

1. PERFORMANCE EVALUATION AND LOS DETERMINATION OF MIXED TRAFFIC AT CRITICAL UNSIGNALIZED INTERSECTIONS IN KHULNA

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ABSTRACT

Transport systems are an important aspect of social and economic growth of cities and especially those cities that rapidly grow such as Khulna City. This paper assesses operational performance of three unsignalized intersections; Shibbari, Zero Point and Moylapota in the heterogeneous traffic scenario taking into account diverse types of vehicles, such as non-motorized vehicles, semi-motorized vehicles, and motorized vehicles. The surveys on traffic volume were performed during the times of maximum traffic, and the data was used to calculate the approach capacities and to estimate the volume-to-capacity (V/C) ratios of the Level of Service (LOS) analysis. The results demonstrated that some methods, including the Khulna City Bypass and Khulna-Satkhira Road, work at LOS E-F, which implies that the methods are overloaded and the flow situation is unstable. Other methods, on the other hand, sustain LOS C, which is an indicator of moderate congestion. Another result of the study was the movement in modal share with an increasing use of motorized mode at peak hours. Its findings highlight the urgent need of capacity, adaptive traffic and web-enhanced public transportation and non-motorized transport infrastructure. This study not only addresses good insights on traffic management planning in Khulna but other mid cities in Bangladesh where the same is being experienced and thereby aiding in improved transportation planning and development of the city.

Key words: *Mixed traffic; Level of Service (LOS); Passenger-car units (PCU); Peak-hour factor (PHF); Unsignalized intersections.*

1. INTRODUCTION

Transportation systems are essential for the social and economic development of any city, providing mobility for people and goods and shaping urban growth. Yet, rapid urbanization and the rising number of vehicles have intensified congestion problems in developing nations such as Bangladesh. The situation is particularly severe at intersections, where multiple traffic streams converge and conflicts occur frequently under mixed and poorly disciplined conditions (Osuolale et al., 2019). One of the main concerns in metropolitan areas of growing nations like Bangladesh is the rise in automobiles brought on by the proportionate increase in people and the rapid development of contemporary culture (Abdulla-Al Kafy et al., 2018). The effectiveness of the road system in Bangladesh is commonly referred to as a catalyst for resolving all transportation-related issues. Since the pattern of urban development is determined by the transportation system, an enhanced transportation system is essential to all forms of development (Khanam & Marufuzzaman, 2019). A baseline in transportation engineering is traffic volume research. With its help, engineering management and operations are accomplished successfully. Study of Traffic Volume is important in assessing the current state of traffic volume and forecasting its future state. The road traffic in emerging nations such as Bangladesh is extremely diverse, encompassing both static and dynamic traffic types. Since it is utilized to predict a road's capacity and level of service under the combined traffic at any time of day, traffic volume data is crucial once more (Abdulla-Al Kafy et al., 2018).

The Level of Service (LOS) is a key performance indicator that qualitatively measures the operational efficiency and user comfort of a roadway, while the Peak Hour Factor (PHF) helps identify traffic concentration and variability. Together, these parameters are widely used to evaluate intersection performance, design capacity improvements, and enhance traffic management (Abdulla-Al Kafy et al., 2018). In the Bangladeshi context—where heterogeneous traffic, lack of lane discipline, and limited enforcement prevail—accurate LOS and PHF analyses are indispensable for sustainable mobility planning (Khanam & Marufuzzaman, 2019). Khulna Metropolitan City (KMC), the third-largest urban area in Bangladesh, has witnessed rapid population growth, increased vehicle ownership, and expansion of commercial activities over the last decade. These developments have aggravated congestion, especially at unsignalized intersections, where diverse vehicle classes—ranging from rickshaws and motorcycles to buses and private cars—share limited roadway space (Abdullah et al., 2023).

Research shows that at KMC's unsignalized junctions, minor-road right-turn movements often operate near capacity, causing high delays and unstable traffic flow. Poor geometric design, roadside parking, and informal driver behavior further diminish intersection performance (Abdullah et al., 2023). These factors collectively reduce LOS and increase travel times, pollution, and accident risks, emphasizing the urgent need for systematic evaluation. Although several studies in Bangladesh—particularly in Rajshahi and Pabna—have analyzed LOS and PHF to assess intersection performance (Hossain et al., 2024; Khanam & Marufuzzaman, 2019), comparable research in Khulna remains scarce. The absence of quantitative assessments limits evidence-based decision-making for infrastructure improvement and traffic control. This study, therefore, focuses on determining the LOS and PHF at the three major intersections of Khulna City—Zero Point, Shibbari, and Moylapota—to quantify operational efficiency and congestion levels. The findings will contribute to formulating strategies for intersection redesign, lane management, and optimized traffic regulation. Ultimately, this research will serve as a guideline for improving intersection performance not only in Khulna but also in other mid-sized Bangladeshi cities with similar traffic characteristics.

2. STUDY AREA

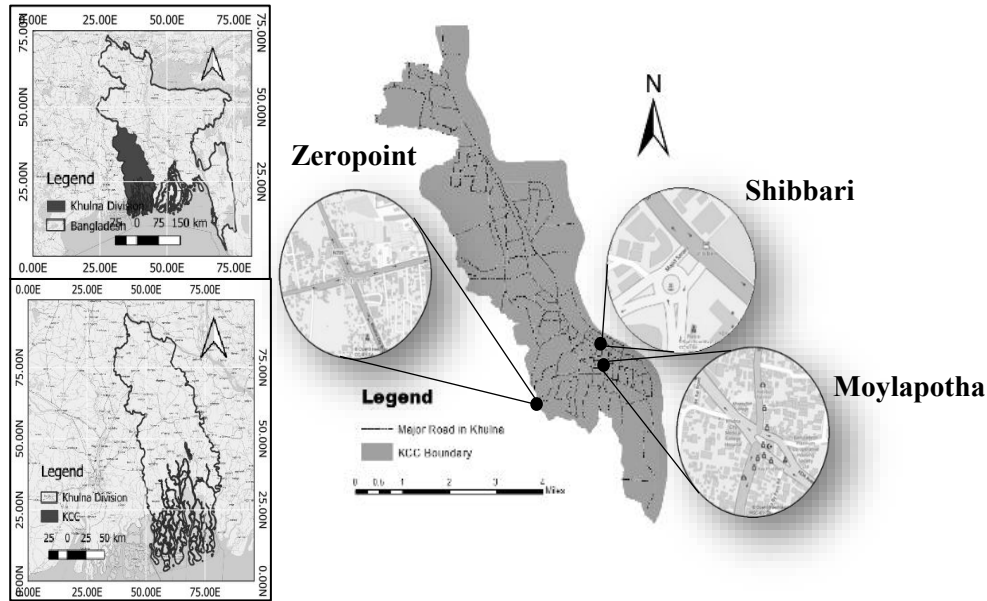


Figure 1: Study Area

The Zero Point intersection serves as one of Khulna’s main gateways, linking inter-district traffic with the city’s central commercial corridor. The Shibbari intersection, located in the heart of Khulna’s central business district, experiences continuous congestion due to the convergence of institutional, retail, and transit-related trips. Meanwhile, Moylapota intersection functions as a key node connecting arterial routes such as KDA Avenue and Khulna–Jessore Highway, making it critical for both intra-city and regional mobility.

Table 1: Road Geometry of Three major intersection in KCC area

Location	Road Name	Number of Lanes	Carriageway Width (m)	Footpath Width (m)
Shibbari Roundabout Intersection	Khan-E-Sabur Road	2	7.5	2.6
	KDA Avenue	2	11.5	2.2
	Majid Sharoni	2	7.2	2.2
	Ibrahim Mia Road	1	6.1	1.2
Zero Point Intersection	Sher-E-Bangla Road	2	10.2	2.0
	Khulna City Bypass (Upper)	2	9.10	-
	Khulna City Bypass (Lower)	2	9.10	-
	Khulna-Satkhira Road	2	8.22	2.4
Moylapotha Intersection	Sher-E-Bangla Road	2	11.5	2.0
	KDA Avenue (From Shibbari)	2	11.5	2.2
	KDA Avenue (To Rupsha)	2	9.4	2.4
	Powerhouse	1	4.95	-

3. METHODOLOGY

This study followed a systematic methodological framework to evaluate the operational performance of three major intersections in Khulna City—Shibbari, Zero Point, and Moylapota—by determining their Level of Service (LOS) and Peak Hour Factor (PHF). The process began with the selection of these intersections based on their high traffic pressure, complex modal composition, and their importance as key mobility nodes within the city. After selecting the study area, detailed geometric data were collected for each intersection, including the number of lanes, carriageway width, footpath width, approach characteristics, and functional road classifications. These measurements were essential to estimating roadway capacity, which forms the basis of LOS analysis.

To assess existing traffic conditions, traffic volume surveys were conducted during peak periods, capturing the heterogeneous traffic stream characteristic of Khulna City. Counts included a wide mix of vehicles such as rickshaws, easybikes, CNG/Mahindra, motorcycles, private cars, buses, trucks, and vans. Since this mixed, non-lane-based flow cannot be analyzed directly in terms of vehicle count, all observed volumes were converted into Passenger Car Units (PCU) using standard equivalency factors. The converted PCU values allowed the comparison of different vehicle types within a single analytical framework.

Once traffic volume and geometric characteristics were established, roadway capacities were calculated for each approach of the intersections. The Volume-to-Capacity (V/C) ratio was then computed using these capacity values and the corresponding traffic volumes. Based on standard LOS thresholds, V/C ratios were interpreted to classify operational conditions ranging from free-flow (LOS A) to oversaturated and highly congested (LOS F). However, because traffic demand can fluctuate noticeably within peak periods, PHF analysis was also incorporated. The Peak Hour Factor was calculated using the relationship between the hourly traffic volume and the highest 15-minute flow within that hour. The PHF-based LOS classification further helped identify traffic concentration, stability, and the presence of sudden surges in vehicle flow.

In addition to these measures, modal share patterns were analyzed to understand how travel behavior varies across intersections and between morning and evening peaks. This provided insights into dominant modes and temporal shifts from non-motorized to motorized travel. Finally, LOS for each intersection was determined by triangulating the results from both the V/C ratio and PHF methods, ensuring a comprehensive and accurate representation of their operational performance. The combined methodology enabled the identification of congestion levels, performance deficiencies, and the overall functionality of the selected intersections under mixed traffic conditions.

$$\text{Volume Capacity Ratio} = \frac{\text{Total Hourly PCU}}{\text{Capacity}} \quad (1)$$

$$\text{Capacity, } C = \frac{\text{Highest Design Capacity} * \text{Effective Width}}{12} \quad (2)$$

$$\text{PHF} = \frac{\text{Hourly Volume}}{4 * \text{volume count at highest 15-min}} \quad (3)$$

Kafy et al., 2018

Table 2: Traffic performance measurement by V/C ratio (Kafy et al., 2018)

LOS	V/C Ratio	Control Delay (sec/veh)	Detailed Description
A	0.00–0.35	≤10	Represents the best operating conditions and is considered free flow. Individual users are virtually unaffected by the presence of others in the traffic stream.
B	0.35–0.58	>10–20	Represents reasonably free-flowing conditions but with some influence by others.
C	0.58–0.75	>20–35	Represents a constrained constant flow below speed limits, with additional attention required by the drivers to maintain safe operations. Comfort and convenience levels of the driver decline noticeably.
D	0.75–0.90	>35–55	Represents traffic operations approaching unstable flow with high passing demand and passing capacity near zero, characterized by drivers being severely restricted in maneuverability.
E	0.90–1.00	>55–80	Represents unstable flow near capacity. LOS E often changes to LOS F very quickly because of disturbances (road conditions, accidents, etc.) in traffic flow.
F	>1.00	>80	Represents the worst conditions with heavily congested flow and traffic demand exceeding capacity, characterized by stop-and-go waves, poor travel time, low comfort and convenience, and increased accident exposure.

Table 3: LOS with respect to its PHF (Kafy et al., 2018).

Peak Hour Factor (PHF) Value	LOS
0.7 or less	A
0.8 or less	B
0.85 or less	C
0.90 or less	D
0.95 or less	E
>1 or less	F

Road Name	Capacity (PCU/h)	Volume (PCU/h)	V/C Ratio	LOS
Khan-E-Sabur Road (Shibbari)	1,500	1,374	0.916	E
KDA Avenue (Shibbari)	2,300	2,100	0.913	E
Majid Sharoni	1,440	1,046	0.726	C
Ibrahim Mia Road	1,220	900	0.738	C
Sher-E-Bangla Road (Zero Point)	2,040	1,850	0.907	E
Khulna City Bypass (Upper)	1,820	2,005	1.102	F
Khulna City Bypass (Lower)	1,820	2,460	1.352	F
Khulna-Satkhira Road	1,644	2,100	1.277	F
Sher-E-Bangla Road (Moynlapotha)	2,300	1,583	0.688	C
KDA Avenue (From Shibbari)	2,300	2,150	0.935	E
KDA Avenue (To Rupsha)	1,880	2,630	1.399	F

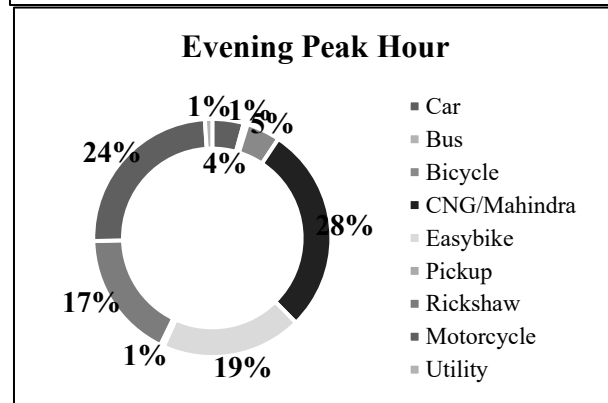
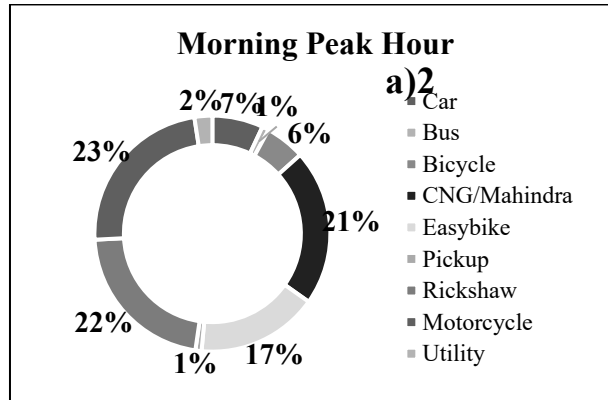
Powerhouse Road	990	800	0.808	D
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The provided data shows the volume-to-capacity (V/C) ratio for different roads in Khulna, indicating the level of congestion and traffic flow efficiency. Roads like Khan-E-Sabur (Shibbari), KDA Avenue (Shibbari) and Sher-E-Bangla Road (Zero Point) have high V/C ratios (above 0.9), placing them in LOS E, suggesting that these roads are approaching or exceeding their capacity and are operating with significant congestion, which may lead to inefficiency and delays. The Khulna City Bypass (Upper and Lower) and Khulna-Satkhira Road, with V/C ratios over 1.0, fall into LOS F, indicating that these roads are oversaturated and severely congested, requiring urgent measures to improve traffic flow. Conversely, roads like Majid Sharoni and Ibrahim Mia Road, with V/C ratios around 0.7, fall into LOS C, showing moderate congestion that still allows for relatively smooth traffic movement but with room for improvement in capacity and efficiency. Powerhouse Road shows LOS D with a V/C ratio of 0.808, indicating that although the road operates under acceptable conditions, there is still noticeable congestion that could worsen during peak hours.

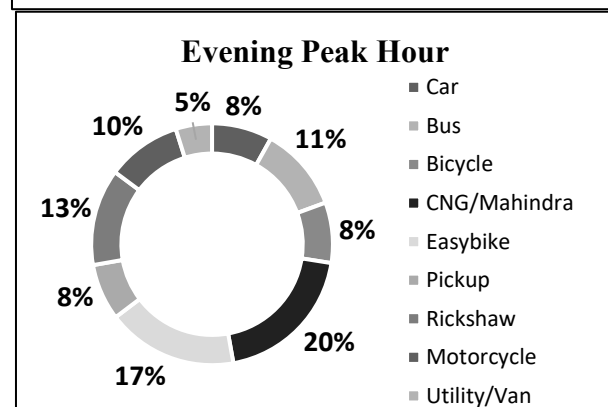
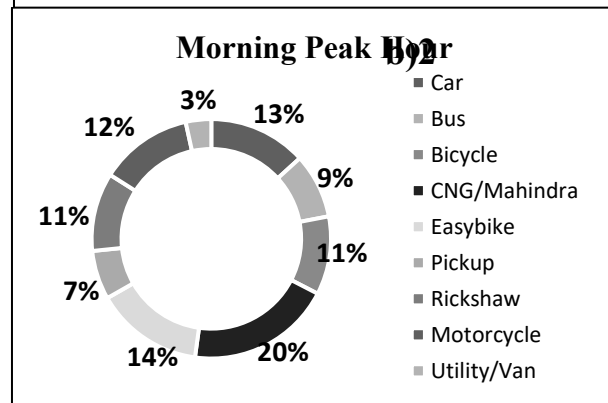
Road Name	PHF	LOS
Khan-E-Sabur Road (Shibbari)	0.881	D
KDA Avenue (Shibbari)	0.815	B
Majid Sharoni	0.921	C
Ibrahim Mia Road	0.930	C
Sher-E-Bangla Road (Zero Point)	0.825	B
Khulna City Bypass (Upper)	0.840	D
Khulna City Bypass (Lower)	0.820	D
Khulna-Satkhira Road	0.89	C
Sher-E-Bangla Road (Moylapotha)	0.910	D
KDA Avenue (From Shibbari)	0.860	D
KDA Avenue (To Rupsha)	0.88	C
Powerhouse Road	0.901	D

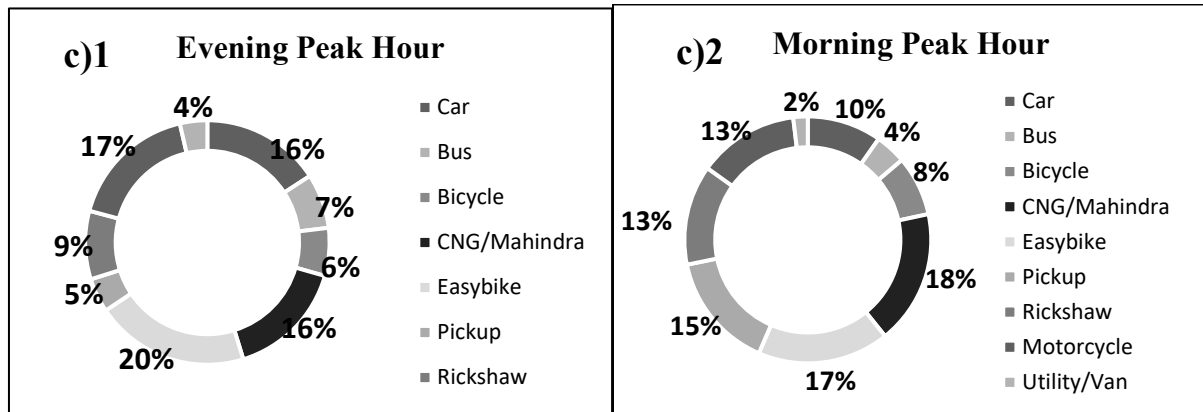
The provided data shows the Peak Hour Factor (PHF) and corresponding Level of Service (LOS) for various roads in Khulna, reflecting traffic flow efficiency during peak hours. Roads such as KDA Avenue (Shibbari) and Sher-E-Bangla Road (Zero Point) with PHF values of 0.815 and 0.825 respectively are classified as LOS B, indicating a relatively smooth traffic flow with minor congestion that is generally manageable, but still needs attention for optimal operation. Majid Sharoni and Ibrahim Mia Road, with PHF values of 0.921 and 0.930, have a LOS C, suggesting moderate congestion that can be tolerated but may cause delays during peak traffic periods. Roads like Khan-E-Sabur Road (Shibbari), Khulna City Bypass (Upper and Lower), and Powerhouse Road with PHF values between 0.840 and 0.910 are placed in LOS D, indicating high congestion with potential for delays, which could benefit from improved traffic management and infrastructure upgrades. In general, most roads show LOS D and C, signaling that while they are not at maximum capacity, further improvements in road infrastructure, signal timings, or public transportation could help improve traffic efficiency and reduce congestion.

a)1



b)2





The modal share analysis across Shibbari, Zeropoint, and Moylapota reveals clear spatial and temporal variations in transport behavior during peak hours. At Shibbari, non-motorized and semi-motorized modes such as rickshaws (23%) and easybikes (22%) dominate the morning peak, while CNG/Mahindra usage rises sharply to 38% in the evening, reflecting a shift toward faster, motorized options for return commutes. Similarly, at Zeropoint, rickshaws (20%) and easybikes (17%) remain prevalent in both peaks, but evening travel shows a slight increase in motorcycles and CNGs, suggesting growing dependence on private and motorized transport. In contrast, Moylapota exhibits a balanced modal mix in the morning—led by easybikes (18%), rickshaws (17%), and motorcycles (15%)—but transitions to a strong evening dominance of CNG/Mahindra (35%), indicating time-sensitive commuter behavior and declining non-motorized mobility after daylight hours. Overall, these findings highlight that evening peak periods are characterized by a distinct modal shift toward motorized transport, emphasizing the need for adaptive urban mobility strategies to accommodate varying travel demands across different city zones.

4. RESULT AND DISCUSSION

The findings of this paper provide insights into major problems with traffic jams at major intersections in Khulna City, which makes the improvement of infrastructure and better traffic control measures an essential requirement. A comparison between Level of Service (LOS) and Peak Hour Factor (PHF) of the roads in the major intersection such as Shibbari, Zero Point, and Moylapota show that a number of roads operate under LOS E and LOS F showing high congestion, irregular flow, and saturation of the roads. In particular, the congestion of roads, including Khulna City Bypass (Upper and Lower) and Khulna-Satkhira Road exceeds the norm as the V/C ratio exceeds 1.0 indicating the serious discrepancy between traffic demand and roadway capacity. This congestion does not only lower the efficiency of the travel, but also raises travel time, dangers of accidents, and overall unease to the commuters. Conversely, there are roads such as Majid Sharoni and Ibrahim Mia Road, which have the LOS C, indicating that even though the two roads have a reasonable degree of congestion, there is a way through which they can be enhanced and wield the future traffic pressure effectively.

It is seen in the modal shift at such intersections that during the peak time, there is evident tendency toward greater use of motorized mode of transport during the evening peak, the modal like CNGs and Mahindras become more dominant modes of transport than the use of non-motorized modes such as rickshaws. This change also indicates that the city is experiencing an increased need of motorized movement and speed, especially during the evening commute, which becomes increasingly more stressful. Nevertheless, the fact that most forms of transport that are not motorized may be found in the city (including rickshaws and easybikes) is also indicative of the multi-dimensional character of the urban traffic and the necessity to find the overall transportation solutions that would consider both motorized and non-motorized traffic.

The results of this research have relevant policy implications of increasing traffic conditions in Khulna City. To start with, infrastructure should be expanded, especially roads of LOS E and LOS F, including

the Khulna City Bypass and Shibbari crossroads, where the expansion of roads, the addition of lanes, as well as the introduction of flyovers and overpasses will help to greatly increase the capacity and to decrease congestion. Moreover there should be adaptive controllers installed at the traffic lights and most of the major intersections to control all mixed traffic flows better. Such systems would be able to modify traffic signal timings in real time and ensure that the flow would be maximized to both motorized and non-motorized types of transportation.

As a response to the increasing reliance on motorized transport, one should consider public transportation options, such as Bus Rapid transit (BRT), as well as raise the quality of accessibility and reliability of CNG/Mahindra fleets. The increase in the number of public transport will reduce the traffic congestion and at the same time will make commuting sustainable and efficient. Additionally, the usability of walking and bicycle infrastructure should be enhanced in order to promote walking and riding, especially in the trading zones such as Shibbari and Zero point where people should walk or ride their bicycles. Increased pedway curbs and pedestrian crossings would be beneficial to the overall traffic situation and promote the use of non-motorized transport.

To sum up, the results of this research highlight the need to create a multi-faceted solution that will provide traffic management in Khulna. The city can alleviate congestion and ease movement by working on the policy front by working with the strategies to widen the road infrastructure, improve the public transportation as well as improve the local traffic management system. The findings are not only useful in Khulna City but a framework or method can also be employed in other adjacent developing cities in Bangladesh that share the same predicament of urbanization and traffic jam. Through strategic intervention, Khulna will be in a position to enhance its transportation system massively so as to see an easier, safer and efficient movement of traffic by all commuters.

5. CONCLUSION

As the discussion of the three biggest intersections in Khulna City is to be provided- Shibbari, Zero Point, and Moylapota- it is evident that the traffic situation in the city has become critical with many of the approaches acting at or even higher than the capacity they are designed to accommodate. The fact that V/C ratios and LOS of E and F are high suggests that the flow and the situation are unstable, there is sharp congestion, and delays are increasing, particularly at the peak hours. Lack of the uniform distribution of traffic, the non-lane movement, and the rapid migration to the motorized vehicles in the evening further lower the efficiency of operations and raise the risk of accidents and discomfort of traveling. To change this, there must be a coordinated and wholesome policy strategy to address this scenario. Premier, physical infrastructures like lanes, expansions of essential roads and flyovers or underpasses in certain busy cross roads can increase capacity and help alleviate the congestion and impediments to large extents. Second, an introduction of adaptive traffic technologies and recent ones with traffic management would enable real-time traffic to be controlled, which will enhance the movement of motorized and non-motorized transportation. Third, by reinforcing a better public transport (Bus Rapid Transit (BRT), shuttle, or enhancing the efficiency of CNG/Mahindra transports, one can alleviate the strain on the private and semi-private vehicles. Enhanced mobility among the bulk of the non-motorized users will also be achieved by improving walks, bicycle lanes, and crossing points.

In general, to make the traffic situation in Khulna better, a balanced approach should be chosen including the infrastructure improvement, smart traffic management, and sustainable transportation means. Through properly designed interventions, the city will be able to remove a lot of congestion, improve safety as well as enhance better and efficient traffic movement by all road users. Other cities in Bangladesh that are also emerging and having the same weaknesses can get the recommendations provided in this study.

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