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Traffic Scheduling Simulation: The Case of Dhaka City

Md. Sanowar Hossain, Moudud Ahmad, Md. Minarul Islam and Md. Asadujjaman

Increasing rate of vehicles on the road, as well as faulty and manual traffic signaling systems, causes a huge traffic congestion which exacerbates during peak hour and makes city roads standstill. Traffic congestion not only causes mental stress and environmental effects but also snatches a large amount of money from the economy. The economic losses are: firstly, the travel time cost caused by losing working hours because the time spent on traveling has an opportunity cost and secondly, the vehicle operating cost by running vehicle during congestion period. In this paper, these two costs have considered for designing the optimal traffic management system. We have found a solution without installing new infrastructure to the existing road capacity. A simulation analysis was performed using PTV VISSIM software for analyzing different scenarios to design the optimal traffic management system.

Keywords: Traffic Congestion Cost, Simulation, PTV VISSIM, Signal Design

1. Introduction

Dhaka, the capital city of Bangladesh is the most densely populated cities in the world. Traffic congestion in Dhaka city is very problematic. The residents are experienced to undergo physical stress and suffer financial losses in terms of man-hours lost the working day. The print and electronic media, as well as social media, cover some news related to traffic congestion. In order to minimize the intensity of the traffic jam in Dhaka city, present and previous government have taken a number of attempts like the construction of roads, highways and over bridges including the special meeting with the agencies.

Dhaka city compelled the rise of increased development without appropriate monitoring within a glimpse of last few decades which resulted in huge urban transport system difficulties. Inadequate transportation system has noticeably affected the physical form and performance of the city. Traffic congestion is now one of the main problems in our daily life. Major causes for this congestion are infrastructure problem, system problem, and human behavior problem etc.

Dhaka city's traffic congestion problem has considered an alarming proportion. People are timid to get out of their houses because the journey from home to office or business place takes away the vital hours that he could devote to his work. Other than being late in the offices, work places or on any scheduled appointments, mental stress, exhaustion and loss of effective man hours are an unavoidable loss of the resources of the whole country.

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The effect of the traffic jam is huge not only for the economy but also the environment. The impact of traffic jam may be different ways where major identifications were found mainly the impact on the economy, health, environment, and industry. Also, the impact on the industry has a great influential effect on the economy. Traffic congestion can impose additional costs on businesses associated with freight and service deliveries. For instance, delay in delivering time sensitive freight can in some cases impose additional inventory costs, logistics costs, and reliability costs or just in time processing costs onto businesses that ship or receive the products. As traffic congestion increased the additional business operating cost and transportation cost it also has an effect indirectly with its productivity. Congestion hence reduces the size of business market areas, customer delivery market areas, and shopper market areas.

The major objective of the study is to estimate the congestion cost and design the optimum signaling system for Shahbagh chatter, Dhaka. The whole process was analyzed through the simulation model with the help of PTV VISSIM software.

The remaining section of the paper is organized as: in section 2 literature review is discussed on this problem and we found a great chasm in the whole period of the study like the cost associated with traffic congestion problem what is our main concern in our paper. In section 3 illustrates the research methodology and data collection. Section 4 organizes the result analysis. Section 5 describes discussion and section 6 concludes the paper with future work.

2. Literature Review

Traffic congestion is a worldwide problem not only in Bangladesh but also in many developed countries. The traffic jam can be considered as one of the serious global problems for both developed and under developed countries (Najneen et al. 2010; Ahsan and Haque 2002). The author analysis both developed and under developed countries to focus the congestion but didn't consider the congestion cost. Dhaka city's traffic system is considered to be one of the most critical ones in the world. According to Hoque et al. (2004) Congestion in Dhaka has been a growing problem during the last 15 years.

Traffic congestion causes and impact have been noticed very extensively in Bangladesh now- a-days. Mahmud et al. (2012) described faulty traffic signaling systems, inadequate manpower, and narrow road spaces and overtaking tendency of drivers create prolonged traffic congestions and intensify sufferings of commuters keeping people motionless as well as creating suffocating condition in the streets. They have observed a rise in hypertension diseases and fall of tolerance among Dhaka dwellers. These behavioral disorders are harmful to human relationships.

Khan and Islam (2013) and Chakrabartty and Gupta (2015) showed the estimation of congestion cost in Dhaka city including vehicle operating cost (VOC), travel time cost (TTC). They consider the whole Dhaka city but didn't analyze the situation at all or how to minimize the total congestion cost. Authors only estimate the total congestion cost without showing any analysis. Traffic congestion generation and signaling system need an extensive analysis to acquire the actual scenario of the problem. This situation can be handled by using simulation for getting the actual result. From

literature background, we found in Europe and North America they used advanced traffic management system with the help of simulation analysis for obtaining the lowest possible congestion on the road. Krajzewicz et al. (2012) and Matin, Herani and Warraich (2012) have presented that a coarse overview of the microscopic traffic simulation package SUMO. They used PTV (VISSIM), TSS (AIMSUN), Quadstone (Paramics), and Rioux Engineering (TEXAS) software for analysis the overall process. They studied total 83 intersections in British Columbia, Canada were modeled in VISSIM. Vigos and Papageorgiou (2010) developed a Kalman-filter-based real-time estimator for the vehicle count within signalized links, using three detector cross stations, to allow for reliable estimates on the basis of one single time-occupancy measurement that is typically available in urban signalized links.

Miller and Horowitz (2007) showed that Free Sim, which is a fully-customizable macroscopic and microscopic free flow traffic simulator. They introduce Graph algorithms for executing the entire freeway system or for the individual vehicle. They didn't simulate any real life situation on their research. Huang et al. (2013) built a VISSIM simulation model and the Surrogate Safety Assessment Model (SSAM) approach provided reasonable estimates for the traffic conflicts measured at signalized intersections. They developed a linear regression model to study the relationship between the simulated conflicts and the observed conflicts.

From the literature review, it can be seen that designing a network for advanced traffic scheduling in Bangladesh for optimizing the total congestion cost is the largest challenge nowadays. Therefore, this research has tried to find an alternative way without costing or changing the infrastructure to reduce the traffic scheduling problems. This paper considered the travel time cost, vehicle operating cost as well as confliction point. The existing traffic control system has analyzed with simulation model with practical design. For this purpose, PTV VISSIM software has been used to analyze the system with simulation and design the road network for minimizing the traffic congestion cost.

3. Methodology and Data Collection

Firstly, a traffic congested area was chosen. Secondly, data was collected from Dhaka Metropolitan Police (DMP), Bangladesh bureau of statistics (BBS), Bangladesh Petroleum Corporation (BPC). Then, a proposed junction was designed by PTV VISSIM software. After that, the result was analyzed by running the simulation. Traffic police of DMP- traffic wing gave the raw data. The data here represented was an average data which was collected on the weekly basis and at peak hour (8 AM- 4 PM).

Table 1 shows the number of different vehicles comes at Shaahbag Junction in one hour.

Table 1: Vehicle Input at Shahbagh Junction

Road Name	Bus	Car	Taxi	Truck	CNG	Motorcycle	PCU
Shahbagh Road	177	234	15	25	23	35	884
KNI Ave.	189	216	75	46	34	45	1024
TSC Road	0	138	35	5	25	62	216
MV Road	188	128	65	54	76	35	965

3.1 Junction Design

Dhaka is one of the populist cities in the world and Shahbagh chatter, a junction point, is one of the most congested roads in Dhaka city. When the junction was designed the parameters mainly consider are vehicle speed, queue length, vehicle travel time, Network performance, Confliction zone. The four junction road named as Shahbagh road, Kazi Nazrul Islam Avenue (KNIA), Mawlana Vashani Road (MVR) and TSC road. The infrastructure of the present junction has available eight lanes. Lane distribution defines distributed a total lane with the pre-assigned route. In this model, the system of the traffic movement minimizes the overall signal. This causes a great effect to minimize the overall traffic congestion cost. By lane distribution, it can possible to assign the vehicle who wants to go left side without any signal. The vehicle who wants to go the right side may turn right from a predefined distance and have to face the signal. For this purpose, a simulation model has developed to analyze the overall system. In this study, PTV VISSIM software was used to demonstrate the simulation for analyzing the junction.

Figure 1 shows the existing Shahbagh junction and Figure 2 shows its corresponding Confliction zone. Figure 3 shows the proposed Shahbagh junction and Figure 4 shows its corresponding Confliction zone below.

Figure 1: Shahbagh Junction (Existing) **Figure 2: Confliction Zone**

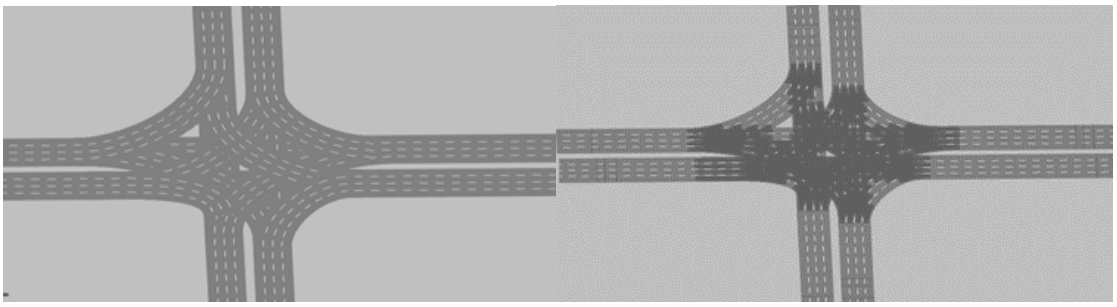
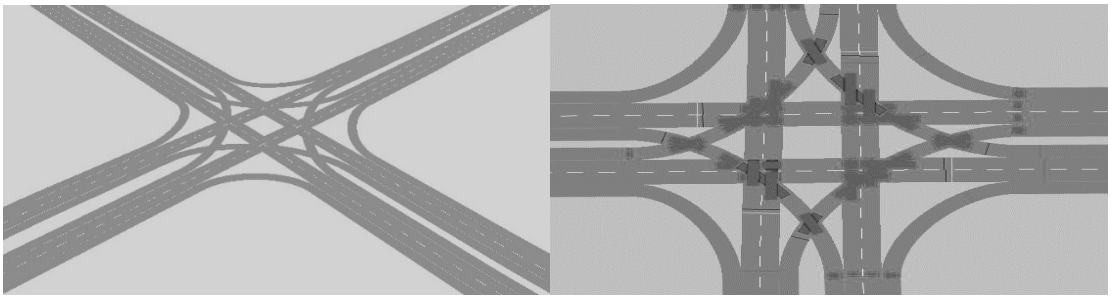


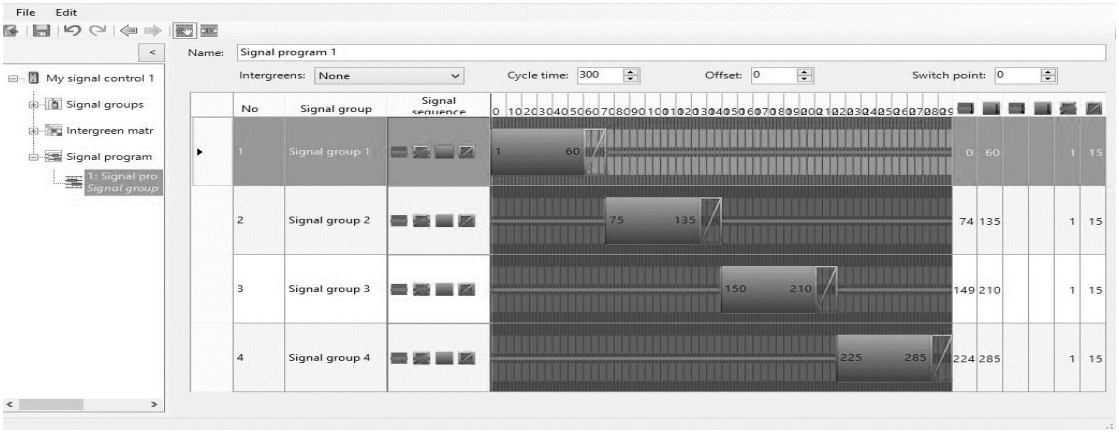
Figure 3: Shahbagh Junction (Proposed) **Figure 4: Confliction Zone**



PTV VISSIM is a microscopic, time step and behavior-based simulation model developed to model urban traffic and public transport operations and flows of pedestrians. VISSIM, the name is derived from "Verkehr in Städten –Simulations Modell" (German acronym for Traffic in Towns: Simulation). The software offers flexibility in several aspects the concept of links and connector help users to model geometries with the highest level of complexity. This software vastly used in Europe and America. VISSIM which helps to design the system very comfortable to use and theoretically correct that helps to understand the practical situation of a system. Some common tool in network objects is link, connector, vehicle input, vehicle route, and the control signal which helps to design the system.

The signal design is one of the major problems in Bangladesh because of manual signal control. In this simulation model signal heads were coded in VISSIM for each travel lane individually at the location of the signal stop line. Four pairs of the signal head were designed by programming the control signal. 15 sec had been taken for the amber signal that's why the vehicle can easily pass. It was an allowance time for the vehicle to pass normally without crashing. Passing the time of each group of the signal is 60 sec with its multiple. In this system, the left lane was always open to moving but others must wait until the signal is open. This signal design will be fruitful when the entire junctions follow the same rule. Figure 5 shows the proposed junctions signal control system.

Figure 5: Signal Control Cycle



3.2 Cost Estimation

Travel time cost and vehicle operating cost were estimated in this paper to obtain optimal traffic schedule. For this reason, a simulation analysis for both existing and proposed model was analyzed through PTV VISSIM software. The travel time of the vehicles on each road was recorded through converted the raw data in a synchronous way and therefore travel time cost was calculated for the existing and proposed system. The equation was a modified form of the equation developed by Khan and Islam (2013).

$$TTC=\sum_i(TT \times VOT \times Ci \times N) \quad \text{..... (1)}$$

Where, TT = travel time in sec, VOT = value of time in taka, Ci = capacity of vehicle type i, N = vehicle no.

Travel time of existing traffic scheduling system is shown in Table 2 for TSC road, Table 3 for MVR and KNIA.

Table 2: Travel Time of Existing Traffic Scheduling System (TSC Road)

Observation no.	Travel time in sec (Shahbagh road to TSC road)			
	Car	HGV	Bus	Bike
1	84.1	123.4	320.9	495.8
2	316.9	306.3	335.8	564.9
3	309.7	301.1	305.3	
4	319.2		289.5	
5	258.9		248.4	
6	254.2			
Avg.(sec)	257.17	243.6	299.98	530.35

Table 3: Travel Time of Existing Traffic Scheduling System (MVR and KNIA)

Observation no.	Travel time in sec (Shahbagh road to MV road)				Travel time in sec (Shahbagh road to KNIA)			
	Car	HGV	Bus	Bike	Car	HGV	Bus	Bike
1	98.1	368.9	334.6		100	354.4	113.3	
2	335.7	383.5	340.9		96.2		111.6	
3	326.9	383.3	330.2		93.3		342.8	
4	331.2	373.5	351.5		98		335.2	
5	308.7	355.4	350.5		321.7		345	
6	277.1	368.8	333.4		317.7		333.5	
7			334.2		312.3		310.9	
8					318.5			
9					315.2			
10					340.2			
11					285.1			
12					278.2			
Avg.(sec)	279.62	372.23	339.33	0	239.7	354.4	270.34	0

Travel time cost for existing system can be calculated as follows by Eq. 1.

TTC = 0.083×72×40×177 = 42310.086 taka, for car, TTC = 0.071×80×3×234 = 3987.364 taka, for HGV as truck and lorry, TTC = 0.06×50×3×25 = 225 taka, for bike, TTC = .0128×56×2×35=70.565 taka
Total TTC = 46593.01 taka
Travel time of proposed scheduling of traffic system is shown in Table 4 for TSC Road and Table 5 for MVR and KNIA.

Table 4: Travel Time of Proposed Scheduling of Traffic System (TSC Road)

Observation no.	Travel time in sec (Shahbagh road to TSC Road)			
	Car	HGV	Bus	Bike
1	100	200	300	600
2	87.6	138	100.4	134.8
3	91.4	131.3	103.7	
4	95.3	132	131.4	
5	110.1		133.8	
6	109.8		132.6	
7	112.9		131.4	
8	127.9		150.1	
9	123.2			
Avg.(sec)	109.47	133.77	126.2	134.8

Table 5: Travel Time of Proposed Scheduling of Traffic System (MVR and KNIA)

Observation no.	Travel time in sec (Shahbagh road to MV road)				Travel time in sec (Shahbagh road to KNIA)			
	Car	HGV	Bus	Bike	Car	HGV	Bus	Bike
1	99.2	373.1	137.3	325.3	186.4	197.9	196.5	197.9
2	95.3		315.9		178.7	198.8	193	
3	306.6		325.8		172	176.5	183.9	
4	315.5		314.2		195.1	188.3	198.8	
5	322.5		335.5		154.6		174.7	
6	331.9		327		157.2			
7	309.7		320.1		158.9			
8	289.7		328.3		162.8			
9	307.3		328.7		170			
Avg.(sec)	264.19	373.1	303.64	325.3	168.34	190.35	189.38	197.9

For bus, the travel time cost for proposed model of the traffic system is calculated as follows.

TTC = 0.035×72×40×177 = 17841.6 taka
For car TTC = 0.03×80×3×234 = 1700.4 taka
For HGV = 0.037×50×3×25 = 139.3 taka
For bike = 0.021×56×2×35 = 82.32 taka
So total travel time cost = 19763.64 taka

This analysis found that for the existing system, the travel time cost due to excessive traffic congestion in Shahbagh junction cost is increasing at a high rate. The study showed around forty-six thousand five hundred ninety-three of BDT loss in just one

hour. The amount increases when the travel time increases due to excess traffic jam in the junction. The proposed traffic management system helps to mitigate vast traffic congestion. The proposed system cost only around nineteen thousand seven hundred and sixty-three BDT for the travel time loss. From the existing system, this amount is quite lower. Therefore, for minimization of the travel time, the system should be more robust with its other junction.

Individual items associated with vehicle operation on which expenses were directly incurred. The energy needed to propel the vehicle other light consumables associated with the mechanical working of the drive-train occasional replacement of vehicle's contact surfaces with the guide way vehicle repair and maintenance, and vehicle depreciation. For junction of Shahbagh, we calculated vehicle operating cost using Eq. 2.

$$VOC = \sum_{v,f}(\mathrm{N} \times \frac{run}{Runperlitre} \times FC) \quad \text{..... (2)}$$

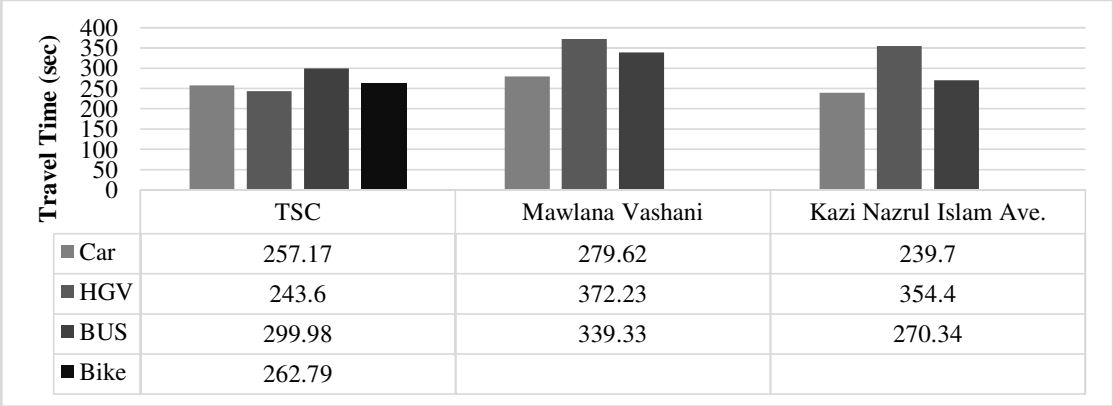
Where, N= vehicle no. and FC= Fuel cost
For diesel fuel operating engine, vehicle operating cost is:
VOC = 274×0.5/15×65=593.67 taka, petrol and CNG found 580 and 51.91 taka

Therefore, the total vehicle operating cost is 1225.58 taka. A study by Khan & Islam (2013) has concluded that Vehicle operating cost (VOC) is considered 40% of traffic congestion. As a result, for the calculation, it was considered only 500m road length for analysis the congestion cost. The amount extra has to pay for the VOC is BDT five hundred. This sounds like a small amount but increases the number of vehicles and the number of road length that will increase the vehicle operating cost.

4. Result Analysis

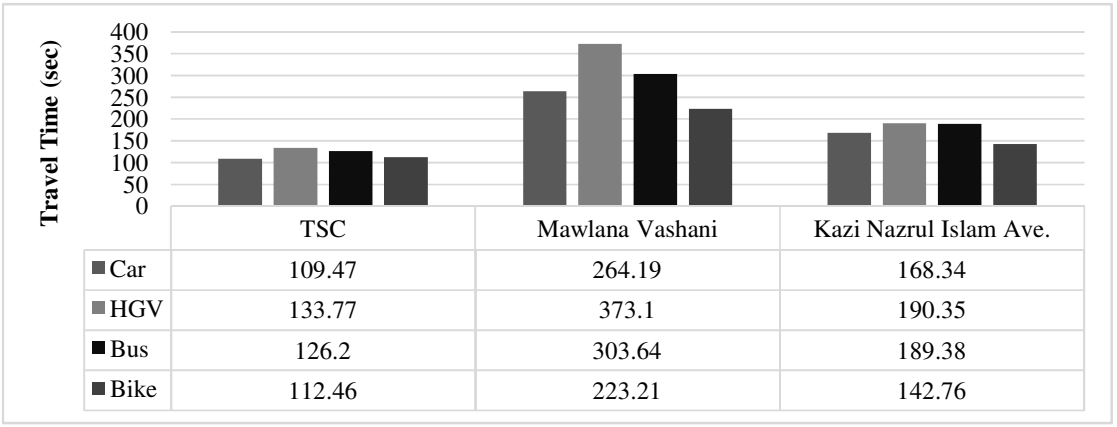
Mainly, travel time, queue length, performance analysis and confliction zone have taken for the result analysis. Performance analysis also discussed in result analysis for observing the overall performance of the two models. In proposed model, it can be seen that the overall travel time was less than existing traffic management. Blockage brings about abundance fuel utilization and expanded costs that include the cost of the fuel and in the estimation of the driver's time. Not all types but different types of vehicle like- car, bus, HGV (Heavy Guided Vehicle) and bike have been considered for the simplification of the calculation. The travel time of these vehicles from Shahbagh road of existing traffic system is shown in Figure 6 and the proposed system is shown in Figure 7.

Figure 6: Travel Time from Shahbagh Road of Existing Traffic System



	TSC	Mawlana Vashani	Kazi Nazrul Islam Ave.
Car	257.17	279.62	239.7
HGV	243.6	372.23	354.4
BUS	299.98	339.33	270.34
Bike	262.79		

Figure 7: Travel Time from Shahbagh Road of Proposed Traffic System



	TSC	Mawlana Vashani	Kazi Nazrul Islam Ave.
Car	109.47	264.19	168.34
HGV	133.77	373.1	190.35
Bus	126.2	303.64	189.38
Bike	112.46	223.21	142.76

From figure 6 and 7, it can be seen that travel time for HGV had increased respect to proposed model. This situation is analyzed from table 2 and 4. Table 2 shows six HGV passed within time interval but in table 4 the HGV vehicle just passed one. That's why the standard deviation was much more than table 4. As the speed of HGV was controlled in proposed model, the corresponding travel time increased.

The existing system of traffic management of Dhaka city in Shahbagh junction is quietly mismanaged that's why a huge travel time needs to cross the junction In existing system the traffic travel time in TSC road around 250 sec for the car, 300 for the bus, heavy guided vehicle take around 250 sec as average. Also in MVR, it can be seen that the travel time for heavy guided vehicle is considerably around 370 sec. But in proposed traffic management system the travel time decrease in a sufficient manner. Therefore, the proposed system of traffic management is a great endeavor towards minimizing the city's traffic congestion cost.

Existing and proposed traffic counting is shown in Figure 8 (at Shahbagh road), Figure 9 (at MVR) and Figure 10 (at KNIA).

Figure 8: Existing and Proposed Traffic Counting at Shahbagh Road

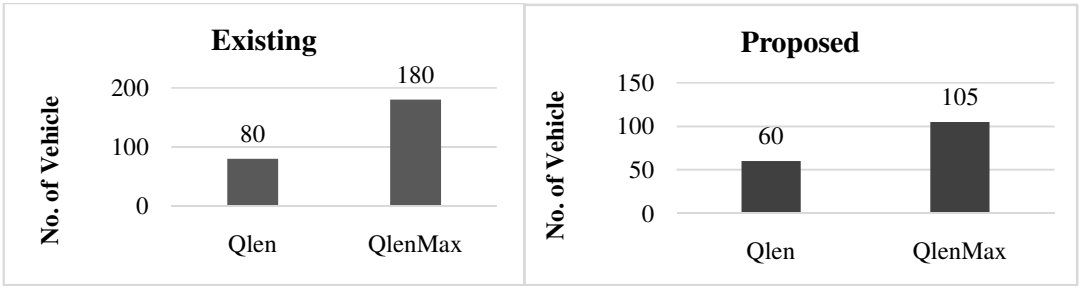


Figure 9: Existing and Proposed Traffic Counting at MVR

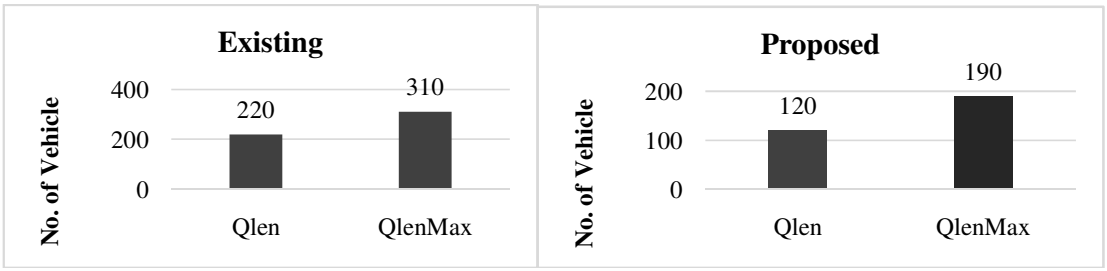
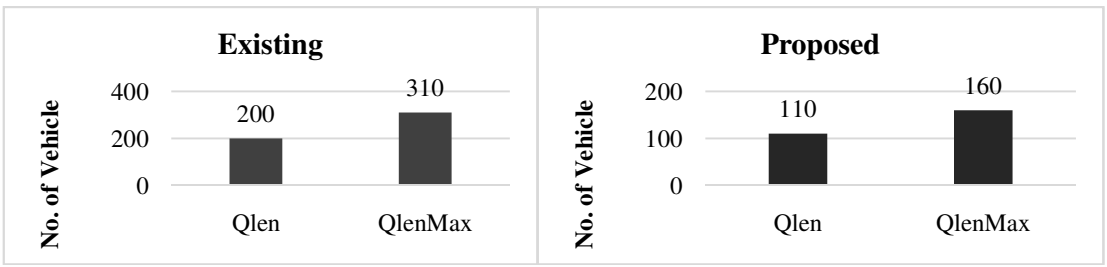


Figure 10: Existing and Proposed Traffic Counting at KNIA

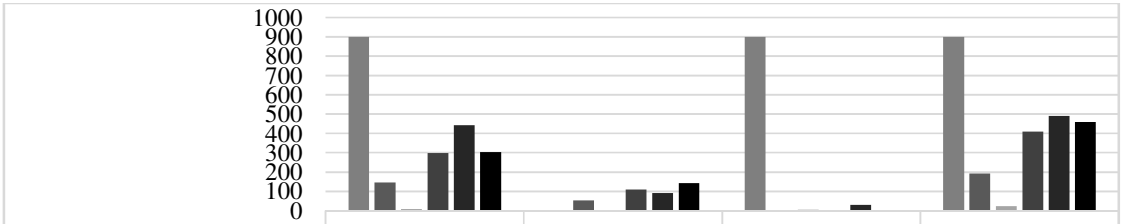


Queue length is another factor which determines the overall performance of the system. This paper showed a strategy to decide the total number of the vehicles in line at a signalized condition. Count queue in the different road in the existing system and proposed system. The study also showed that the estimation of traffic queue length is important to decide the performance of a system.

With the help of PTV VISSIM software, the performance evaluation for 10 consecutive times has analyzed which takes 900 seconds for each time interval for each simulation in a PC having 3.10 GHz with 4 GB RAM. Delay average means the minimum time for the delay of each vehicle from Shahbagh to other roads. Vehicle active represents the total active vehicle on the road intersection. Speed average indicates how the vehicle runs with its predetermined speed.

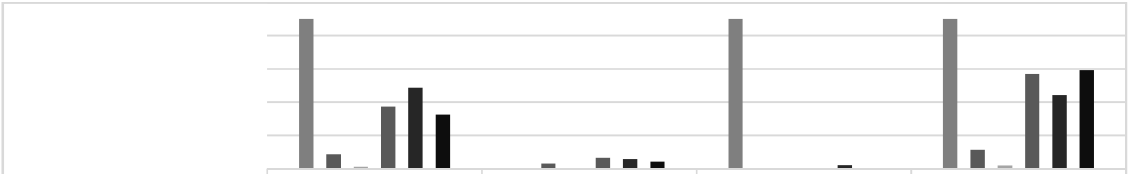
Figure 11 shows the performance evaluation of existing system and Figure 12 shows for the proposed system respectively.

Figure 11: Performance Evaluation of Existing System



	Average	Standard deviation	Minimum	Maximum
Time Interval(sec)	900	0	900	900
Delay Average(sec)	145.734342	53.359453	0.004319	191.305817
Speed Average(km/h)	7.538438	3.690539	5.265725	23.284834
Distance Total(m)	297.754196	108.56719	1.951398	409.889187
Vehicle Active(Veh. No.)	442	92	30	491
Vehicle Arrive(Veh. No.)	304	141	0	460

Figure 12: Performance Evaluation of Proposed System



	Average	Standard deviation	Minimum	Maximum
Time Interval(sec)	900	0	900	900
Delay Average(sec)	85.734	30.359	0.0031	112.305
Speed Average(km/h)	10.5384	2.69	0.65	16.24
Distance Total(m)	372.75	64.46	1.951	569.79
Vehicle Active(Veh. No.)	487	56	20	442
Vehicle Arrive(Veh. No.)	324	41	0	593

From Figure 11 and Figure 12, it can be easily seen that the time travel, the delay time, the average time travel in proposed model is less than the existing system. Therefore, the proposed method minimizes the overall travel time and the delay. From the upper two graphs, it is seen that the existing system has a drawback with its excessive delay time because of its relative flow and speed control barrier.

5. Discussions

Traffic congestion cost is a huge amount of loss during peak hour. This study provides a sophisticated model for the economic analysis of the traffic congestion considering a little portion of Dhaka city. This study found that the city's major traffic congestion can minimize through different pragmatic decisions and overall management of traffic system. Increasing travel time in the pick hours is minimized by the simulated model using VISSIM software. The city dwellers just lost around forty-six thousand Bangladeshi taka only in one hour for travel time loss and also about five hundred taka for extra vehicle operating cost which incurred only in half kilometer road. In this research work, it was just concentrated to the travel time and

the vehicle operating as a prime congestion cost and scheduling i.e. signaling of the vehicle as a prime obstruction and only one junction was considered where the entire routes have same numbers of the lane. Therefore, the future aspirants can consider other junctions with the accumulation of all other congestion costs to find the real amount.

6. Conclusions

Bangladesh economy swells day by day with an increasing rate of GDP in every year. Increasing its overseas investment on its garments industry, IT sector and cement industry etc. make its growth at a high rate. That's why, to fulfill the transportation problem, a huge number of vehicles enter in the road of Dhaka city every day. This increasing rate of vehicle blocks the road which causes world's one of the worst traffic congestion. Along with the signaling fault in traffic system in Dhaka and the lack of awareness of people plays a major role for the highest traffic congestion in that region, which causes a loss of huge amount of money every day from the economy. Therefore, a sustainable and advanced traffic management system is necessary to maintain its growth of the economy. In our paper, we have designed a simulation based traffic scheduling system, which is more efficient than the existing traffic system without installing new infrastructure to the existing road capacity. At the same time, the proposed approach reduces the traffic congestion cost and increase the smoothness of flows which ultimately reduces mental stress and environmental effects. Although we have reduced the overall traffic congestion cost but we could not accumulate the whole data of Dhaka city in our research spectrum. Moreover, it is our limitation to just consider the cross section where there are an equal number of lanes in the roads.

Finally, success in achieving smooth traffic flow in Dhaka city will bring to light, if the government takes steps to ensure proper traffic scheduling and management with mass infrastructure program.

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