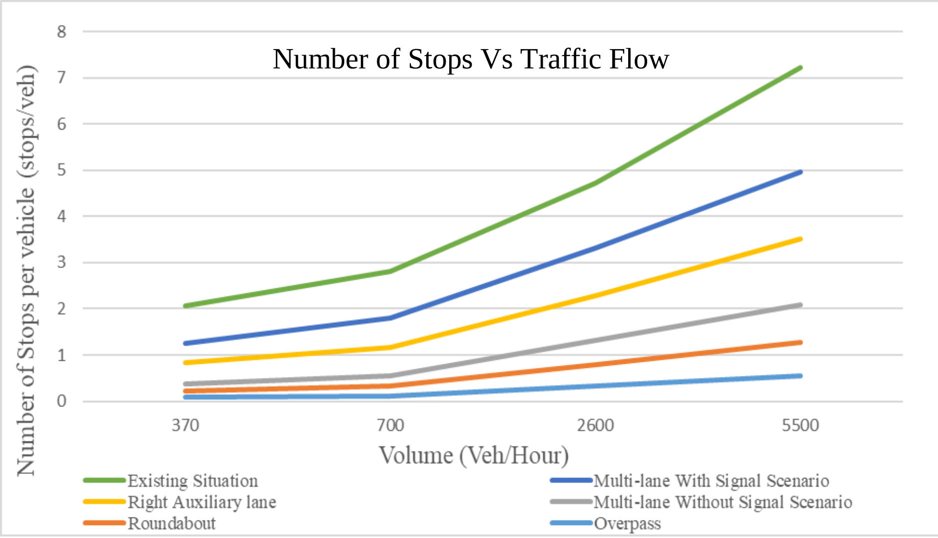

Figure 5: Relationship Between Number of Stops Per Vehicle and Traffic Volume for all of the Intersection Geometric Layouts

Here, all the traffic flow of peak and off peak hours in both the two time periods (2017 and 2032) were taken to see the relationship between traffic flow and number of stops per vehicle. A common scenario can be concluded from the Figure 3 that all of the intersection geometric layouts are showing an increasing trend in number of stops per vehicle with the increase of traffic flow. But different intersection geometric layouts are responding differently. From the Figure 3, All of the proposed intersection geometric layouts provide better performance than Existing geometric layout in terms of intersection delay at both high and low volume.

Relationship between number of stops per vehicle and traffic flow can be clearly understand from the Table 2 by measuring sensitivity of number of stops per vehicle to traffic flow. It can be seen that all the slopes are positive which refers to the fact that number of stops per vehicle is rising along with the increase in traffic volume. The higher the value of the slopes, the more the number of stops per vehicle is sensitive. From Table 2 it can be seen that existing layout has the highest sensitivity (0.28) for number of stops per vehicle with respect to traffic flow, which means number of stops per vehicle is likely to increase more with increasing traffic flow. Among all the intersection geometric layouts, Overpass and Roundabout have the least value of sensitivity (0.09 and 0.11) which means the intersection delay will rise slowly over the years with the ever increasing traffic flow. Multilane with Signal Scenario and Existing Situation provide the highest sensitivity with respect to traffic volume which reflects more increases of number of stops per vehicle with respect to increasing traffic volume.

Table 2: Sensitivity of number of stops per vehicle to traffic flow

Intersection Geometrical Layout	**Sensitivity of number of stops per vehicle to traffic flow**
Existing Situation	0.28
Multilane Without Signal Scenario	0.13
Multilane With Signal Scenario	0.21
Roundabout	0.11
Overpass	0.09
Right Auxiliary Lane	0.19

4. CONCLUSIONS

It has been found that introducing any kind of signalling system is not suitable for Bhulta intersection even in the case of constructing Multilane with Signal Scenario and Right Auxiliary Lane in the place of existing two-lane layout. Multilane without Signal scenario provides much better performance than Multilane with Signal scenario. Separate lanes for non-motorized vehicles would be recommended in order to reduce conflicts and intersection delay. It has been also found that intersection delay increases with increase in traffic volume for all the proposed intersection layouts. Overpass has the best performances among the proposed layouts and offers lower intersection delay and a lesser number of stops for both time periods (Present and future) because of less number of conflicts among various modes. Except for Roundabout and Overpass, all the proposed geometric layouts are more sensible with respect to traffic volume which reflects more increase of intersection delay and number of stops per vehicle with an increase in traffic volume.

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