IMPROVING TRAFFIC PERFORMANCE AT AN URBAN INTERSECTION USING HCM-BASED AND MICROSIMULATION-BASED LOS ANALYSIS IN GAZIPUR

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ABSTRACT

Level of Service (LOS) is widely recognized as a key indicator for assessing the operational quality of roadway approaches at intersections. In Gazipur, intersections operate under heterogeneous and non-lane-based traffic conditions; however, systematic interventions to improve traffic performance remain limited due to the scarcity of LOS-focused studies in Bangladesh. This research assesses the LOS of the Shibbari intersection using both Highway Capacity Manual (HCM 1994 and 2010) procedures and a microscopic simulation technique to identify performance issues and propose improvement strategies. Traffic volume data during morning and evening peak hours over three survey days, along with geometric information, were collected and analyzed. LOS values were determined using HCM methods, while a PTV VISSIM 2025 model was developed to replicate existing traffic conditions and compute LOS for comparison. In addition, field investigations were conducted to identify factors contributing to traffic performance degradation at the study location. The results indicate that electric three-wheelers (E3Ws) dominate the traffic composition, accounting for more than 63% of total vehicles, and significantly contribute to capacity reduction. HCM 2010 showed LOS A on all three approaches, which matches the microsimulation results for all approaches except Shimultoli to Shibbari, where LOS E was observed. In contrast, HCM 1994 indicated poorer operating conditions, with LOS E and F on approaches. Among the approaches, Shibbari–Chowrasta recorded the worst LOS, while Shibbari–Railgate performed relatively better. The microsimulation-based LOS analysis further revealed that the base condition becomes non-functional by 2050. However, when a grade-separated interchange and modal shift are integrated simultaneously, all nine (9) movements achieve LOS A. The main factors contributing to LOS degradation include the dominance of E3Ws, erratic non-lane-based driving behavior, and curbside parking. Overall, this study suggests that implementing modal shift strategies along with interchange integration can significantly improve intersection performance. Future research may focus on the integration of traffic control devices to further increase the LOS of the intersection.

Keywords: *Level of service(LOS), Highway Capacity Manual (HCM), Traffic performance, VISSIM.*

1. INTRODUCTION

Gazipur is one of the most economically important industrial zones in Bangladesh, and its strategic geographic position provides a vital connection between several major districts and the capital city, Dhaka. In modern urban road networks, intersections play a crucial role in ensuring smooth traffic movement and minimizing operational inefficiencies. However, being the most complex elements of road networks, intersections in developing countries often experience severe congestion and operational problems due to highly heterogeneous traffic conditions. Roadways in Bangladesh carry a mixed stream of buses, trucks, cars, auto-rickshaws, and non-motorized vehicles, mostly without strict lane discipline (M. K. Hossain et al., 2020). Under such mixed traffic environments, vehicle arrivals at uncontrolled intersections follow complex probability patterns (Rengaraju & Rao, 1995). Drivers frequently ignore lane markings and traffic rules, weaving through any available gaps to move ahead (Hadiuzzaman et al., 2008). Combined with weak enforcement of traffic laws and frequent pedestrian interference, such as random road crossing, this results in non-lane-based intersection behaviour (Kafy et al., 2018). As a consequence, intersections suffer from long delays, frequent stops, poor space utilization, and intense competition for road space. The absence of proper channelization, including dedicated turning lanes and separate facilities for slow-moving vehicles, further worsens congestion by forcing fast- and slow-moving traffic to operate within the same space (Saha et al., 2019).

In Gazipur city, the Shibbari intersection is one of the busiest and most congested junctions, where traffic delays have become a persistent daily problem. Despite its strategic importance as a gateway to major industrial and residential areas, the intersection continues to perform poorly due to uncontrolled mixed traffic flow and inadequate traffic management. This situation highlights the urgent need for both policy-oriented and infrastructure-based measures to improve operational efficiency and support sustainable urban mobility. In Bangladesh, where formal public transport services remain limited, intermediate public transport (IPT) modes such as electric three-wheelers, locally known as "easy bikes," play a dominant role in daily travel (Pramanik et al., 2023). Introduced in 2004 and widely commercialized by 2008, these vehicles now number around one million nationwide and serve as a critical last-mile transport option for low- and middle-income commuters (Awal et al., 2019). However, their frequent stopping in active traffic lanes for passenger boarding and parking severely disrupts traffic flow. Surveys reveal that more than 54% of commuters in the Chowrasta area lose four to five hours daily due to traffic congestion (Siraj et al., 2023). Growing concerns regarding road safety and accidents have led policymakers to consider stricter regulations and even possible bans on battery-powered three-wheelers (Hossain et al., 2023; Nurunnahar et al., 2022). Overall, the Shibbari intersection clearly demonstrates how the dominance of electric three-wheelers in a mixed traffic environment reduces roadway capacity and intensifies congestion and safety risks in urban Bangladesh.

Microsimulation has emerged as a powerful analytical tool for modelling heterogeneous and non-lane-based traffic conditions, especially where conventional analytical approaches become inadequate. Among the available platforms, PTV VISSIM is the most widely used microsimulation software in Bangladesh and has been applied in studies related to intersection performance, bus lane evaluation, and interchange feasibility (Chowdhury et al., 2019; Mashrur, 2018). When properly calibrated, microsimulation provides a dynamic and realistic way to replicate actual field conditions, validate analytical level-of-service (LOS) estimates, and test improvement strategies before physical implementation. This integrated modelling approach offers a deeper understanding of traffic flow behaviour and is particularly effective in complex urban settings such as Gazipur, where diverse vehicle types, informal transport modes, and weak traffic discipline create unique operational challenges.

Several studies across South Asia and other regions have demonstrated the effectiveness of combining Highway Capacity Manual (HCM)-based analysis with microsimulation modelling for intersection performance evaluation. Kafy et al. (2018) applied HCM procedures to unsignalized intersections in Rajshahi, Bangladesh, converting observed traffic flows into passenger car units (PCUs) and estimating LOS based on volume-to-capacity ratios and peak hour factors. Their findings revealed extremely poor operating conditions (LOS E–F), primarily due to the dominance of slow-moving vehicles such as auto-rickshaws and rickshaws. Similarly, Dagnal et al. (2023) evaluated a four-lane divided urban arterial in Delhi using both HCM analysis and PTV VISSIM simulation and found strong consistency between manual and simulated LOS results. Their study confirmed that well-calibrated microsimulation models can reliably reproduce HCM-based performance measures under heterogeneous traffic conditions. In Nepal, Nepal et al. (2024) applied HCM-2010 procedures to evaluate major intersections in Kathmandu and found that all were operating beyond capacity at LOS E–F. Luitel et al. (2023) further demonstrated through SIDRA modelling at the Buspark junction in Birgunj that optimized signal timing and controlled left-turn movements could improve LOS from E to D and reduce delays by nearly 40%. Additionally, Jolovic et al. (2016), in a comparative study conducted in California, emphasized the importance of proper calibration when applying HCM and VISSIM under different traffic environments to ensure consistency between field and simulation outputs. Collectively, these studies confirm that HCM frameworks and microsimulation tools are complementary methods for evaluating traffic performance, particularly in the complex traffic environments typical of South Asian cities.

Against this backdrop, the present study focuses on improving traffic performance at an urban intersection in Gazipur using integrated HCM-based and microsimulation-based LOS analysis. The research evaluates the operational efficiency of the Shibbari intersection by combining field observations with analytical capacity analysis and PTV VISSIM microsimulation. This integrated approach allows a realistic representation of mixed and non-lane-based traffic conditions and provides a comprehensive understanding of intersection performance. By linking empirical field data with simulation modelling, the study offers practical guidance for designing sustainable intersection improvement strategies. This research undergoes the following objectives-

1. To assess the LOS of the Shibbari intersection using HCM methods and find performance degrading factor by a reconnaisance survey.
2. To develop and apply a microscopic traffic simulation model to analyze existing intersection performance and compare LOS results with HCM outcomes.
3. To evaluate improvement strategies including modal shift and interchange integration.

2. METHODOLOGY

This study utilized both HCM-based analysis and PTV VISSIM microsimulation to evaluate the LOS at the Shibbari intersection in Gazipur. Field data on traffic volume, composition, turning movements, and intersection geometry were collected during both peak and off-peak hours to assess existing operational conditions. The data were first analysed using HCM procedures to determine the current LOS. A calibrated PTV VISSIM model was then developed to simulate real-world traffic behaviour and test multiple improvement scenarios.

2.1 Study Area

The study was conducted at the Shibbari intersection in Gazipur city, Bangladesh, an industrial hub located approximately 37 km north of central Dhaka. Shibbari intersection, situated at 23°59'48"N and 90°25'01" E, serves as a major economic and administrative centre, home to numerous factories, offices, and educational institutions. The Shibbbari intersection connects Gazipur Chowrasta-Joydebpur, Rajbari-Joydebpur, and Shimultoly-Joydebpur roads, forming a vital junction linking the city's industrial, commercial, and residential zones. It occupies a strategic position within Gazipur's urban network, integrating major regional corridors and experiencing consistently high traffic volumes throughout the day. This makes it a critical site for analysing congestion and evaluating intersection performance. The geographic location of the study area is illustrated in Figure 1.

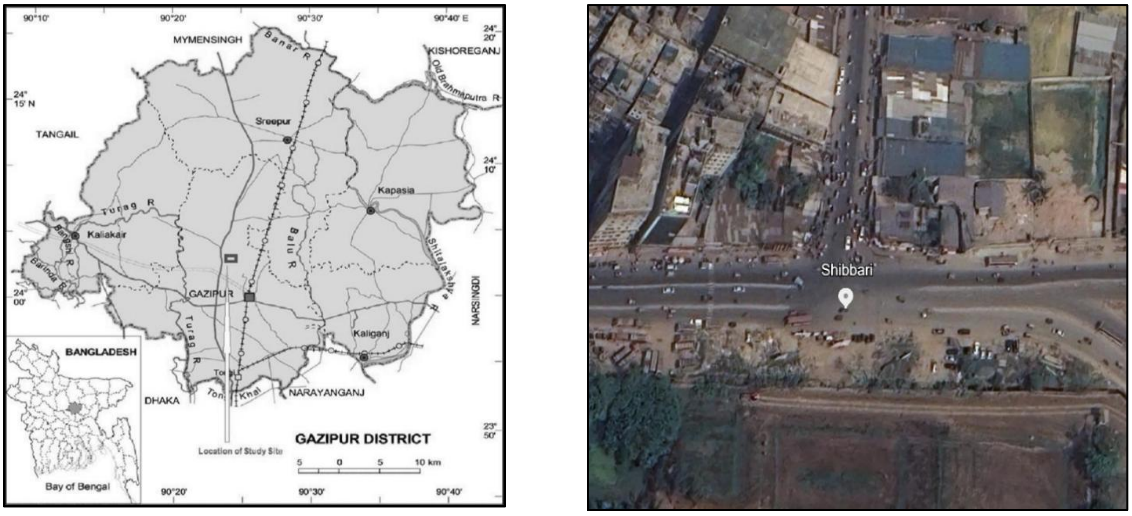


Figure 1: Aerial view of the Shibbari intersection.

2.2 Data Collection

Data collection for this research was conducted in two main phases. In the first phase, field data were gathered from the Shibbari intersection, and it adjoin road links were used to accurately develop the network model in PTV VISSIM. In the second phase, following model calibration, simulation outputs were analysed to assess the effectiveness of various improvement strategies, including modal shift grade-separated interchange options. The collected data included traffic volume, vehicle composition, road geometry, and travel speed distributions across different vehicle types. Intersection layouts and segment lengths were measured using standard tools such as measuring tapes. These datasets were essential for building and calibrating a realistic microsimulation model representing existing traffic conditions.

2.3 Highway Capacity Manual-Based LOS

The field data collected comprised traffic volume and speed for various vehicle types. To manually determine the LOS, the total traffic volume was converted into passenger car units (PCUs), allowing different vehicle categories to be expressed in a common unit. This conversion accounts for the varying influence of each vehicle type on overall traffic flow. The PCU conversion factors applied in this study were adopted from HCM 2010 for urban conditions.

Table 1: Level of service (LOS) criteria based on HCM 2010

Level of Service	V/C
A	0.00 to 0.60
B	0.61 to 0.70
C	0.71 to 0.80
D	0.81 to 0.90
E	0.92 to 1.00
F	Greater than 1.00

The LOS is found using the mathematical equation mentioned below. To find the level of service:

$$LOS = V/C \qquad (1)$$

Where, V = volume
C = capacity

LOS provides a qualitative measure of traffic performance, reflecting flow characteristics such as speed, density, and congestion. According to HCM, LOS ranges from A (free-flow condition with minimal delays) to F (severe congestion and over saturation). For the determination of LOS as per HCM 1994, the study considered. Measuring the operating speeds of each vehicle type. A roadway strip of 80ft was taken into consideration, and time was recorded for each vehicle to calculate the speed of the vehicle. Later on, the operating speed of a particular motorized vehicle was calculated by following the formula.

$$Operating\ Speed = \frac{\Sigma(number\ of\ individual\ motorized\ vehicles \times average\ speed)}{total\ number\ of\ motorized\ vehicles} \quad .... (2)$$

Table 2: Level of service (LOS) based on traffic flow condition as per HCM 1994

Level of Service	Description	Operating Speed (mph)
A	Free Flow	≥ 60
B	Stable	≥ 50
C	Approaching Unstable Flow	≥ 40
D	Approaching Unstable Flow	≥ 35
E	Unstable Flow	30
F	Forced Flow	< 30

2.4 Simulation Modelling in VISSIM software

After completing the necessary data collection, a microscopic simulation model of the Shibbari intersection was developed in PTV VISSIM 2025 (SP 10) to represent the real conditions driving behaviour, and operational challenges at the site. The network was coded using detailed geometric information from the field, including lane width, link length, turning movement, and approach volumes. Since the intersections are uncontrolled, conflict areas and priority rules were added to capture real intersections between vehicles. Route decisions were included to ensure accurate directional movements, and locally common vehicle types such as CNGs, electric three-wheelers, minibuses, light trucks, tempos, and rickshaws were modelled in SketchUp and imported into VISSIM. Their desired speed distributions, based on GPS logged data, were assigned to reflect actual driving behaviour. The model was then calibrated by adjusting driving-behaviour parameters related to lane changing. Lateral movement and headway to match field observations in a mixed traffic environment. Validation was performed to confirm that the model accurately reflected real congestion and flow patterns. This validated model served as a reliable tool for evaluating delay, queue length, and Level of service (LOS), and for testing various proposed improvement scenarios under current and future traffic conditions.

2.5 Identification of traffic performance degradation factors

Degradation factors have been identified in this study by studying the following: (i) Vehicle composition, (ii) Lane discipline, and (iii) Geometric features of the intersection and roadway. The degradation factors were solely identified through a reconnaissance survey conducted in the Shibbari intersection.

2.6 LOS under Improvement Scenarios

To assess traffic performance and identify effective improvement strategies at the Shibbari intersection, five simulation scenarios were developed in PTV VISSIM. Each scenario represents different conditions ranging from the existing traffic situation to future growth and proposed intervention, allowing comparative evaluation of operational performance and Level of Service (LOS).

2.6.1 Existing Traffic Conditions Scenario

The base-year scenario (2025) represents current traffic conditions, incorporating observed vehicle compositions, turning movement, traffic volume, and geometric features of the intersection. This scenario serves as the benchmark for analysing future congesting levels and quantifying LOS improvements under proposed strategies.

2.6.2 Modal Shift to Minibuses Scenario

This scenario examines the potential impact of replacing low-occupancy E3Ws with higher-capacity minibuses to enhance traffic efficiency at the Shibbari intersection. The intent is to maintain equivalent passenger throughout while reducing the total number of vehicles on the road, thereby improving traffic flow and lowering congestion. Simulation inputs were adjusted using occupancy factors analysis and field survey data to ensure comparable person movement across modes This demonstrates the effectiveness of a modal shift policy in mitigating congestion, enhancing travel speed, and improving LOS and network performance under future traffic conditions.

2.6.3 Trumpet Interchange Integration Scenario

In this scenario, a modified trumpet interchange was proposed to achieve grade separation and ensure uninterrupted traffic flow through the Shibbari intersection. The interchange geometry and lane configuration were designed following Indian Roads Congress (IRC) guidelines, with specific parameters adapted to local site conditions. The interchange model was developed and simulated in PTV VISSIM under both current and projected traffic volumes. A comparative analysis between the proposed design and IRC standards (IRC, 2017; 2018) confirmed that most geometric parameters meet or exceed the recommended values, validating the feasibility of the design. Minor deviations, such as a slightly reduced direct-ramp radius, were found acceptable under the site's operational constraints. The proposed interchange is expected to substantially improve traffic flow, safety, and LOS, offering a sustainable long-term solution for congestion management at the Shibbari intersection.

2.6.4 Combined Scenario

This final scenario combines both the modal shift to minibuses and the construction of a modified trumpet interchange. It represents a long-term solution and was analysed to evaluate its impact on congestion reduction, vehicle delay, and overall intersection performance.

3. RESULT AND DISCUSSION

3.1 Intersection Performance Analysis as per Field observations

At the study site, several congestion factors were noted, including informal stops, illegal parking, improper drop-off manoeuvres, and inconsistent lane use. A large presence of three-wheelers was evident at Shibbari intersection. Figure 2(a) illustrates that three-wheelers dominate the vehicle mix at this junction. Figure 2(b) shows electric three-wheelers parked on the curb lanes (left lane in both directions), a pattern attributable to the absence of designated parking areas and weak regulatory enforcement. Poor passenger drop-off practice was frequently observed among three-wheeler drivers (Figure 2(c)).

(a) Traffic flow at Shibbari

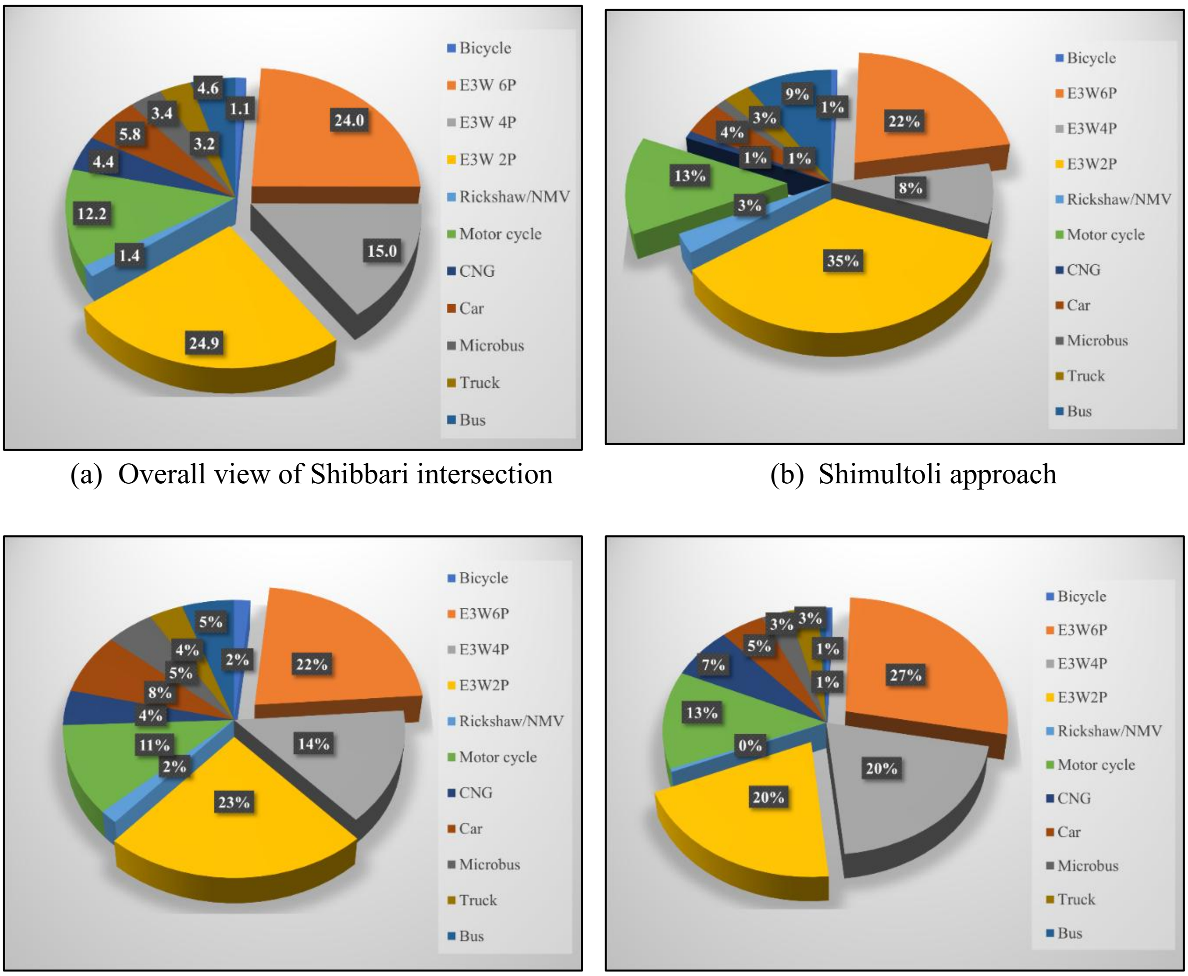
(b) Parking behavior

(c) Drop off Maneuvers

(d) Lane violations

Figure 2: Traffic congestion caused by the three-wheeler

Numerous lane-violation incidents also occurred at the intersection (Figure 2 (d)). Such lane-violating behaviour is likely linked to driver characteristics and operating incentives. Figure 3 shows the vehicle composition at the Shibbari intersection, and its three approaches, and the result clearly indicates that electric three-wheelers (E3Ws) are the most dominant vehicles in this area. In the total intersection, two-person E3Ws account for 24.9% and six-person E3Ws for 24%, meaning that almost half of all vehicles are E3Ws make up 35% and six-person E3Ws 22% of the traffic, showing that more than half of the flow consists of E3Ws. At the Chowrasta approach, two-person and six-person E3Ws contribute 23% and 22% respectively, again making them the largest group. The Railgate approach also reflects the same condition, where six-person E3Ws form 27% and two-person E3Ws form 20% of the total vehicles. In all cases, heavier vehicles such as buses, trucks, and private cars appear in very small shares. Overall, the information in Figure 3 shows that E3Ws dominate traffic flow at the Shibbari intersection, and their high share as small, low-capacity vehicles contributes significantly to congestion and operational difficulties in the area. This dominance mainly exists because electric three-wheelers are the most affordable, convenient, and widely available option for short-distance and last-mile travel around Shibbari.



(a) Overall view of Shibbari intersection

(b) Shimultoli approach

(c) Chowrasta approach

(d) Railgate approach

Figure 3: Vehicle composition at the Shibbari intersection and its approaches.

3.2 Intersection Performance Analysis as per HCM-based LOS

Table 3 shows a comparison of Level of Service (LOS) for the three approaches using HCM 1994, HCM 2010, and VISSIM. The result indicates that HCM 1994 produces poor LOS values (E-F), suggesting heavy congestion under its older assumption. In contrast, HCM 2010 and VISSIM show improved performance for most approaches. Both methods classify the Railgate and Chowrasta approaches as LOS A, indicating smooth and stable flow. However, for the Shimultoli approach, VISSIM reports LOS E while HCM 2010 shows LOS A. This difference suggests that VISSIM captures mixed-traffic conditions, E3W dominance, and irregular driving behaviour more accurately than HCM 2010, making it a more realistic tool for evaluating the operational challenges at the Shibbari intersection.

Table 3: Comparison of LOS Across different assessment methods

Approach	**LOS**		
	HCM 1994	HCM 2010	VISSIM
Railgate to Shibbari	E	A	A
Chowrasta to Shibbari	E	A	A
Shimultoli to Shibbari	F	A	E

3.3 Intersection Performance Analysis as per Microsimulation-based LOS

The Level of Service (LOS) distribution under the base condition shows a steady deterioration over time. In 2025, most traffic movements operate at LOS A, indicating smooth flow. However, as traffic volume increases, the number of movements at LOS E and LOS F grows sharply, becoming dominant by 2050. This trend signifies that the existing intersection layout cannot handle future traffic demand efficiently and will experience severe congestion and unstable operations without major interventions. This condition is illustrated in Figure 4.

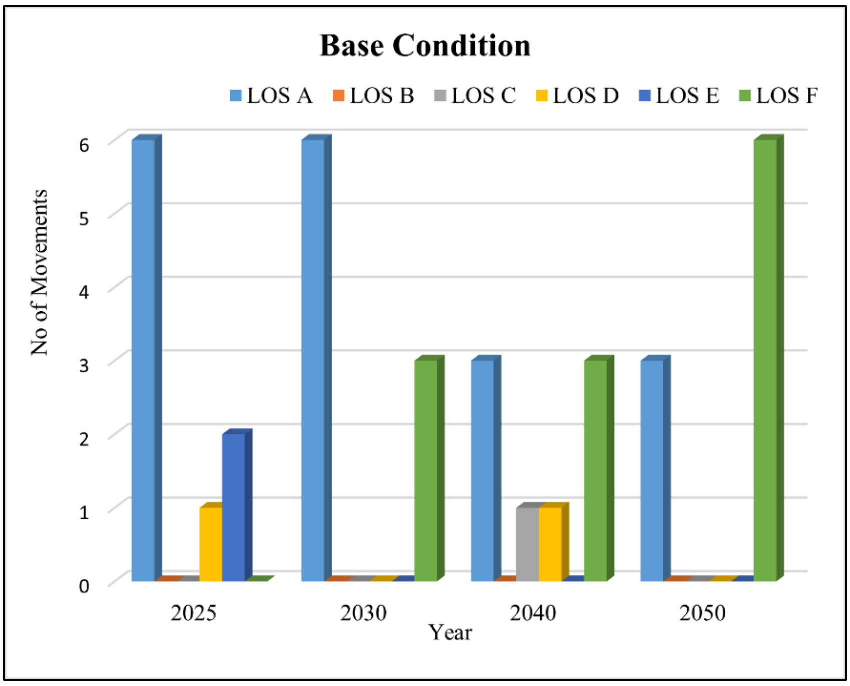


Figure 4: Comparative analysis of LOS across traffic scenarios under base conditions

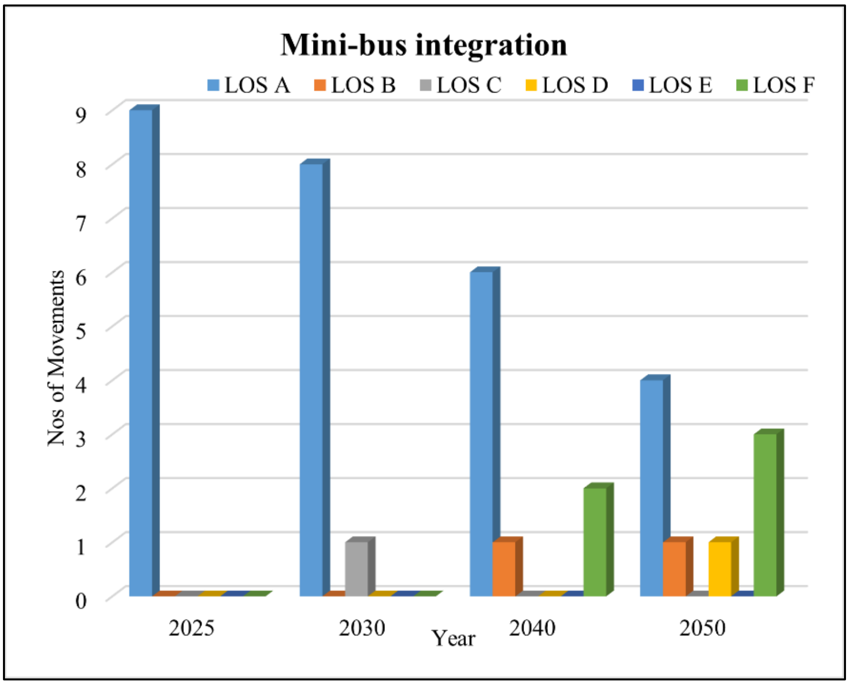


Figure 5: Comparative analysis of scenarios with LOS under the modal shift condition

The Level of Service (LOS) pattern under the minibus integration scenario demonstrates noticeable improvement compared to the base condition. In 2025 and 2030, almost all movements operate at LOS A, indicating efficient flow due to the reduction in vehicle numbers through modal shift. Although some movements gradually shift to LOS D-F by 2050, the overall network performance remains significantly better than the base case. This confirms that substituting electric three-wheelers with minibuses enhances capacity utilization and delays congestion growth over time. This condition is illustrated in Figure 5.

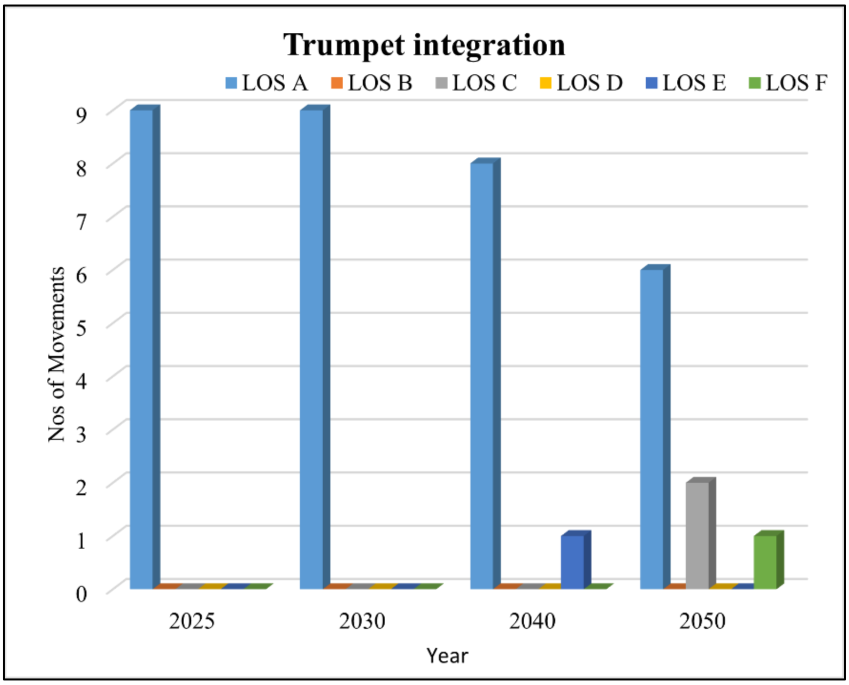


Figure 6: Comparative analysis of scenarios with LOS under trumpet condition

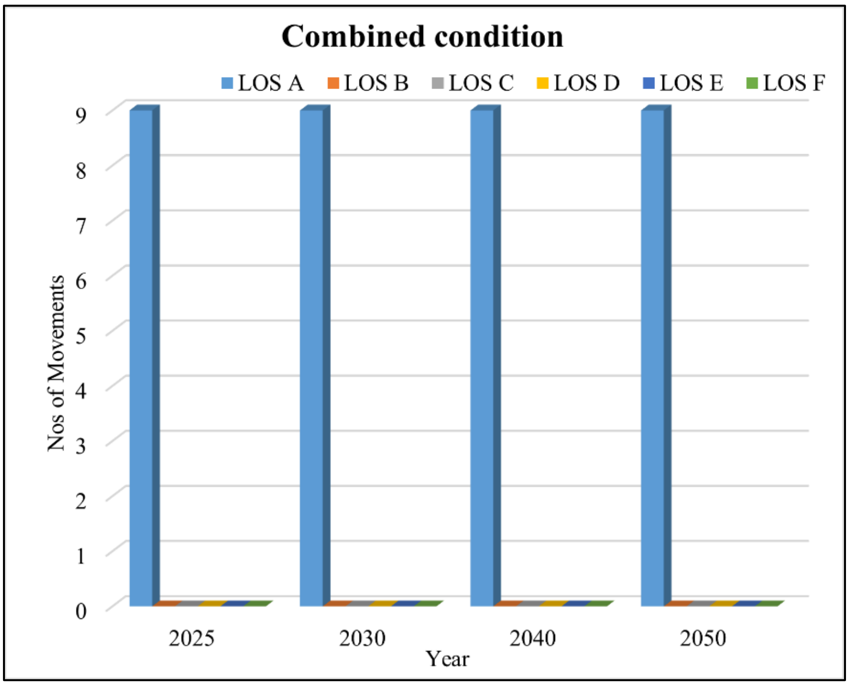


Figure 7: Comparative analysis of scenarios with LOS under trumpet condition

The Level of Service (LOS) results for the trumpet integration scenario indicate a significant improvement in traffic performance compared to existing conditions. Up to 2030, all movements operate at LOS A, reflecting free-flow conditions due to the grade separation that eliminates conflict points. Even by 2050, most movements still perform at LOS A–C, with only a few shifting to LOS E–F. This demonstrates that the trumpet interchange effectively enhances capacity, minimizes intersection delays, and sustains high operational efficiency over the forecast period. This condition is illustrated in Figure 6.

The combined condition illustrated in Figure 7, which merges the modal shift to minibuses and trumpet interchange integration, exhibits the best overall network performance. As shown in the figure, all traffic movements consistently operate at LOS A from 2025 to 2050, with no deterioration over time. This indicates that the combined strategy effectively minimizes congestion and ensures smooth, uninterrupted traffic flow even under projected future growth, proving it to be the most sustainable and efficient solution for the Shibbari intersection.

4. CONCLUSIONS

This study examined traffic flow improvement strategies at the Shibbari intersection by evaluating the Level of Service (LOS) under various intervention scenarios. Based on this study's findings, the following conclusions and recommendations are drawn:

a) Field observations showed that E3Ws create several operational problems at the Shibbari intersection, including informal stopping, illegal parking, poor drop-off behaviour, and frequent lane violations. These activities interrupt traffic flow because there are no designated stopping areas, and enforcement is weak.

b) The vehicle composition analysis confirmed that E3Ws are the dominant mode on all approaches, making up about half of the total traffic. Their low capacity, frequent stopping, and unstable manoeuvres reduce overall traffic speed and contribute to congestion and poor intersection performance.

c) The LOS analysis showed that under the base condition, traffic flow worsens over time, with many movements falling to LOS E-F by 2050.

d) The minibus integration scenario improves LOS by reducing the number of vehicles through modal shift, especially in the early years. The trumpet interchange further improves performance by removing major conflict points, keeping most movements at LOS A-C. The combined scenario performs the best, maintaining LOS A from 2025 to 2050.

e) Overall, the study recommends adopting the combined strategy of minibus integration and trumpet interchange, as the most effective long-term solution for reducing congestion and improving traffic flow at the Shibbari intersection.

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DECLARATION OF USE OF AI

The authors confirm that artificial intelligence (AI) tools were not used in the research methodology, technical analysis, or logical reasoning; Only Grammarly was used for grammatical checking of the manuscript.

REFERENCES

Kafy, A.A., Ferdous, L., Poly, S.A., Arafat, M., Monira, S., Rahman, M.S., Rahman, N., Afroz, F., Mahzabin, F., Ahmed, T., and Khan, N.A. (2018). *Estimating traffic volume to identify the level of service at major intersections of Rajshahi, Bangladesh*. Trends in Civil Engineering and Its

Architecture, 2(4).

Awal, R., Rahman, M. M., Islam, A. K. M. N., & Al-hossain, J. (2019). *Energy Consumption Analysis of Electric Three-Wheelers in Bangladesh*. *December* 1–5.

Chowdhury, T. R.(2019). *Investigation of road intersection operation using micro-simulation technique investigation of road intersection operation using micro-simulation technique*. MSc Thesis, BUET.

Dangal, N. R., Wangmo, D., Meena, S., Kumar, S., & Delhi, N. (2023). *Study of Traffic Flow for Estimation of Level of Service*. *8*(4), 1348–1353.

Hadiuzzaman, M., Rahman, M., and Karim, M.A. (2008). Saturation flow model at a signalized intersection for non-lane-based traffic. *Canadian Journal of Transportation*, *2*(1), 77–90.

Hossain, J. Al, Hasan, Z., & Khan, Z. R. (2023). *Affordable Electric Three-Wheeler in Bangladesh : Prospects, Challenges, and Sustainable Solutions*.

Hossain, M. K., Ahmed, T., & Islam, R. (2020). *Vehicle Characteristics and Roadway Level of Service of Industrial Zone : A Typical Example of Gazipur Chowrasta Intersection Vehicle Characteristics and Roadway Level of Service of Industrial Zone : A Typical Example of Gazipur Chowrasta Intersection*. *October*. https://doi.org/10.13140/RG.2.2.34082.15049

Jolovic, D., Stevanovic, A., Sajjadi, S., & Martin, P. T. (2016). Assessment of Level - Of - Service for Freeway Segments Using HCM and Microsimulation Methods. *Transportation Research Procedia*, *15*(June), 403–416. https://doi.org/10.1016/j.trpro.2016.06.034

Luitel, S., Pokhrel, A., Tiwari, H., & Dhakal, A. (2023). *Evaluation of Operational Performance of Intersection and Optimizing Signal Timing : A Case Study of the Buspark Intersection in Birgunj Metropolitan*. *December*. https://doi.org/10.24321/2456.4370.202307

Manual H. C.: HCM2010. Transportation Research Board, National Research Council, Washington, DC (2010).

Mashrur, Sk.(2018). *Modeling bus priority with intermittent bus lane for local traffic conditions, october 2018*. MSc Thesis, BUET.

Nepali, S., University, T., Bohara, S. S., Lama, N., Thapa, R., & University, T. (2024). *Assessment of Traffic Characteristic at Major Urban Road Intersection of Kathmandu Valley: A Case Study of Khanivivag, Kesarmahal, and Narayanhiti Intersections*. *10*(1), 22–31. https://doi.org/10.46610/JOCCE.2024.v010i01.003

Nurunnahar, S., & Rahman, M. (2022). *Electric vehicles in Bangladesh : Impact on the environment, mobility, and the economy of an impending ban*. *August* 1–5. https://doi.org/10.1002/puh2.43

Pramanik, A., Rahman, S., & Fahim, A. U. (2023). *Travel behavior characteristics of informal public mode users : A case study of E-rickshaw users of Rangpur city corporation (RpCC) in Bangladesh*.

Rengaraju, V. R., & Rao, V. T. (1995). Vehicle-arrival characteristics at urban uncontrolled intersections. *Journal of Transportation Engineering*, *4*(121), 317–323.

Saha, U., Islam, M.F., and Neema, M.N. (2019). A microsimulation-based approach to investigate intersection performance: A case study on the Bhulta intersection of Dhaka. *Proc. Int. Conf. on Engineering Research and Practice (ICERP 2019)*.

Siraj, S. Bin, Farjana, M., Billah, M., Hasan, M., & Azid, T. (2023). *Impact of Traffic Congestion in Roundabout: A study on Gazipur Chowrasta*, November 2023.