CALIBRATION AND VALIDATION OF MICROSCOPIC SIMULATION MODEL FOR NON-LANE BASED HETEROGENEOUS TRAFFIC STREAM OF DEVELOPING COUNTRY

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ABSTRACT

Micro-simulation is a widely used and one of the most effective ways to predict traffic behavior of urban intersections and corridors. However very few simulation models have been developed for the non-lane based heterogeneous traffic streams of the developing countries. The advanced microscopic traffic simulators like CORSIM, MATSim, PTV VISSIM, PARAMICS etc. with the in-built default characteristics do not represent the non-lane based heterogeneous traffic conditions. In this study the state-of-practice micro-simulator PTV VISSIM has been used to evaluate the peak-hour traffic operating condition for non-lane-based heterogeneous traffic prevailing in a selected urban corridor of Dhaka city. To replicate the real scenario, several local vehicles were modeled in 3D Studio-Max and converted into VISSIM recognizable vehicle element by V3DM. The model was duly calibrated using field data and validated using Geoffrey E. Heavers (GEH) statistic comparisons or GEH values. The 1.29 kilometer long corridor namely the Moghbazar-Kakrail Corridor (MKC) has been modeled along with three major intersections. With the model the existing traffic operating condition of the selected corridor was found out. The calibrated parameters can be effectively used to build, calibrate and simulate traffic conditions of other corridors of Dhaka city with heterogeneous non-lane based traffic streams.

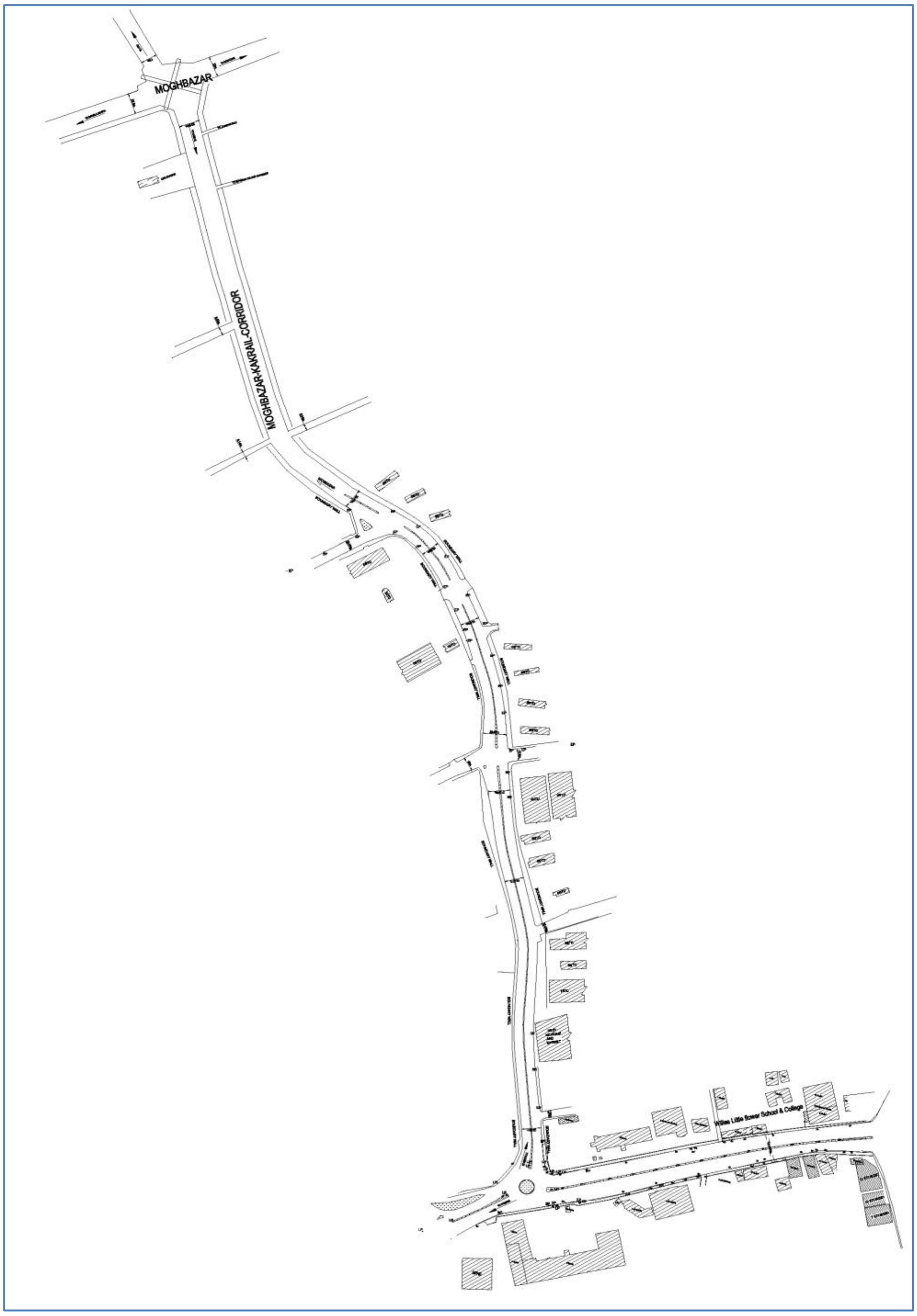
Introduction

Traffic growth in the road network of large cities in developing countries, like Bangladesh, is a serious concern from the traffic engineer's point of view. Traffic should be a major consideration in the planning of new or expanding developments. Simulation is an important and effective tool to estimate the outcome of any existing or future development on the road network. To do this the developing countries with heterogeneous traffic condition need to use the proper tools which replicate the real traffic scenario. Traffic simulation models can be an effective tool in this regard. Again, most of the models which are developed for heterogeneous traffic condition deal with lane-based traffic only. In a metropolitan city of a developing country, for instance, Dhaka city of Bangladesh, where lane discipline is not common, this cannot give dependable predictions **[1]**. An attempt has been made by Lawrence and Chiung-Wen **[2]** to develop a particular-hoping model with fixed moving rules to describe motorcycle's moving behavior in mid blocks of heterogeneous traffic flows. Chu et al. **[3][4]** analyzed several specific behaviors of the motorcycle traffic including overtaking and paired riding behaviors at mid-blocks, deceleration behavior at signalized intersections and the speed-flow-headway relationships of motorcycle traffics. Previously Hossain (2004) **[5]** calibrated the heterogeneous traffic model to match saturation flows measured by video at an intersection in the city of Dhaka. In this study a simulation model has been developed using rickshaw, leguna, CNG, Bicycle to replicate the real scenario. The model has been developed for a selected busy corridor of Dhaka. The model was calibrated from actual field data and using the outcome the total delay for an intersection of that corridor was estimated.

Selection Of Corridor

Model was developed for Moghbazar-Kakrail Corridor (MKC), one of the busiest roads in Dhaka city running in North-South direction. This corridor was selected mainly because of two reasons: firstly this corridor is suffering from huge delays because of the on-going flyover construction and secondly the numbers of NMV as well as non-standard vehicles are high in this corridor. On 7th March of 2011 the Executive Committee of National Economic Council (ECNEC) had approved the Tk 7.73 billion Moghbazar- Mouchak project to construct the 7.75-kilometer long flyover, aiming to ease the worsening traffic congestion in the area. The construction started on 16th February 2013 with a deadline of December 2014. But recently the deadline has been extended till June

Figure 1: Moghbazar-Kakrail corridor

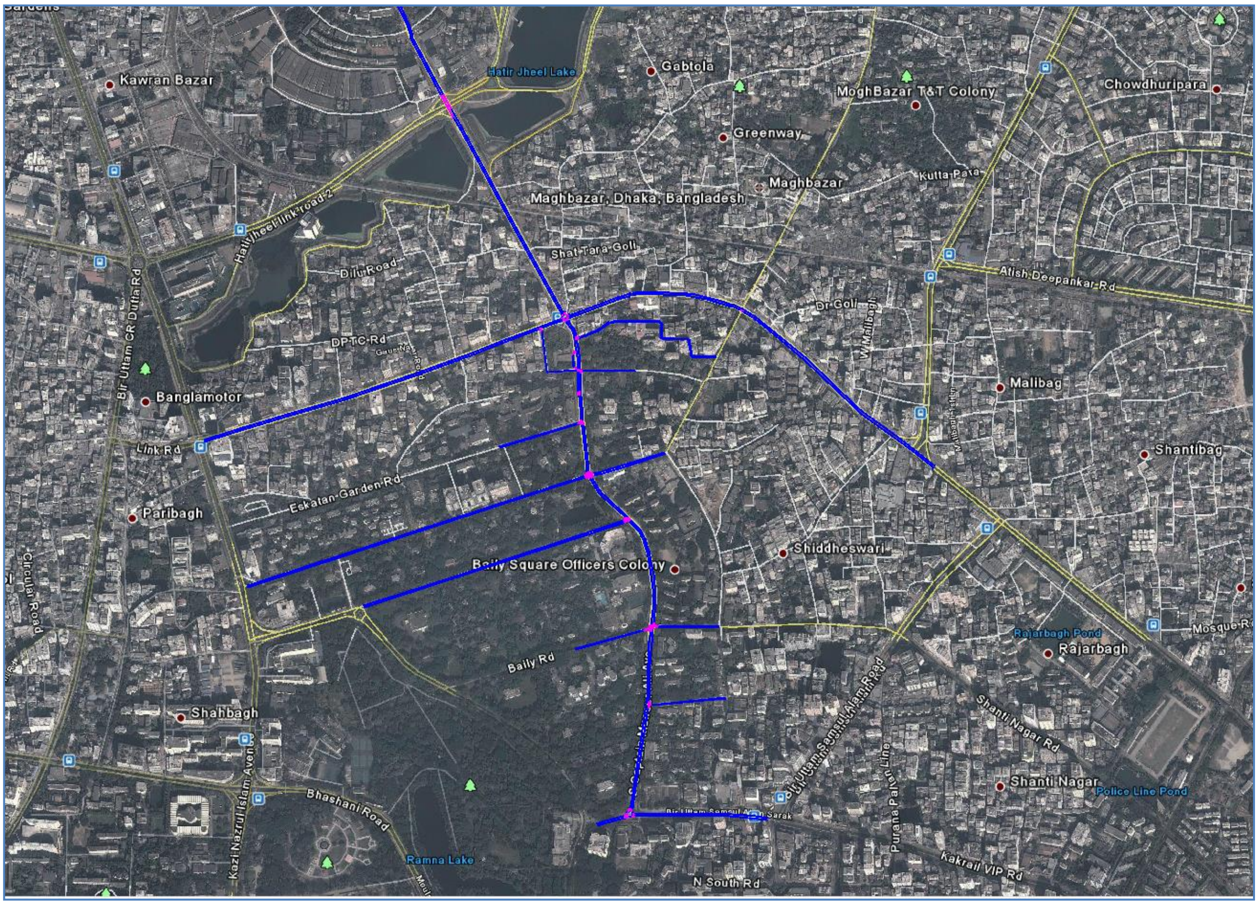


2015. For the construction of Moghbazar-Mouchak Flyover this road segment is severely affected, the worst sufferer is the 1.8 Km road segment from Moghbazar intersection to the Sat Rastar More.The volume of pedestrian in Moghbazar intersection is very high and the situation is worse than ever as the only foot over bridge has been demolished to make way for the flyover construction. The MKC has a length of 1.29 km has a variable width between 19 to 26 m. The following figure shows the selected corridor for MKC VISSIM model.

Building MKC VISSIM MODEL

Heterogeneous traffic conditions as found in many developing countries require modeling a mix of different vehicle types and the lack of lane discipline **[12]**. For this model, eight hour (07.00 am-11.00 am& 4.00 pm-8.00 pm) manual traffic survey data of a single day was analyzed to define the peak hour traffic flow. The peak hour (6:15 pm - 7:15 pm) traffic survey data was used to find out the vehicle composition, vehicle classification, total traffic, percentage turning movement in the network which was used for the MKC VISSIM model inputs. Detailed network geometry, including ongoing construction of Mouchak-Moghbazar flyover geometric data was coded through the VISSIM graphical user interface (GUI) as shown in Figure 2.

Figure 2: Coded VISSIM network of Moghbazar-Kakrail corridor



To make the model representative of the real-world, both the motorized vehicle (bus, truck, car etc.) and non-motorized vehicle (rickshaw, human hauler, bi-cycle etc.) were defined in the model.

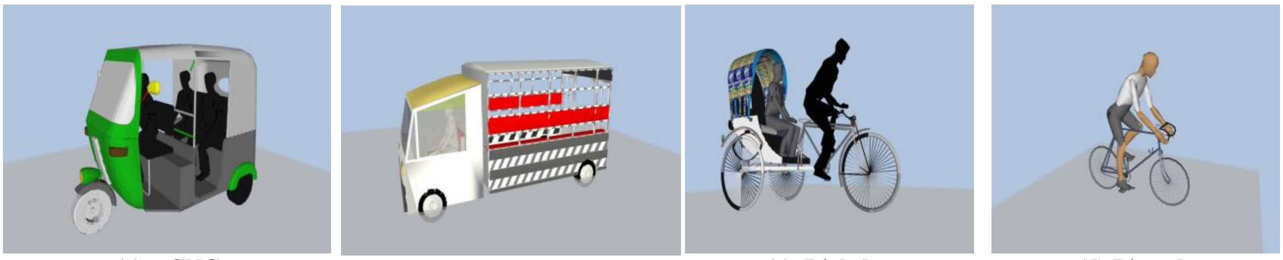
There is no enforcement of lane discipline, which results non-lane based traffic situation in the study area. Though it is quite complicated to model the non-lane based flow but by changing different parameter values (related to driving behavior, lane changing behavior, lateral distance, headway distance etc.) in VISSIM and with the ease of sophisticated programming it was made possible to build a non-lane based MKC VISSIM model. After coding of the network, the base model was run with Wiedemann 74 car following driver behavior model.

MKC VISSIM Model Calibration

In earlier studies, manual changes were used for calibrating model parameters **[6]**, which were found not efficient and practical. Fellendorf and Vortisch **[7]** calibrated the car following behavior of VISSIM with measurement on the level of single vehicles, i.e., data about headways, perception thresholds, and driving characteristics. However, it is difficult for model users to collect some of such data in the field. Merritt **[8]** proposed a methodology for the calibration and validation of CORSIM using empirical data. He found that extensive field data need to be collected to improve accuracy of the model calibration. In our study to replicate the real-life traffic operation, calibration was conducted from both system and operational point of view.

After creation of network, the vehicle input for various links was given according to the survey. This is followed by specifying the various routes in which vehicles travelled and the volume of these vehicles in each route is specified. Five vehicle types were created to replicate traffic composition in the project site: (1) MKC motorbike/bi-Cycle (16.0%); (2) MKC car/jeep/leguna/micro-bus/taxi/tempoo (47.0%); (3) MKC CNG (17.0%); and (4) MKC bus/truck (8.0%) (5) MKC rickshaw/van (12.0%). Local vehicles are modeled in 3D Studio-Max first and then converted into VISSIM recognizable vehicle element by V3DM (Figure 3).

Figure 3: Modeled local vehicles

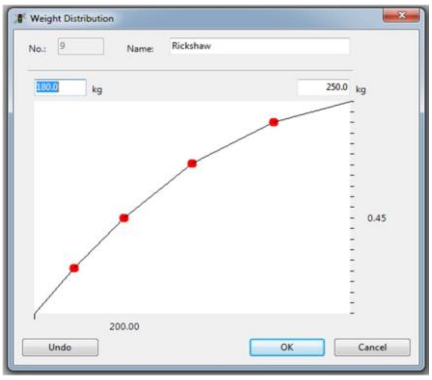


(a) CNG (b) Leguna (c) Rickshaw (d) Bi-cycle

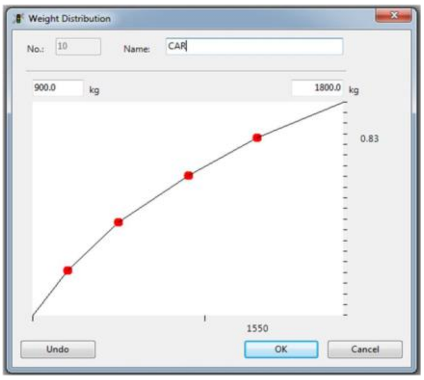
The simulation warm-up period was set to 30 minutes. Local vehicles are calibrated for the desired speed distribution, weight distribution, power distribution (Figure 4) as well as for the physical dimension. The data collection points, travel time sections, queue counters and nodes are placed to obtain data from the model which is used to validate the MKC model.

To replicate the bottleneck formation in the studied network, three customized link behavior types were defined: (1) the construction zone along the roadway; (2) roadway capacity reduction adjacent to gas station; and (3) random pedestrian movement at intersection. The driving behavior parameter sets for the customized freeway links were adjusted to alter the aggressiveness of the drivers near the merge areas. For example, from field observation it was found that at Moghbazar to BanglaMotor approach, BanglaMotor to Moghbazar approach, and FDC to Kakrail approach partial lanes are closed due to construction of Mouchak- Moghbazar Flyover. So, those particular lanes are closed in the model (Figure 3-6). At Kakrail to FDC approach adjacent to Moghbazar intersection there was a long queue of car because of gas station. . From the survey, it was found that in an hour around fifty (50) pedestrians use the at-grade road for crossing. In MKC VISSIM Model these scenario was also accounted and pedestrian priority over vehicle was given to replicate existing condition at intersections.

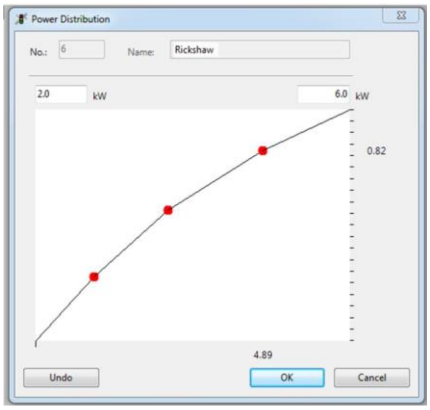
Figure 4: Distribution of kinematic parameters (examples of rickshaw and car).



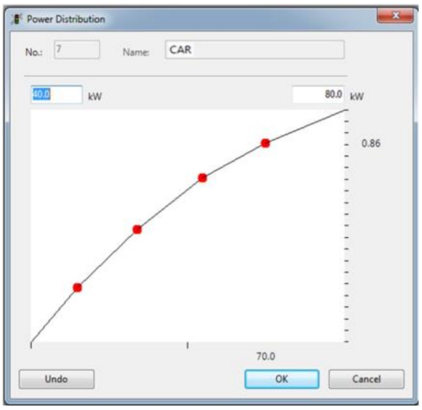
(a) Weight Distribution of Rickshaw



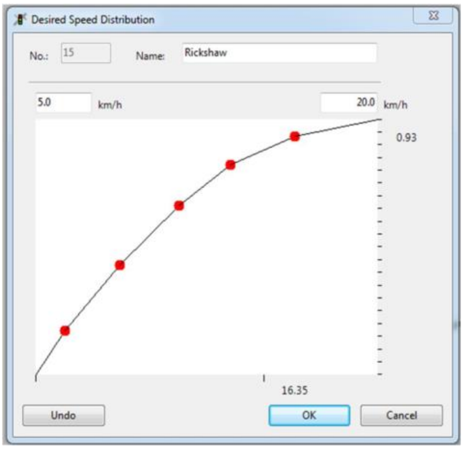
(b) Weight Distribution of Car



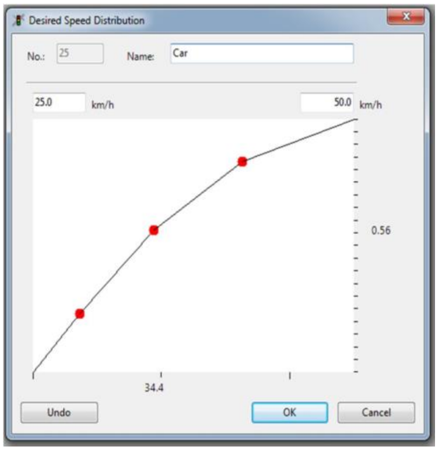
(c) Power Distribution of Rickshaw



(d) Power Distribution of Car



(e) Speed Distribution of Rickshaw



(f) Speed Distribution of Car

With regard to operational calibration, traffic simulation model contain numerous parameters to define and replicate traffic flow in the network, traffic flow characteristics and driver behavior. VISSIM simulation model contains default values for each parameter, but also allows a range of user applied values for each parameter. These parameters are changed to replicate field measurements and observed conditions. Local driving behavior is calibrated for the following parameters: standstill longitudinal distance between the stopped vehicles, headway time in seconds, following variation which restricts the longitudinal oscillation and indicates how much more distance than desired distance a driver allows before he intentionally moves closer to vehicle in front, speed dependency of oscillation, oscillation acceleration, standstill acceleration, minimum headway, maximum deceleration of vehicle and trailing vehicle for lane change, overtaking characteristics, minimum lateral distance at different speeds, waiting time for diffusion e.g. the default value of Wiedemann 74 car following model for average standstill distance, additive part of safety distance, multiplicative part of safety distance were changed from 2.00 m, 2.00 m, and 3.00 m to 1.20m, 1.50 m, and 1.75 m respectively.

MKC VISSIM Model Validation

The calibrated MKC VISSIM model was further validated against field data independent of the calibration dataset. Four parameters were used to validate the MKC base model.

1. GEH
3. Traffic flow
3. Speed, and
4. Queue length

This study adopts the Geoffrey E. Heavers (GEH) statistic to compare field traffic volumes with those obtained from the MKC base model. As a general guideline for model validation, GEH values less than 5 indicate good fit; values between (5-10) require further investigation, while values above 10 indicate a poor fit **[9]**.

$$\text{GEH}=\sqrt{\frac{(Simulated-Observed)^2}{0.5(Simulated+Observed)}}$$

GEH values of eleven approach roads of three major intersections (Moghbazar, Old Elephant Road, and Kakrail intersections) were computed. Table 1 shows the GEH values at different approaches of those three intersections. The GEH value varies from 0.37-3.92. Five simulation runs with different random seeds were performed to confirm the GEH values. Observed traffic with simulated traffic which is used to calculate GEH values of the MKC VISSIM. The GEH values are less than 5.0 which indicate good fit. The difference between the observed and simulated traffic volume varies from 1.4% to 32.3%.

Table 2: GEH values at different intersections using simulated and observed traffic flows (6:15 pm - 7:15 pm)

Intersection Name	Approach Name	Observed Vehicles (No.)	Simulated Vehicles (No.)	GEH
Moghbazar	1.Kakrail-FDC	874	774	3.484
	2.BanglaMotor-Moghbazar	620	569	2.092
	3.FDC-Kakrail	530	462	3.053
	4.Moghbazar-BanglaMotor	124	84	3.922
Old Elephant Road	1.Kakrail-Eskaton	1001	970	0.987
	2.Old Elephant Road-Fakruddin	738	645	3.537

	3.Eskaton-Kakrail	614	573	1.683
	4.Fakruddin-Old Elephant Road	985	948	1.190
Kakrail	1.Moghbazar – Kakrail	719	709	0.374
	2. Bijoynogor – Kakrail	1105	1000	3.237
	3. Kakrail – Bijoynogor	1001	887	3.710

Table 3 summarizes the differences between the observed and simulated queue length in meters and speed in Km/hr.

Table 3: Comparison between simulated and observed queue length

Intersection Name	Approach Name	Queue length(m)			Speed (km/h)		
		Observed	Simulated	Difference (%)	Observed	Simulated	Difference (%)
Moghbazar	1.Kakrail-FDC	192	254	32.3	18.7	19.5	4.3
	2.BanglaMotor-Moghbazar	340	356	4.7	8.2	10.7	30.5
	3.FDC-Kakrail	341	383	12.3	14.5	16.1	11.0
	4.Moghbazar-BanglaMotor	162	202	24.7	17.3	16.9	-2.3
Old Elephant Road	1.Kakrail-Eskaton	170	109	-35.9	30	35.6	18.7
	2.Old Elephant Road-Fakruddin	230	207	-10.0	13.8	12.7	-8.0
	3.Eskaton-Kakrail	50	33	-34.0	14	14.2	1.4
	4.Fakruddin-Old Elephant Road	198	141	-28.8	13.5	14.8	9.6
Kakrail	1.Moghbazar - Kakrail	35	29	-17.1	9.6	9.8	2.1
	2. Bijoynogor – Kakrail	390	469	20.3	13.5	14.4	6.7
	3. Kakrail – Bijoynogor	151	151	0.0	16.3	18.1	11.0

At Moghbazar intersection the highest queue length observed was 341 meters at FDC to Kakrail approach and the highest queue length found in simulation was at the same approach which was 383 meters. At Old Elephant Road intersection maximum queue length found from both field observation and simulation at Old Elephant Road to Fakruddin approach, which was 230 meters and 207 meters, respectively. And at Kakrail intersection Bijoynogor to Kakrail approach simulated maximum queue. From field observation it is obtained 390 meters while the simulated value produces 469 meters long queue along this approach. Kakrail to Bijoynogor approach produces 151 meters long queue for both field observation and simulation. During the field survey it was observed that during the peak hour the link directed to Bijoynogor intersection from Kakrail intersection remains congested. Simulation produces same scenario for queue along this approach. Vehicles approaching Old Elephant road intersection from Moghbazar to Kakrail have highest speed and vehicles approaching Moghbazar from Bangla Motor have lowest speed.

Existing Traffic Operating Conditions

The calibrated traffic model MKC VISSIM was used to analyze the traffic operating conditions in the project area. The analysis of the existing conditions was carried out using the traffic as well as the geometric data collected in the project area. The traffic operating conditions are analyzed microscopically for several major intersections and macroscopically for the total network. The assessment of the traffic operating conditions of the study intersections were based on the delays experienced by the vehicles at the intersection approaches. The results of the analyses are given in Table 4.

Table 4: Existing Traffic Operating Conditions of Three Major Intersections of MKC

Parameters	Intersections		
	Moghbazar Intersection	Old Elephant Road Intersection	Kakrail Intersection
Intersection Level of service (LOS)	F	F	F
Worst Movement Level of service	F	F	F

Average Intersection Delay (sec/veh)	366.2	147.5	180.8
Total Vehicle Delay (h)	239.8	159.5	169.9
Average Speed (km/h)	12.8	16.6	10.7

From the table it is clear that all the three major intersections are currently operating at Level of Service F. In terms of average intersection delay and total vehicle delay Moghbazar intersection suffers the most with average intersection delay of 366.2 second per vehicle and total vehicle delay of about 240 hours. Average speed is lowest (10.7 Km/h) at the Kakrail intersection.

The traffic operating conditions for the whole network was assessed using the following traffic parameters (measures of effectiveness): Total delay time, Total travel time, Total stopped delay, Average speed, Average stopped delay per vehicle, Average delay time per vehicle. Table 5 summarizes the total network performance in terms of delay and stops of vehicles. Average delay time per vehicle in total network is 584.2 seconds. Average speed of heterogeneous traffic of the network is obtained 9.1 km/h.

Table 5: Total Network Performance

Parameter	Value
Total delay time [h], All Vehicle Types	1686.5
Total travel time [h], All Vehicle Types	2707.7
Total stopped delay [h], All Vehicle Types	1247.2
Average speed [km/h], All Vehicle Types	9.1
Average stopped delay per vehicle [s], All Vehicle Types	432.0
Average delay time per vehicle [s], All Vehicle Types	584.2

Total delay, total travel time and total stopped delay are 1686.5 hours, 2707.7 hours and 1247.2 hours, respectively. Based on the results presented in Tables 5, it can be concluded that the current traffic operating conditions in Mogbazar-Kakrail Corridor is not satisfactory in terms of the selected mobility parameters.

Cost of total delay

Using the total delay time of all vehicles which has been fund from the simulated result to be 1686.5 hours the monetary value is calculated. To divide the total delays in individual vehicle the percentage shares of the different vehicles in the observed field data are used. The total costs of delays include the Vehicle Operating Cost (VOC) and Value of Travel Time (VOT). Corresponding features to calculate VOC and VOT are taken from the Road User Cost manual prepared by Roads and Highways Department (RHD) of the Government of Bangladesh **[10]**. The values provided in the manual are converted to present value (2015) by using the inflation rates **[11]** for each year. Table 6 provides the total cost of delays including the cost of delays for individual vehicle classes.

Table 6: Cost of Delays for Total Network Traffic.

Vehicle Class	% Share in Traffic Stream	Delay Time (hr)*	VOC (BDT)**	VOT (BDT) **
Motorbike/Bi-Cycle	16	269.84	9708.843	17512.62
Car/Jeep/Leguna/Microbus/Taxi/Tempoo	47	792.655	129301.1	199543
CNG	17	286.705	14590.42	46482.91
MKC bus/truck	8	134.92	47900.11	300656.4
MKC rickshaw/van	12	202.38	5149.761	16405.73
	Total =	1686.5	206650.2	5806006
		Total Cost of Delay =	BDT 787,250 Or USD 10,122	

**From Simulation Results from Table 5.*

*** Using RHD Road User Cost Manual [10] and Annual Inflation Rates [11]*

As found from the table the total cost of delays is 101,220 USD. This is only for the peak 1.5 hour traffic of a single weekday. The average loss in a year (with 320 days of weekdays and 5 peak hours each day) will be 83.97 billion Taka or USD 10,809,268 or nearly 1.08 Million USD.

Conclusion And Recommendation

This yearly loss of 1.08 Million USD is just for a segment of the corridor affected for the flyover construction. The total loss for the whole segment including Sat Rastar More and the section from New Eskaton Road to Malibag Intersection will be more. The relevant transport authorities should take a note of the deteriorating traffic operating conditions of the surrounding areas. The Moghbazar intersection should be signalized. The authorities may also think about coordinating the traffic lights among the critical intersections for smooth operation of traffic flow. Moreover, banning NMT on the study corridor and constructing pedestrian guard railings can also improve traffic flow. However, signalization and coordination alone cannot solve the traffic congestion problems. Due to the high traffic growth rate, the capacity is near exhaustion, and consequently capacity expansion measures may be warranted to ensure satisfactory level of traffic operations in the surrounding area. Several capacity augmentation projects, e.g. BRT line 3 and MRT line 4 within the STP will be implemented in near future. It is expected that these projects would improve traffic operation in the study area. However, to confirm the maximum benefit from these sustainable urban transport projects, integration of under-construction Mouchak-Moghbazar Flyover with the future projects will play a critical role.

References

Islam M. M. (2009), A FRAMEWORK FOR MODELING RICKSHAW MOVEMENTS IN HETEROGENEOUS TRAFFIC CONDITIONS. Undergraduate Thesis Paper.

Lawrence W. L. and Chiung-Wen C. (2003), Motorcycle’s Moving Behavior in Mixed Traffic: Particle-Hoping Model with Cellular Automata, Journal of the Eastern Asia Society for Transportation Studies, Vol. 5, pp. 23-37.

Chu C. M., Sano K. and Matsumoto S. (2005a), Characteristics of Passing and Paired Riding Maneuvers of Motorcycle, Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, pp. 186-197.

Chu C. M., Sano K. and Matsumoto S. (2005b), The Speed, Flow, and Headway Analyses of Motorcycle Traffic, Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, pp. 1496-1508.

Hossain MJ (2004) Calibration of the microscopic traffic flow simulation model VISSIM for urban conditions in Dhaka city. Master thesis, University of Karlsruhe, Germany.

Daigle, G., M. Thomas, and M. Vasudevan. 1998. Field applications of CORSIM: I-40 freeway design evaluation, Oklahoma city, OK. Proceedings of the 1998 Winter Simulation Conference:1161-1167.

Fellendorf, M., and P.Vortisch. 2001. Validation of the microscopic traffic flow model VISSIM in different real-world situations. Paper presented at the 81st Transportation Research Board Annual Meeting, Washington, DC.

Merritt, E. 2003. Calibration and validation of CORSIM for Swedish road traffic conditions. In Preprints of the 83rd Transportation Research Board Annual Meeting, Washington, DC.

Holm, P., Tomich, D., Sloboden, J., and Lowranc, C. (2007). Traffic Analysis Toolbox Volume IV: Guidelines for Applying CORSIM Microsimulation Modeling Software. Federal Highway Administration, Report No. FHWA-HOP-07-079, Washington D.C.

RHD ROAD USER COST ANNUAL REPORT For 2004 – 2005. Roads and Highways Department, Ministry of Communications, Government of the People’s Republic of Bangladesh.

CIA World Fact Book 2013. And Bangladesh Bank http://www.bangladesh- bank.org/econdata/inflation.php

Fellendorf M. and Vortisch P., Microscopic Traffic Flow Simulator VISSIM. http://www.springer.com/978-1-4419-6141-9.