DEVELOPING A VISSIM-BASED CALIBRATION AND VALIDATION FRAMEWORK FOR MIXED TRAFFIC: THE CASE STUDY OF KHULNA'S SHIVBARI INTERSECTIONS

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ABSTRACT

Rapid urbanization and increasing vehicle density have placed severe pressure on transportation systems in developing cities like Khulna, Bangladesh. The city's heterogeneous traffic, composed of various vehicle types such as Easy-Bikes, Mahindras, rickshaws, buses, and private cars, creates complex flow patterns and frequent congestion, particularly at unsignalized intersections. Understanding these dynamics is crucial for designing efficient, safe, and sustainable traffic management solutions. The primary objective of this study was to develop, calibrate, and validate a microscopic traffic simulation model using PTV VISSIM to accurately represent Khulna's mixed-traffic conditions and evaluate the model's reliability in reflecting real-world scenarios. The research utilized detailed field data collected from two key intersections— Shibbari and Zero Point—during peak hours, including traffic volume, vehicle composition, turning movements, and parking activities. The model incorporated realistic lane usage, conflict areas, and reducedspeed zones to simulate authentic driver behavior under non-lane-based, mixed-traffic conditions. Calibration was performed using the Wiedemann 74 car-following model, adjusting parameters such as standstill distance and safety distance to reflect local driving characteristics. Validation was achieved through the Geoffrey E. Havers (GEH) statistic and Mean Absolute Percentage Error (MAPE), where GEH values ranged from 0.75 to 3.4 and MAPE from 1.79% to 9.84%, indicating strong agreement between simulated and observed traffic volumes. The results confirm that the model accurately reproduces Khulna's heterogeneous traffic behavior and congestion patterns. This study demonstrates that a well-calibrated VISSIM model can serve as a powerful decision-support tool for traffic engineers and urban planners, aiding in evaluating existing infrastructure, forecasting future traffic conditions, and designing targeted interventions such as signalization, dedicated lanes, or parking management strategies. Overall, the research contributes to developing more efficient, safer, and environmentally sustainable urban transport systems in growing South Asian cities.

Keywords: *PTV Vissim; Simulation; Calibration; GEH; MAPE.*

INTRODUCTION

The infrastructure supporting transportation has been significantly affected by the rise in urban population and vehicle density. Research indicates that there is an increased need for transportation infrastructure as the number of people living in cities increases. This demand is made worse by the growing number of cars on the road, which causes traffic jams, traffic congestion, longer travel times, increased air pollution and problems with transportation system efficiency (Hossain et al., 2025; Hafram et al., 2023). Before putting new control strategies, physical improvements or both into place for addressing this rapidly growing population's needs, it is extremely difficult to effectively measure and evaluate the system's performance as the surface transportation system grows more complicated and expands in coverage area (Park et al., 2006). Microscopic simulation models are becoming useful tools for transportation engineers due to the advancement of computer technology and the increasing complexity of road design. These models make it possible to estimate difficult variables including fuel consumption, air quality, accident risks and toll revenues as well as to evaluate potential designs. But if the results are not properly calibrated and validated, they may be misleading and lose the confidence of decision-makers, the general public, or both (Park & Schneeberger, 2003). Many times, skeptics see simulation modeling as a "black-box" technology and an imperfect science. Unrealistic expectations regarding the capabilities of simulation models and the use of improperly calibrated ones are typically the main causes of this skepticism. It is challenging to collect and analyze real-world data because of the complexity of mixed traffic, and there aren't easily accessible methods for calibrating simulation models. Understanding how drivers behave in diverse traffic situations and adjusting micro-simulators appropriately is a significant challenge (Manjunatha et al., 2012).

Recent studies highlight the importance of proper calibration in mixed-traffic environments, where the diversity in vehicle types—ranging from non-motorized vehicles (e.g., bicycles, rickshaws) to motorized ones (e.g., buses, cars)—creates unique challenges. Research conducted in Khulna, for instance, developed a VISSIM-based calibration and validation framework to simulate the city's traffic accurately. By adjusting parameters such as standstill distance, safety distance, and driving behavior models (e.g., Wiedemann 74), the study successfully replicated the real-world conditions at key intersections like Shibbari and Zero Point. The results indicated strong accuracy, with GEH values below 5 and MAPE values ranging from 1.79% to 9.84%, confirming the model's reliability.

This study demonstrates that with precise calibration and validation, VISSIM can serve as a powerful decision-support tool for evaluating existing infrastructure, forecasting traffic growth, and testing potential interventions, such as signalization or dedicated lanes. The findings underscore the potential of simulation models to optimize traffic flow and reduce congestion, contributing to more sustainable and safer urban transport systems in growing cities.

STUDY AREA

Khulna, the third largest and second seaport of Bangladesh is organized about a National Highway which is parallel to the river which is a part of the urban development of the city. The arterial network of the city with a ring road makes it rather complicated, and the public transportation does not manage to meet the standards of sustainability. The primary solutions to traffic congestion in the city are non-motorized transport and paratransit especially Easy-Bikes, because of the small size of the city and short distances to commuting destinations. Although there are numerous forms of transportation such as bus, Easy-Bikes, Mahindras and rickshaw, Easy-Bikes is the most common because it is cheap and is available in many locations (Ahsanul, 2019).

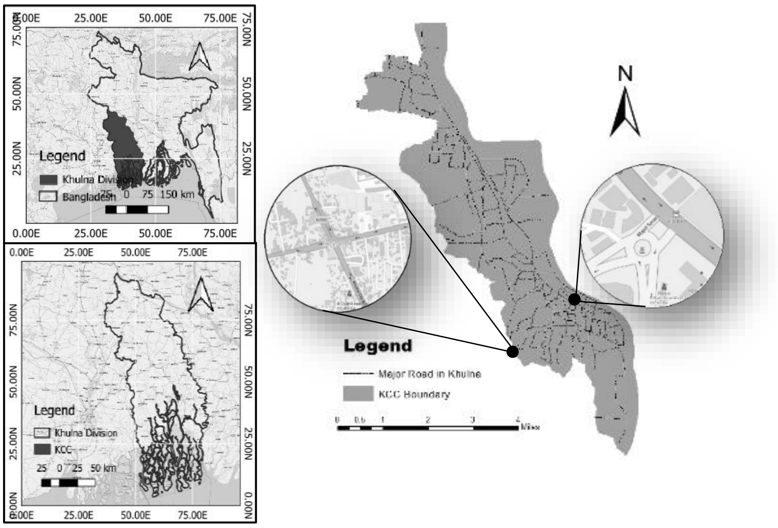

Figure 01: Study Area Map

METHODOLOGY

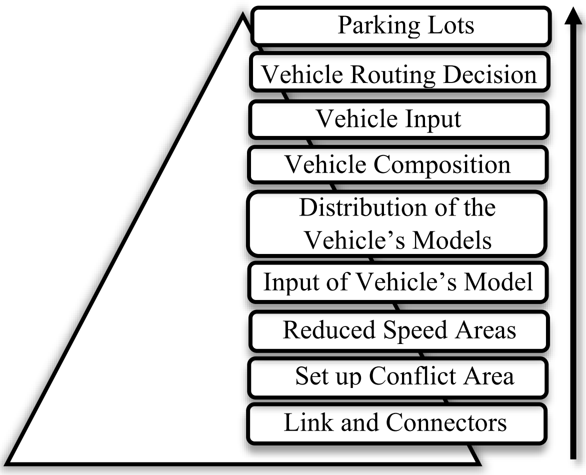

Figure 02: Methodological Hierarchy

In the VISSIM model generation process, we try to ensure accurately collected field data. For this, we conducted a field survey to measure the length–width of each inbound and outbound road at Shibbari and Zero Point intersections and ran a peak-hour traffic count survey from which detailed vehicle composition, total vehicle counts, vehicle speeds, turning routes and detailed parking activity were extracted. Using these measurements as the sole inputs, we first started building the network using link and connectors. Links were created as separate inbound and outbound links, with the circulatory roadway represented explicitly. After creating links, each lane was set to 'Urban Motorized,' and lane usage was defined based on local driving practices in Bangladesh. buses typically utilize the right lane, except when stopping to pick up passengers. Conversely, cars and pickups generally avoid the left lane. Easy-bikes, auto-rickshaws, motorcycles, cycles, and vans utilize both left and right lanes. Finally, connectors were added to link the inbound and outbound roads. once the links and connectors were created, VISSIM generated and reviewed conflict areas. Since all intersections in Khulna are unsignalized, drivers generally follow the 'first-come, first-go' rule, which increases the chance of conflicts and accidents. In the model, these were marked as 'Undetermined,' shown in red. Undetermined means which vehicle comes first at that location, will cross first, which perfectly matches the real-life scenario. Vehicles tend to experience a reduction in speed at conflicting points—especially while making left or right turns in and around the conflict clusters and curved sections identified on site. These reduced speed zones in and around the conflict clusters and curved sections identified on site were manually defined within the VISSIM traffic simulation model to reflect realistic driving behavior at the intersection. In our country, the roads operate under mixed traffic conditions, a wide variety of vehicles are present, including pickup trucks, e-bikes, Mahindras, rickshaws, vans, bicycles, motorbikes, buses, and minibusses. While VISSIM already provides built-in models for cars, buses, motorbikes, cycles, and trucks, additional models such as rickshaws, auto-rickshaws, Mahindra, CNG, Van and easy-bikes were manually added. Accurate measurements (Standard dimensions of the vehicles, Noor et al., 2021) were applied to ensure the model realistically reflects actual traffic conditions.

Table 1: Standard dimensions of the vehicles in the study area (Noor et al., 2021)

Vehicle Type	**Passenger Capacity (Persons)**	**Dimension (m)**	
		Length	Width
Mahindra	5	2.6	1.7
Easy-bike	4	2.7	1.4
Bus	35	10.3	2.5
Car	4	4.0	1.6
Motorcycle	2	1.9	0.5
Minibus	6	5.0	1.9
Van	3	2.2	1.4
Rickshaw	2	2.2	1.4
Cycle	1	1.9	0.5

Table 2: Standard Weight of Vehicle (Herrera Dappe, Kunaka, Lebrand, & Weisskopf, 2020)

Number of Axles	**Bangladesh**	**India**
3 (1 front, 2 back)	22	25
4 (steering + 3 axles)	25	31
5 (3 prime mover, 2 trailer)	38	44
6 (3 prime mover, 3 trailer)	41	44
7 (3 prime mover, 4 axles)	44	—

All input models were categorized into ten main vehicle classes with subcategories

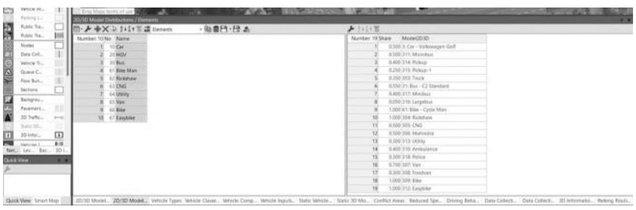

Figure 03: Vehicle Distribution

Specific vehicle configurations were created for each different route for both intersections. The possible paths that vehicles could follow from each entry link to their destination links were defined. The relative flow percentages for every origin–destination pair were determined from video observations and then entered into the model. This step allowed VISSIM to distribute the total incoming traffic across different routes accurately, representing real-world turning and through-movement behavior. After doing all things, the parking section of the model was created. The specific parking zones were added to the network, and parking routes were defined for each area. For every parking zone, the type of vehicles that usually park there, their average parking durations and the parking lengths were set based on field data. This setup helped simulate the temporary stoppage of vehicles and its effect on traffic flow.

After completing the VISSIM model, the next phase was model calibration and validation to ensure the simulation accurately reflected real-world traffic conditions. Two types of calibration were carried out to align the model with real-life conditions. First, vehicle behavior was calibrated by adjusting the desired speed for each vehicle. Although each vehicle was initially assigned a fixed speed during the composition setup, real-world vehicles within the same class vary in their speed. To account for this, the initial fixed speeds were calibrated with upper and lower limits to accommodate such fluctuations. Next, driving behavior was calibrated using the Wiedemann car-following model. Two car-following models are available in PTV VISSIM: Wiedemann 74 and Wiedemann 99. For this model, Wiedemann 74 was chosen, as it is more suitable for low-speed urban and weaving sections, both inside cities and out-of-town areas. Here are the Calibrated Parameters for Heterogeneous Traffic.

Table 3: Wiedemann 74 car following model parameters (MANUAL PTV Vissim 2024, 2024)

Parameters	Description
Average stand still distance (w74ax)	ax: Base value for the average desired distance between two stationary cars. The tolerance lies within a range of –1.0 m to +1.0 m which is normally distributed at around 0.0 m, with a standard deviation of 0.3 m. This leads to "stochastic smearing" of ax. Default 2.0 m.
Additive part of safety distance (w74bxAdd)	bx_add: Value used for the computation of the desired safety distance d. Allows for adjusting the time requirement values. Default 2.0 m.
Multiplicative part of safety distance (w74bxMult)	bx_mult: Value used for the computation of the desired safety distance d. Allows for adjusting the time requirement values. Greater value = greater distribution (standard deviation) of safety distance. Default 3.0 m

$$d = ax + ((bx_{add} + bx_{multi} * z) * \sqrt{v}$$
(1)

v = speed of slower vehicle

z = is a value of range [0.1], which is normally distributed around 0.5 with a standard deviation of 0.15

Table 4: Calibrated parameters for vehicle class (Kabir et al., 2019).

Vehicle class	Parameters		
	ax	bx_add	bx_multi
Car	0.70	0.50	0.70
EBus	1.00	0.50	0.70
Bike	0.25	0.30	0.50
Autorickshaw	0.70	0.50	0.70
Pickup	0.70	0.50	0.70
Rickshaw	0.70	0.50	0.70
Bicycle	0.30	0.50	0.70

The other parameters used for calibration are listed below-

- Maximum look ahead distance – 250m
- Minimum look ahead distance – 30m
- Maximum look back distance – 150m
- Minimum look back distance – 30m
- General behavior – Free-lane section
- Desired position of free flow – Any
- Diamond queuing – Yes (for Bangladesh condition)
- Collision time gain – 3 (default)
- Minimum longitudinal speed – 1 km/h (default)
- Time between direction changes – 3 (default)

Validation is an essential phase in assessing the accuracy of the simulated model. This involved comparing the simulated results with real-world data. To validate the VISSIM model, two metrics were used: the Geoffrey E. Havers (GEH) and the Mean Absolute Percentage Error (MAPE) (Hafram et al, 2023).

$$\mathrm{GEH} = \sqrt{\frac{2(V_a - V_m)^2}{(V_a + V_m)}}$$

$$\mathrm{MAPE} = \frac{1}{n} \sum_{t=1}^{n} \left| \frac{V_a - V_m}{V_a} \right| * 100\%$$

Where, Va = Actual traffic flow in veh/h and Vm = Traffic flow of simulated model in veh/h.

Table 5: Description of the GEH outcome (Hafram et al., 2023)

GEH Statistics	Total Link Flows
GEH < 5	85% of Cases
GEH Statistics - Individual Link Flows	
GEH < 4	All Accepting Links

The simulated results are considered accurate and appropriate for further analysis and planning when the GEH value is less than 5.00. A GEH number between 5.00 and 10.00, on the other hand, indicates a possible error or questionable data and calls for additional research. A GEH value greater than 10.00 suggests a significant difference between the observed and simulated values, which calls for caution and means that the model shouldn't be used for further planning or analysis.

Table 6: Description of the MAPE outcome (Hafram et al., 2023)

MAPE Range	**Description**
≤ 10%	Simulation results are very accurate
10% - 20%	Good Simulation results
20% - 50%	Simulation results are feasible (good enough)
≥ 50%	Inaccurate simulation results

Table 7: Simulation Result of Zero-Point Intersection

	Actual Volume	**Simulated Volume**	**GEH**	**MAPE**	
From Shonadhangha	2216	2289	1.37	3.29%	**5.97%**
From Moylapotha	3070	3167	1.5	3.16%	
From Dakbangla	2596	2748	2.49	5.86%	
From New Market	2356	2537	3.4	7.68%	
From L mia Rd	305	335	1.72	9.84%	

Table 8: Simulation Result of shibbari Intersection

	Actual	**Simulated**	**GEH**	**MAPE**	
From Gollamari	2140	2208	1.3	3.18	**3.78%**
From Bypass	1560	1588	0.75	1.79	
From Rupsha	1360	1454	2.5	6.91	
From Opposite	1850	1910	1.4	3.24	

The simulated volumes are consistently higher than the actual volumes across all locations, indicating a slight model overestimation trend. GEH values mostly remain below 5, suggesting that the simulation model performs within acceptable accuracy limits for traffic studies. MAPE values range between roughly 2% and 10%, showing that prediction errors are relatively small but higher at lower-volume sites such as L Mia Rd. Overall, the model demonstrates good reliability, with stronger accuracy at major intersections and slightly weaker performance at minor ones.

RESULT & DISCUSSION

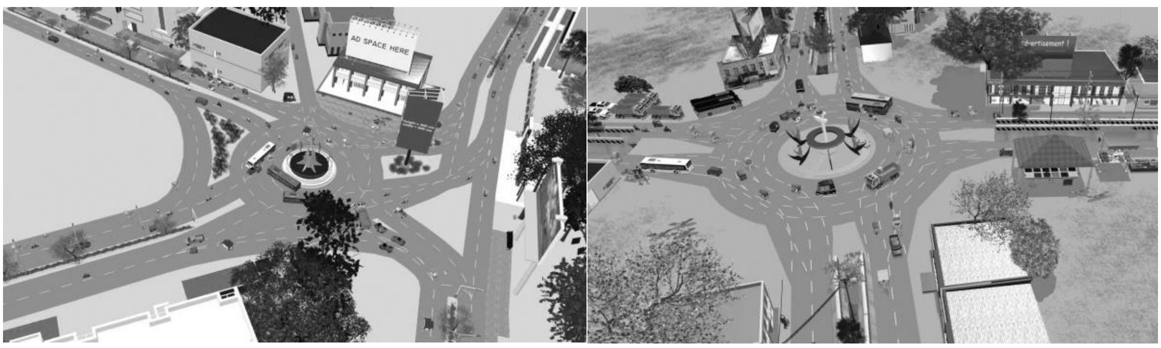

Figure 04: Simulation of Shibbari and Zeropoint Intersection

The VISSIM simulation model for Khulna city was developed to replicate the city's complex mixed-traffic conditions, where a diverse array of vehicles, including buses, cars, motorcycles, Easy-Bikes, rickshaws, Mahindras, vans, and bicycles, share the same road space. Mixed-traffic scenarios present unique challenges due to the varying sizes, speeds, and maneuvering behaviors of these vehicles. The model was built using data collected from two critical intersections, Shibbari and Zero Point, during peak traffic hours. Key data points included vehicle composition, traffic counts, vehicle speeds, turning movements, and parking activities. The model incorporated these elements to define the traffic flow dynamics, lane usage, and vehicle interactions within the network. A key aspect of the model was its ability to capture the behavior of different vehicle types within a shared traffic space. The lanes were designed to reflect real-world practices, where larger vehicles such as buses tend to occupy the right lanes while smaller vehicles like Easy-Bikes and rickshaws freely navigate both left and right lanes. This simulation was essential to replicate the real-life congestion and maneuvering behavior that typifies mixed-traffic systems. The VISSIM model also simulated reduced speed zones around conflict areas, particularly at unsignalized intersections, where vehicle interactions are more frequent and unpredictable. These areas were critical to capturing the slowdowns caused by the close proximity of various vehicle types, as well as the increased likelihood of traffic conflicts.

The calibration of the model was conducted in two phases to ensure the accuracy of the simulated traffic flow. First, vehicle behavior was calibrated by adjusting the desired speeds for each vehicle class, as real-world vehicles within the same category often exhibit variability in speed. This step was particularly important for Khulna's mixed-traffic system, where vehicles of different types interact frequently, leading to fluctuating speeds. Second, the driving behavior was fine-tuned using the Wiedemann 74 car-following model, which is specifically designed for low-speed urban environments. This model was chosen due to its suitability for capturing the dynamics of closely interacting vehicles in congested city traffic. Key parameters, such as the desired standstill distance and safety distance for each vehicle type, were calibrated to match observed traffic patterns, ensuring that the simulation accurately reflected the real-world behavior of vehicles on Khulna's roads.

The validation process involved comparing the simulated traffic volumes with actual observed volumes at several key intersections. The model demonstrated a high degree of accuracy, with the GEH values ranging from 0.75 to 3.4, well within the acceptable threshold of 5, indicating a close match between the simulated and actual traffic volumes. The MAPE values ranged from 1.79% to 9.84%, further confirming that the model reliably reproduced the real-world traffic behavior under mixed-traffic conditions. These validation results suggest that the model is robust and capable of accurately simulating the traffic dynamics of Khulna, making it a valuable tool for analyzing current traffic conditions and predicting the impacts of potential infrastructure changes.

The presence of mixed traffic in Khulna posed a significant challenge in terms of modeling the interactions between different vehicle types. Unlike homogeneous traffic systems, where vehicles of the same type share the same lanes, mixed traffic requires modeling the varying behaviors of vehicles with significant differences in size, speed, and maneuverability. The VISSIM model successfully captured this complexity by accounting for the specific lane usage patterns and speed variations associated with each vehicle type. Furthermore, the simulation incorporated reduced speed zones, which were particularly important in areas with high traffic conflict. These zones were calibrated to reflect the slowing of vehicles at intersections and other congestion-prone areas, where vehicle types with differing speeds and sizes interact more frequently.

The results highlight the importance of accurate model calibration and validation in mixed-traffic environments. The close alignment of the simulation results with observed traffic data confirms that the VISSIM model is a reliable tool for assessing traffic flow in Khulna. However, there are certain limitations. The model was primarily validated for two specific intersections, and the traffic dynamics of other areas in Khulna may not be fully represented. Additionally, while the model captured the current traffic conditions accurately, it did not account for dynamic changes, such as fluctuations in traffic volume due to special events or long-term growth in traffic demand.

Future enhancements to the model could involve expanding the simulation to cover a broader network within Khulna, incorporating real-time data for better predictive accuracy, and integrating dynamic traffic elements such as seasonal variations and changes in public transportation usage. Moreover, future studies could explore the effects of different traffic management strategies, such as signalization or dedicated lanes for specific vehicle types, to assess their impact on mixed-traffic flow and overall congestion.

CONCLUSION

The VISSIM simulation model developed in this study provides critical insights into Khulna's mixed-traffic conditions, highlighting the challenges posed by the interaction of various vehicle types. By accurately modeling traffic flow, congestion, and the impact of unsignalized intersections, the study offers valuable data to guide policy decisions aimed at improving urban mobility. The findings align with key transportation policy goals, including optimizing traffic management, enhancing safety at conflict points, and promoting sustainable transport solutions. The model can support policies focused on dedicated lanes for specific vehicle types (e.g., buses and Easy-Bikes), improving intersection design, and implementing traffic flow measures to reduce congestion. Moreover, the model's ability to simulate real-world traffic conditions makes it a valuable tool for ongoing traffic planning and infrastructure development. In conclusion, this simulation framework can aid policymakers in Khulna to make informed decisions that align with broader objectives of reducing congestion, improving traffic safety, and creating a more efficient transportation network for the city's diverse mobility needs.

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