Journal of Engineering and Applied Science Vol. 08, No. 01, pp. 19–28, November 2024

Journal of Engineering and Applied Science

Contents are available at www.jeas.ruet.ac.bd

Level of Service (LOS) of Rajshahi-Dhaka Highway: A Case Study on Belpukur Intersection

Md. Naimur Rahman[1], Abdullah Al Rakib[1*], Kaniz Shaleha Akter[1], Sudipto Arpi[1], Md. Shakil Ar Salan[1], Muhammad Waresul Hassan Nipun[1]

[1]*Urban & Regional Planning, Rajshahi University of Engineering & Technology, Bangladesh*

ARTICLE INFORMATION

Received date: 25th Feb 2024
Revised date: 5th Nov 2024
Accepted date: 9th Nov 2024

Keywords

Transportation System
Level of Service
Gateway
Peak Hour Factor
Fluctuated Traffic

ABSTRACT

To picturesque the transportation system's condition, the vehicle's concentration and user ratio must be compared to the design capacity. Traffic Volume Survey (TVS) offers insight into these data and creates a Level of Service (LOS) evaluation for any particular lane. This study focuses on one of the major intersections of Rajshahi to Dhaka Road, the Belpukur Intersection (Gateway). Three different approaches, i.e., V/C ratio, Peak Hour Factor, and Speed Based Evaluation were considered, which showed a massive concentration of LOS B in the survey area, whereas the Natore connectivity resulted in LOS C, making the actual LOS of the intersection, C. Higher concentration of motorcycle, fluctuated traffic of trucks, and modified travel behavior during the weekend are some contributing factors behind this result. This study will help transport planners and policymakers to better understand the influx of vehicles towards Rajshahi and make effective strategies and plans for it.

1. Introduction

A good transportation system is a necessity for extensive economic growth in one region (Niger, 2013; Tong and Yu, 2018). To understand the condition of a traffic infrastructure or transport system, in particular, is a difficult task. Different approaches were taken to better understand the traffic infrastructure based on different variables like road width, speed, stoppage, and presence of TOD, even the number of vehicles or existing traffic. Traffic Volume Survey (TVS) is the basic measurement among all of those, but is still more suitable to identify the present need in a certain traffic infrastructure (Singh and Pantle, 2021) and its future capability it (Das and Tsapakis, 2020). Though various approaches have been developed, most of them are for homogeneous traffic. The present traffic infrastructure in Bangladesh is highly heterogeneous and mixed traffic can be noticed in almost all comers of the country (Mahmud et al., 2019). Traffic Volume Survey thus, is necessary for normalizing the traffic volume into a homogeneous traffic and understanding if the present capacity fulfills the present

* Corresponding authors: Urban & Regional Planning, Rajshahi University of Engineering & Technology, Bangladesh
E-mail addresses: mdnaimurrahmanndc35@gmail.com (Abdullah Al Rakib)

demand. With the survey data during a certain time period, the LOS is calculated, which is a metric to understand the condition of infrastructure (Mathew V. Tom, 2019) that can be divided into six parts starting from A depicting the best scenario to F, denoting the worst scenario (Marwah and Singh, 2000). The context of Rajshahi in transportation is greatly deteriorating due to a massive urban surge in the city. The use of private cars massively surged during the last couple of years and the use of para-transit majorly reduced due to increases in fare price, and the modal choice being transferred to private vehicles. Already the lack of public transit like the public bus was not present in the area earlier thus reducing the possibility of converting para-transit to public-transit.

According to the latest reports, in the last few decades, traffic volume increased by 6 % by 2015 with an increased sum of 19397 (Haque, 2014). The increased quantity of small shops around the roadside and the alarming growth of Autos affected the speed delay time, resulting in massive congestion and reduced LOS for many parts of the city. The creation of Bypass Roads actually reduced the concentration of heavy vehicles in the center part of the city and to understand the full potentiality and effectiveness of Belpukur intersection due to the construction of Khorkhori Bypass Road, a traffic volume survey (TVS) is a necessity that would ultimately be helpful for successful and sustainable transport planning. This survey focuses on a similar intersection containing the Belpukur Bypass to understand the potentiality of the bypass because it serves as the gateway to the north-western divisional center, Rajshahi, and as the major connection point of Rajshahi and Natore road to understand the potential of the bypass.

Table 1. Study details.

Questions	Hypothesis	Objective
1. What is the potentiality of constructing Belpukur intersection?	1. The present LOS of Belpukur intersection is not satisfactory.	1. To assess the present LOS of Belpukur intersection.

This study incorporates the total scenario of Belpukur intersection for weekdays and weekends for individual peak hours. With this detailed approach, the concentration of vehicles was known and possible solutions were recommended. By using this study data, Rajshahi City Corporation (RCC) can incorporate this data to measure the incoming traffic of Rajshahi City and make possible modifications to the traffic infrastructure of Rajshahi City. This study will also be helpful for urban planners and policymakers to better understand the economic growth and commercialization rate and its spatial distribution by analyzing the travel behavior of commercial vehicles and the temporal distribution of the Belpukur intersection.

2. Literature review

2.1 LOS calculation in the foreign context

The concept of LOS, fully known as Level of Service was first mentioned in the Highway Capacity Manual (HCM) in 1965, classifying the road into 6 (six) categories from A to F, having the worst possible scenario for the greater alphabetical value (Afshar, 2014). (Rodrigue, 2020) in his book *"The Geography of Transport Systems"* discussed the exact definition of the six categories upon sharing his thoughts on various indicators of technical and economic performances. **Table 2** denotes the exact definition given by him for the six different classes.

Table 2. LOS and its characteristics.

LOS	Characteristics
A	Free flow traffic
B	Steady traffic
C	Steady traffic but limited
D	Steady traffic at high density
E	Traffic at saturation
F	Congestion

Source: (Rodrigue,2020)

An attempt was made to successfully understand the context of LOS by calculating each time for six lanes in Kolkata, India (Biswas et al., 2016). The authors extensively discussed certain limitations of the Highway Capacity Manual for mixed traffic congestion in a densely populated area. Percentage Speed Reduction (PCR) and Free Flow Speed (FFS) were considered for the LOS calculation process using the 16-hour surveyed data that was further validated using the K - mean clustering method and Kolmogorov - Smimov (K - S) test that ultimately gave birth certain LOS ranges for the Indian context. A different approach was noticed in Pakistan where LOS was calculated using the peak hour factor approach and volume capacity ratio approach (Tariq et al., 2021). With the use of Signalized Intersection Design and Research Aid Software (SIDRA), traffic volume was calculated that was further normalized using PCU values recommended by Urban Unit Punjab. Due to the deterioration rate in capacity amount followed by the effective width and the increased ratio of vehicles, the volume capacity ultimately failed and the LOS was F in that intersection.

2.2 LOS calculation in Bangladesh context

Though neighboring countries have extensively discussed the importance of this survey for traffic infrastructure improvement, very little attention was paid to the major roads of Bangladesh. A survey was conducted to understand the highway capacity connecting the capital with one of the major industrial center points, Gazipur (Hossain et al., 2019). The authors have discussed the time interval of the survey being 15 minutes and the number of observations used for three peak hours. The results were calculated using the peak

hour approach and volume capacity approach that revealed homogeneous traffic during all the peak hours but reduced capacity ultimately resulted in lower LOS, showing the need of road expansion and other innovative measures. The roads available in Bangladesh are National Highways, Regional Highways, Zila Roads, Upazila Roads, Union Roads, Village roads where the highways serve as a connection between district headquarters and divisional headquarters/Asian Highways (Hasan, 2010).

Major intersections of Rajshahi were also evaluated based on the same approach (Kafy et al., 2018) as the authors took 3 (three) major unsignalized intersections for LOS calculation that ultimately resulted in a LOS of F using two approaches for the evaluation process, i.e., peak hour factor and volume capacity approach. It is seen in recent times; the concerned authority is expanding the roads for providing better capacity to incoming vehicles. Upon this discussion, it is clear that to understand the need for improving a traffic infrastructure, LOS evaluation is a necessity and the use of peak hour factor, speed-based method, and volume/capacity ratio is justified.

3. Materials and methods

3.1 Reconnaissance and survey area

Before the actual TVS survey, a reconnaissance survey was conducted to understand the road geometry and the vehicles passing in that intersection. The positions of the four observers were also located during this survey. Road geometry was further verified with the Google Earth Pro satellite data and it showed an approximately 2 % fluctuation between the observed and surveyed value. In **Figure 1,** the road geometry is shown where for the roads connecting the Rajshahi and the Natore road had an effective width of 15 ft, followed by a 10 ft width for the Bypass Road.

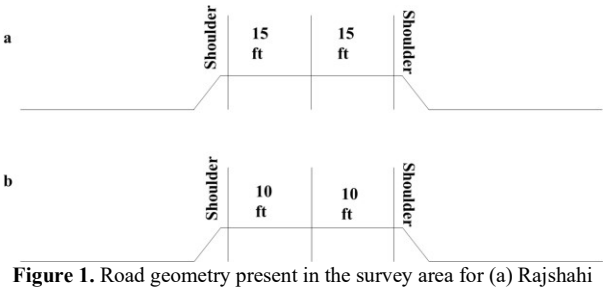

Figure 1. Road geometry present in the survey area for (a) Rajshahi and Natore road; (b) Bypass road.

The road was divided into six parts for each of the present lanes that is shown in the **Table 3.** There was a total of four observation points noticed during the reconnaissance survey. The first observer would count the vehicle in just road IA, whereas the second observed would notice the incoming vehicle coming from Rajshahi to Natore but not moving into Bypass.

Table 3. Road inventory of the survey area.

Road	From	To
IA	Intersection	Rajshahi
IB	Rajshahi	Intersection
2A	Intersection	Natore
2B	Natore	Intersection
3A	Intersection	Bypass
3B	Bypass	Intersection

The third observer would notice the vehicle use of lane 3B, and the four observed would take the directional route for incoming vehicle from Rajshahi road and Natore that used the bypass for various purposes. After that, summation of vehicle observed by first observer and the fourth observer would result in the vehicle count for Road 2B and the other calculation with the third observer would result in the vehicle for 1B.

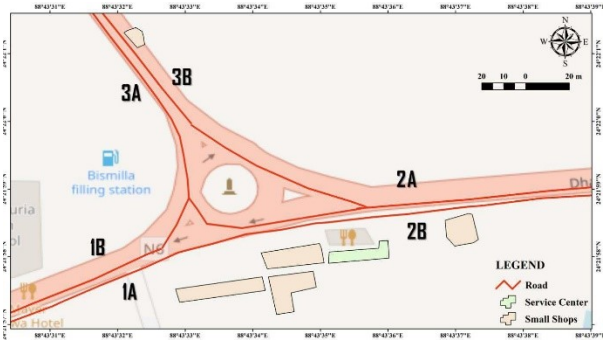

Figure 2. Layout of survey area.

In **Figure 2,** six of the different lanes have been showed with the surrounding infrastructure around the survey area. Katakhali Bazar / Rajshahi was connected with the intersection through Road 01 whereas Baneshwar bazar was connected with the intersection through Natore road, i.e., Road 02. Bypass Road consisted of vehicles going to the Bypass Road, also known as the Khorkhori bypass. Different types of small shops were noticed around the survey area. Though just 500 m back, the total amount of settlement was very scarce, near the intersection, there was a major number of small shops, along with certain service centers.

3.2 Traffic survey method

A total of 16 vehicle categories was selected for the survey and the duration was taken for three peak hours, i.e., morning peak, afternoon peak, and evening peak. **Table 4** contains detailed information about the survey time variation during three peak hours. A 15-minute interval was taken after each survey to simplify the survey process for all observers during the same period. The survey was conducted on two consecutive days containing one weekday, i.e., Thursday and one weekend, 1.e., Friday for a better understanding the scenario of the intersection.

Table 4. Time Distribution during TVS survey for each peak period.

Peak	Time Interval	
	From	To
Morning Peak	8:00	8:15
	8:30	8:45
	9:00	9:15
	9:30	9:45
Afternoon Peak	12:00	12:15
	12:30	12:45
	1:00	1:15
	1:30	1:45
Evening Peak	4:30	4:45
	5:00	5:15
	5:30	5:45
	6:00	6:15

3.3 PCU Identification

Different secondary observations were taken to identify the appropriate PCU for each observed vehicle concerning Rajshahi norm. A total of 16 vehicles were observed during the reconnaissance survey and that was associated with certain PCU values for further normalization. **Table 5** depicts the PCU value for each observed vehicle during the survey process.

Table 5. PCU values for each observed vehicle.

Vehicle	PCU
Heavy Truck	5.00
Medium Truck	4.00
Small Truck	3.00
Large Bus	3.00
Minibus	1.50
Microbus	1.00
Utility	1.00
Car	1.00
Auto Rickshaw / Van	2.00
Auto	2.00
Motor Cycle	0.75
CNG, a three-wheeler motorized by Compressed Natural Gas (CNG)	2.00
Tractor Trailer	4.50
Trolley	3.00
Bicycle	0.50
Improvised motorized three-wheelers (Votvoti, Nasimon)	2.50

Source: (Kadiyali L, 2003; Kafy et al., 2018; Kittelson and Roess, 2001)

3.4 LOS calculation

Three different approaches was applied to identify the LOS for the particular intersection. Each LOS for a respective lane calculated with three different approaches was considered for the ultimate consideration. However the lowest LOS was considered as the actual LOS of the intersection or the particular lane.

3.4.1 Volume/Capacity Approach

The volume Capacity approach is one of the most discussed approach to calculate the LOS for a particular lane based on the design capacity (Kafy et al., 2018; Othayoth and Rao, 2020; Singh and Saraswat, 2019). The capacity was calculated using the highest design capacity and the effective width which was calculated to be 10 and 15 ft, in this instance. The highest design capacity differed according to the size and use of the road and for this survey, a major arterial road was considered to be the best match for the existing road based on length and use of the road. The capacity of the road was calculated using **Equation 1** followed by LOS calculation using **Equation 2.**

$$C = \frac{Highest\ Design\ Capacity\ x\ Effective\ Width}{12} \quad (1)$$

$$\frac{V}{C}\ ratio = \frac{Total\ Hourly\ PCU}{C} \quad (2)$$

Generally, the LOS was calculated using the ranges mentioned in **Table 6.**

Table 6. LOS value according to V/C ratio.

V/C Ratio	LOS
< 0.6	A
0.6 - < 0.7	B
0.7 - < 0.8	C
0.8 - < 0.9	D
0.9 - < 1.0	E
≥ 1.0	F

Source: (Kafy et al., 2018)

3.4.2 Peak Hour Factor Method

Another discussed approach to identify the LOS of a particular lane was Peak Hour Factor method that was used in this survey. To understand the variation between the concentration of three peak hours and to avoid the sudden influx of vehicles, this approach is used to identify the vehicle characteristics and the underlying factors behind it (Ben-Elia and Ettema, 2011). Using the **Equation 3,** the peak hour factor was calculated and that was used to identify the LOS range for a particular lane.

$$Peak\ Hour\ Factor = \frac{\text{Average PCU of 1 hour}}{\text{15 minutes highest PCU x number of reading}} \quad (3)$$

The 15-minute highest PCU was considered to be from the whole day and the number of readings was considered to be 4 (four) as there can only be the respective number of observations if the survey time is 15 minutes.

Table 7. LOS value according to Peak Hour Factors.

Peak Hour Factor	LOS
< 0.7	A
0.7 - < 0.8	B
0.8 - < 0.85	C
0.85 - < 0.9	D
0.9 - < 0.95	E
≥ 1.0	F

Source: (Kafy et al., 2018)

3.4.3 Speed Based Method

The average speed of one vehicle was also considered to be a factor-based analysis of the cumulative sum of the

recorded speed for all the vehicles. The average speed of one vehicle was multiplied by the modal share coefficient (converted to the total percentage of the shared mode) and the sum was used as the speed for that road. But as noticed during the reconnaissance survey, all the lanes shared the same kind of traffic according to the speed, only one lane was considered to be ideal for all the other lanes. The speed was calculated using **Equation 4.**

$$\text{Speed} = \sum_{i=n}^{n} Wi \, {di}/{ti} \qquad (4)$$

Table 8. LOS value according to speed recorded.

Speed (km/h)	LOS
≥ 40	A
30 - < 40	B
25 - < 30	C
15 - < 25	D
<15	E

Source: (Hossain et al., 2018)

4. Result and Discussion

4.1 Modal Share Delineation

4.1.1 Connection of Belpukur intersection with Rajshahi road

The roads were divided into two parts as lA denoted the use of road through the Intersection to Rajshahi direction whereas lane lB resembled the opposite route. Road IA denoted the outgoing vehicle from the intersection to Rajshahi. The main source of those vehicles is from Baneshwar Bazar Road using the road for business and other commercial purposes. Also, the modal share of large bus, medium bus, and small bus was considered to be at the origin of Dhaka and Natore. The survey period was divided into three main peak hour parts, i.e., morning peak hour, afternoon peak hour, and evening peak hour, both for working day and weekend day. **Figure 3** shows the modal share of lane IA at the three peak hours for the working day, followed by the weekend scenario shown in **Figure 4.**

The working day scenario shows the highest concentration of motorcycle vehicles in the evening peak, followed by the second-highest concentration of auto rickshaw/van. The concentration of large buses increased as the day passed but the opposite is true for heavy and medium trucks. Motorcycles recorded in the morning, afternoon, and evening peak hour respectively which showed an increasing rate of approximately 52 % during morning to evening. Large bus, followed the same trend, people's choice of this vehicle increased by 2.5 times, followed by an increase rate of nearly 10 % for utility vehicles.

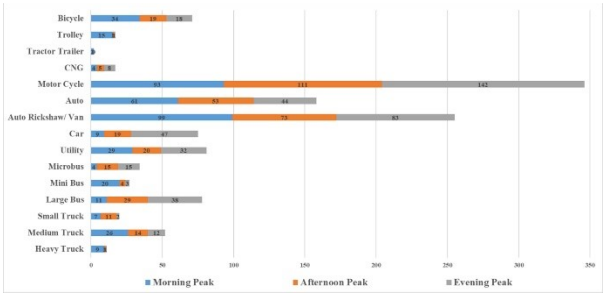

Figure 3. Modal Share of Lane lA during three peak hours in working day.

The opposite scenario can be observed for medium truck as the deterioration rate for that modal choice was nearly 50 %, followed by a 70 % decrease rate of concentration of small trucks. This was due to the restriction for heavy and medium trucks from using the main Rajshahi road due to afternoon and evening hours. All of those vehicles were diverted to the Bypass Road connecting to Rajshahi. The weekend scenario shows a nearly similar scenario but with a much higher concentration of certain vehicles.

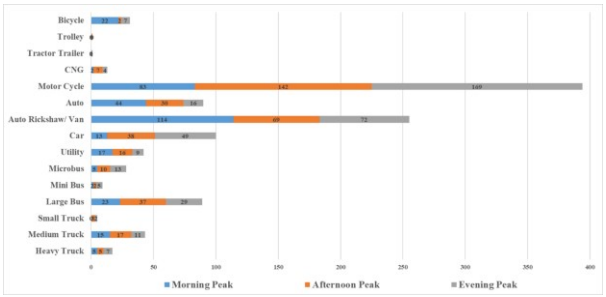

Figure 4. Modal Share of Lane lA during three peak hours in the weekend.

The choice of motorcycle massively surged in the evening peak as the people left their houses for joyriding during the vacation day. A comparatively decreasing scenario can be seen for auto and auto van / rickshaw. A deterioration scenario was also observed for large bus where the use of that vehicle slightly decreased from the weekday due to less travelling choice by bus comparatively to other modes. Utility vehicles and Microbus also decreased in the same ratio but the choice differed as during the weekday the concentration was primarily based on ambulance and other official vehicles that was replaced by vacation purpose cars and grouped vehicles for any occasion like celebration or ceremony. All kinds of trucks showed similar reduction picture as during the weekend, the pressure on the urban markets was not that much higher and the interrelation of Natore and Baneshwar with Rajshahi and Katakhali majorly decreased. Road 1B depicted the opposite lane scenario resembling the choice of mode for weekdays **(Figure 5)** and weekends **(Figure 6).** The weekday scenario shows a massive surge of motorcycle traffic from Rajshahi travelling towards Natore or Bypass Road.

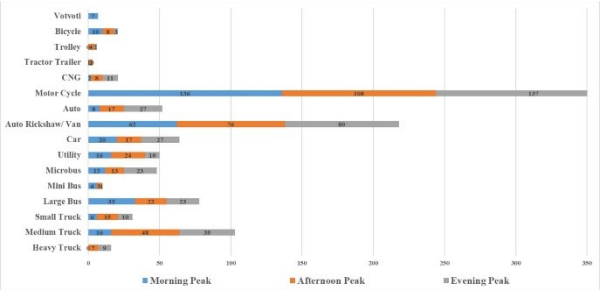

Figure 5. Modal Share for Lane lB during three peak hours in working day.

This particular lane shared the traffic for both the bypass road and the Natore road. The cumulative observation shows a massive modal share for motor cycle and auto rickshaw/ van but it was majorly shared by the Natore road, as observed from the modal share percentage for lane 2A. Opposite scenario can be observed for all kinds of trucks that shared major percentage with the lane 3A, i.e., Intersection to bypass road. Heavy truck volume, on the other hand, was kind of similar for afternoon and evening peak.

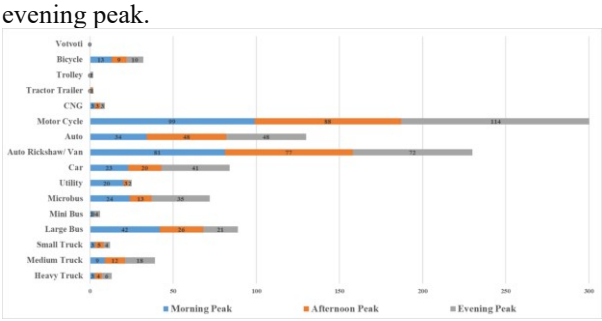

Figure 6. Modal Share for Lane lB during three peak hours in the weekend.

Road lB, on weekend, shared different picture of traffic compared to the working day. The motorcycle share reduced to more than 20 %, combining all the three peak hour volume, whereas Auto Van / Rickshaw share increased by 5.5 % for the same criteria compared to working and weekend day, respectively. An important observation was seen for heavy truck was seen in the morning peak hour whereas in the weekday there was no vehicle of the respective category but there were 3 vehicles of the same category for the weekend day. Car and Utility vehicle increased by 34 %, but the utility share exceptionally reduced in the afternoon and evening peak, mainly due to the increased traffic of vehicles like car, microbus, and other private vehicles and reduced need of para-transit vehicles.

4.1.2 Connection of Belpukur intersection with Natore road

This particular connection connected the southern part (Dhaka, Natore) of the city to Rajshahi, delineating the roads as 2A and 2B, observed for the same days. Lane 2A resembled the modal share of the vehicles travelling from the intersection towards Natore road, whereas lane 2B showed the opposite scenario. In **Figure 7,** it was observed that motor cycle was the most concentrated vehicle in that road having the highest concentration in morning, afternoon, and evening peak, followed by the same scenario of Auto Rickshwa / Van, Car, Medium. Almost all the heavy vehicles like heavy and medium trucks used the bypass road for the travelling whereas major percentage of car, microbus, utility, and other public transports used the Rajshahi road for travelling. In weekday, the concentration almost tripled for all kind of trucks during morning to evening. Bicycle was shared equally in both of the shared road for travelling to Natore road.

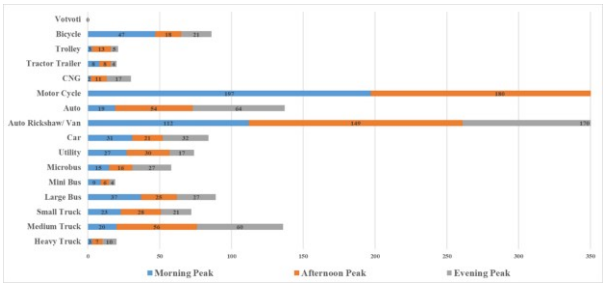

Figure 7. Modal Share for Lane 2A during three peak hours in the working day.

The weekend scenario showed a similar trend for the lane 2A but with a reduced number of vehicles. Large bus and Microbus increased by 13 % and 38 %, respectively from weekday to weekend, the most noticed in the afternoon and evening peak due to recreation purpose. CNG, a three-wheeler motorized by Compressed Natural Gas (CNG) was used by passengers as a para-transit mode in the afternoon and evening peak most of the time. Tractor Trailer and trolley vehicle was used in the bypass roads and the Rajshahi road sharing business of Baneshwar with Khorkhori Bypass and Katakhali, respectively. Road 2B depicts the lane used to travel from the intersection to the Natore road / Dhaka Road. **Figure 9** shows the modal share ratio for the weekday where it shows the highest concentration of motor cycle having the highest percentage in the evening peak, followed by the second - highest scenario for Auto Rickshaw / Van, where the lowest concentration was seen for afternoon peak.

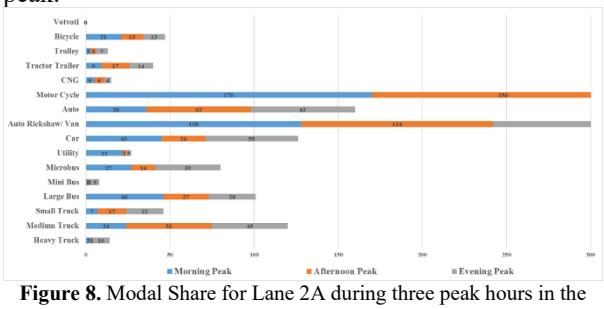

Figure 8. Modal Share for Lane 2A during three peak hours in the weekend.

The third - highest concentration was for auto followed by almost same rate for car, utility, medium truck and

large bus that differed in amount individually in three peak hours. Whereas all kinds of trucks were majorly seen in the morning peak followed by a minimal surge in the afternoon peak, the opposite scenario with the highest concentration in the afternoon and evening peak was seen for private owned vehicles like cars, microbus, and other types of para-transits. Nosimon was also seen only in the morning peak using the bypass road connecting to Natore road, making it primarily used mode for the bypass road.

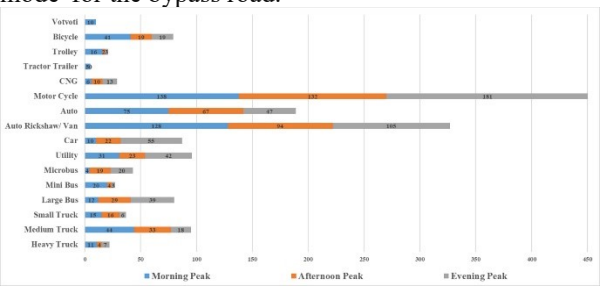

Figure 9. Modal Share for Lane 2B during three peak hours in the working day.

The weekend scenario shows that Nosimon vehicle also increased in the afternoon peak times as 13 vehicles entered the Natore road through that bypass road. The autorickshaw / van concentration also significantly dropped during the afternoon and evening peak followed by an increase in the same period for car, microbus, utility, and large buses. Medium truck followed the same percentage during the three peak hours in the weekend, also being true for heavy truck volume. Minibus and the CNG volume increased the evening peak, followed by the second - highest concentration in the afternoon peak. This was due to the people's choice of private transport modes during the afternoon and evening peaks.

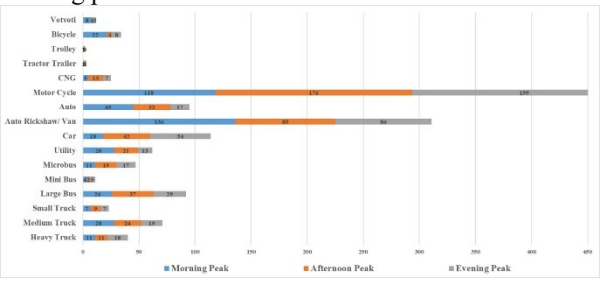

Figure 10. Modal Share for Lane 2B during the three peak hours in the weekend.

4.1.3 Connection of Khorkhori Bypass with Belpukur intersection

Road 3A and 3B depicted the scenario for the modal share of the Bypass Road, resembling from and to intersection scenario, respectively. Road 3A consisted of two traffics incoming from the Rajshahi road and the Natore road. Lane 3B was used only by the outgoing vehicles coming from the bypass road used by various commercial road of the city. In working day, the concentration of motor cycle or auto rickshaw / van was higher comparative to other vehicles but was significantly lower than other lanes of the survey area. In **Figure 11,** it can be seen that the concentration of motor cycle was higher as the primary modal choice where the use was higher morning and the evening peak hours. Auto Rickshaw / Van was also second - highest in the road where the choice was higher in the morning peak.

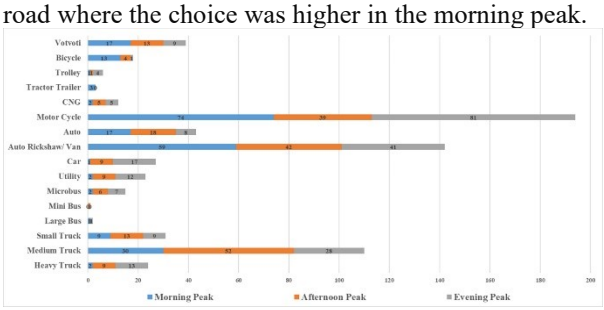

Figure 11. Modal Share for Lane 3A during three peak hours in the working day.

On the other hand, the concentration of all kinds of trucks was higher in this lane as all of the trucks were restricted from using the Rajshahi road after morning peak hours. This resulted in significant increase in all kinds of trucks during morning peak to afternoon peak. Though in evening peak, a decreasing rate was seen for the same mode, but the number of vehicles were higher than the morning peak hour amount. Another significant medium used in this road was Nosimon / Votvoti (used in local language) that was massively higher than other routes in the survey area. During the morning peak hour, 17 vehicles of this category used the bypass road for their business. With the overview and the characteristics of the vehicle, and followed by a quick questionnaire, it was clear that the small businessmen travelled from the Baneshwar Bazar to Rajshahi using the bypass roads as it directly attached them with the key commercial locations for their products.

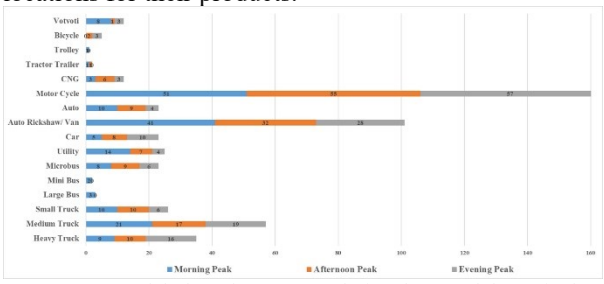

Figure 12. Modal Share for Lane 3A during three peak hours in the weekend.

Though similar kind of increasing and decreasing rate and the ratio of vehicle was observed in the weekend also, the total number of vehicles dropped significantly. Motor cycle was seen to only increase during the afternoon peak hour where it significantly dropped in other lanes during the same peak period. Auto Rickshaw / Van number was also approximately halved during the weekend and the concentration of small and medium truck was reduced by 16 % and 51 %, where the

concentration of heavy truck was increased by 31 %. No significant number of buses were seen in this lane and the nosimon vehicles were also seen in reduced quantity. This shows the commercial importance of this road used by the stakeholders living in Baneshwar Bazar and other surrounding areas.

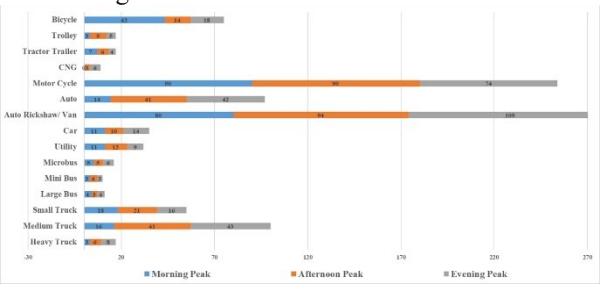

Figure 13. Modal Share for Lane 3B during three peak hours in working day.

Lane 3B is the only lane in the study area that had the higher percentage of auto rickshaw / van compared to motor cycles. In the weekday scenario, shown in **Figure 13,** the percentage of auto rickshaw / van use was raised as day passed whereas a decreasing rate was seen for motor cycle volume for the same time period. Heavy trucks were not significantly seen in the weekday, fo11owed by a moderate scenario of car and utility vehicles. Significant surge of bicycle was also seen in the morning peak period.

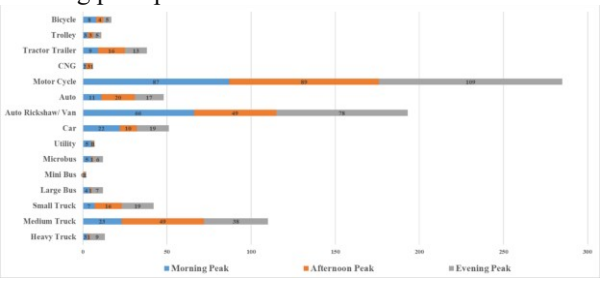

Figure 14. Modal Share for Lane 3B during three peak hours in the weekend.

In the weekend, the scenario changed as the motorcycle concentration was higher in the lane, increasing 1.5 times from the morning peak time in evening peak. Auto Rickshaw / Van was reduced significantly as the use of that vehicle in that particular lane was not greatly required in that lane. The concentration of car significantly increased in that lane whereas the microbus, utility, and minibus were greatly shared by the Rajshahi road. In the afternoon peak, the concentration of medium truck was much higher in the respective lane as shown in **Figure 14.** The large bus, small truck, and heavy truck also was reduced in the weekend compared to the working day.

4.2 LOS calculation

This section deals with the LOS calculation for each of the six different lane, i.e., IA, lB, 2A, 2B, 3A, and 3B using the three different methods mentioned in the methodology section focusing on the underlying reasons behind these scenarios.

4.2.1 Rajshahi-Belpukur connectivity

In **Table 9,** the weekday scenario was noticed to have a LOS of A whereas the weekend scenario showed an LOS of B. In vehicle / capacity approach, 1200 PCU was taken as the per hour design capacity whereas the effective width was 15 ft. The capacity for this road did not exceed by half the amount during the week day and it was even less during the weekend, making the LOS A. There was no variation of total PCU recorded during the 12 data taken during the whole day of the workday. But there was a little variation present in the weekend making the LOS B. This was due to the lesser vehicle concentration in the afternoon peak as people stopped travelling during the prayer time as the area majorly covered the Muslim neighborhoods but the higher concentration of cars and other medium trucks that had a higher PCU, which ultimately resulted in a higher cumulative, making the LOS B, and comparing with the speed- based method, which was always A, making the actual LOS B.

Table 9. LOS Calculation for Lane lA during workday and weekend respectively.

Road Number	Road		Time		PCU	Peak PCU / hr	LOS					
	From	To	From	To			V/C Approach			Peak Hour Factor	Speed Based	Actual LOS
1A	Intersection	Rajshahi	8:00	8:15	238.75	743.75	0.495833	A	A	0.69895288	A	A	A
			8:30	8:45	195.75								
			9:00	9:15	157.25								
			9:30	9:45	152								
			12:00	12:15	125.75	598.75	0.399167	A					
			12:30	12:45	128.75								
			1:00	1:15	184.75								
			1:30	1:45	159.5								
			4:30	4:45	149	660	0.44	A					
			5:00	5:15	175.5								
			5:30	5:45	168.25								
			6:00	6:15	167.25								

Road Number	Road		Time		PCU	Peak PCU / hr	LOS					
	From	To	From	To			V/C Approach			Peak Hour Factor	Speed Based	Actual LOS
1A	Intersection	Rajshahi	8:00	8:15	124.5	585.25	0.390167	A	A	0.805594	B	A	B
			8:30	8:45	112.5								
			9:00	9:15	167								
			9:30	9:45	181.25								
			12:00	12:15	181.75	602.5	0.401667	A					
			12:30	12:45	165.5								
			1:00	1:15	150.5								
			1:30	1:45	104.75								
			4:30	4:45	136.5								
			5:00	5:15	175	569.25	0.3795	A					
			5:30	5:45	149								
			6:00	6:15	114.75								

On the opposite side, meaning in lane lB, was calculated similarly resulting the lane had the perfect LOS of A in the vehicle / capacity approach that varied in peak hour factor approach where in the working day, the morning peak hour had the lowest amount of vehicle concentration and during the weekend, afternoon peak had the lowest concentration, particularly during the prayer time, making the actual LOS of B.

4.2.2 Belpukur-Natore connectivity

Table 10 depicts the LOS scenario for the road 2A, which shows an actual LOS for lane 2A as C. This was due to the higher concentration of vehicles in the Intersection to Natore road during the afternoon and evening peaks as many large bus and trucks travelled from the Rajshahi road and the bypass road, respectively. These higher PCU vehicles increased the cumulative sum, exceeding the design capacity by a moderate amount and making the LOS C. The concentration was lessened during the afternoon peak of weekend for the prayer time.

Table 10. LOS Calculation for Lane 2A during the weekday and weekend respectively.

Road Number	Road		Time		PCU	Peak PCU / hr	LOS						
	From	To	From	To			V/C Approach		Peak Hour Factor		Speed Based	Actual LOS	
2A	Intersection	Natore	8:00	8:15	179	843.75	0.5625	A	C	0.690382942	A	A	C
			8:30	8:45	218.5								
			9:00	9:15	199.25								
			9:30	9:45	247								
			12:00	12:15	292.5	1141	0.760667	C					
			12:30	12:45	261.25								
			1:00	1:15	233.75								
			1:30	1:45	353.5								
			4:30	4:45	383	1188.25	0.792167	C					
			5:00	5:15	301								
			5:30	5:45	224.75								
			6:00	6:15	279.5								

Road Number	Road		Time		PCU	Peak PCU / hr	LOS						
	From	To	From	To			V/C Approach		Peak Hour Factor		Speed Based	Actual LOS	
2A	Intersection	Natore	8:00	8:15	216	892.5	0.595	A	C	0.772791	B	A	C
			8:30	8:45	216								
			9:00	9:15	232								
			9:30	9:45	228.5								
			12:00	12:15	279.25	957.5	0.638333	B					
			12:30	12:45	282.25								
			1:00	1:15	222.5								
			1:30	1:45	173.5								
			4:30	4:45	320.5	1126	0.750667	C					
			5:00	5:15	301.75								
			5:30	5:45	255.25								
			6:00	6:15	248.5								

Similar calculation was done for the road 2B. In vehicle/capacity approach, the concentration of heavy vehicles was higher going to the bypass road for better connectivity with commercial Rajshahi, making the peak PCU / hr for the morning peak higher than the rest of the two peak hours. A similar scenario in peak hour approach was seen for the weekday and weekend as both the LOS was B though the variation was higher in the weekend as for major reduction of heavy trucks than the weekday. These underlying factors made the actual LOS for that road B.

4.2.3 Bypass-Belpukur connectivity

The **Table 11** shows the scenario of road 3A. In the road 3A, the prime vehicle present in the road were heavy vehicles like heavy trucks and medium trucks with mere presence of large bus. Cars, utilities, and motorcycles. This resulted in comparatively lower PCU / hr rate for the respective road, despite being the highest welcomer of the trucks and other commercial vehicles. This ultimately resulted in the LOS A in the vehicle/ capacity approach whereas in the peak hour factor approach, the LOS was B during the weekday and A was in weekend. This was due to the highest PCU during the afternoon peak and lower volume was present in the evening peak. Now, it can be noticed during the weekend, the ultimate calculation was majorly differed in the 12 observations, but the actual peak PCU / hr never fluctuated during the three peak times.

Table 11. LOS Calculation for Lane 3A during working day and weekend respectively.

Road Number	Road		Time		PCU	Peak PCU / hr	LOS						
	From	To	From	To			V/C Approach		Peak Hour Factor		Speed Based	Actual LOS	
3A	Intersection	Bypass	8:00	8:15	87.25	442	0.442	A	A	0.733019854	B	A	B
			8:30	8:45	122								
			9:00	9:15	105.75								
			9:30	9:45	127								
			12:00	12:15	159.5	514.25	0.51425	A					
			12:30	12:45	152.75								
			1:00	1:15	110.25								
			1:30	1:45	90.75								
			4:30	4:45	96.25	446.75	0.44675	A					
			5:00	5:15	94.25								
			5:30	5:45	121								
			6:00	6:15	135.25								

Road Number	Road		Time		PCU	Peak PCU / hr	LOS						
	From	To	From	To			V/C Approach		Peak Hour Factor		Speed Based	Actual LOS	
3A	Intersection	Bypass	8:00	8:15	50.5	371.75	0.37175	A	A	0.561765	A	A	A
			8:30	8:45	61								
			9:00	9:15	148.75								
			9:30	9:45	111.5								
			12:00	12:15	88.75	315.25	0.31525	A					
			12:30	12:45	105.75								
			1:00	1:15	85.5								
			1:30	1:45	35.25								
			4:30	4:45	112.75	315.75	0.31575	A					
			5:00	5:15	81								
			5:30	5:45	65.25								
			6:00	6:15	55.75								

The road 3B depicted the scenario of Bypass to Intersection Road, where the weekday the vehicle capacity ratio showed the scenario of LOS B where the concentration majorly varied between the morning peak and afternoon and evening peak. Similar scenario was true for weekend as the evening peak varied with the morning and afternoon peak. The peak hour factor approach also varied in the weekday and weekend where in the weekend, for higher motorcycle concentration in the evening peak differed the LOS to be B, ultimately making the actual LOS to be B.

4.2.4 Intersection LOS

Both the weekday and weekend scenario presented the LOS C in the road 2A for both days whereas making the actual LOS of the intersection as C. For the weekday, road IA was LOS A, where the same was noticed for 3A. Other roads were seen as the LOS of B. But for the road 2A, the actual LOS for the road was considered to be C.

Table 12. Actual LOS for the Intersection.

Day	Road No.	Road		LOS	Actual LOS
		From	To		
Thursday	1A	Intersection	Rajshahi	A	C
	1B	Rajshahi	Intersection	B	
	2A	Intersection	Natore	C	
	2B	Natore	Intersection	B	
	3A	Intersection	Bypass	B	
	3B	Bypass	Intersection	B	
Friday	1A	Intersection	Rajshahi	B	
	1B	Rajshahi	Intersection	B	
	2A	Intersection	Natore	C	
	2B	Natore	Intersection	B	
	3A	Intersection	Bypass	A	
	3B	Bypass	Intersection	B	

5. Conclusion

A functional transportation system is necessary for economic progress where successful engineering operations and management are accomplished. Traffic volume survey is a key step for determining the present status of traffic volume and forecasting its future state. By comparing all three shifts, which is identified by employing modal variation, it is found to have the highest concentration of dominating vehicles (Motorcycle) during both working days and weekends. But, the frequency of Motorcycle is less in the lanes of Belpukur Bypass Road compared to the other lanes of the road. The frequent flow of buses having a steady interval is observed more in "Belpukur intersection Natore Road" and "Belpukur intersection Rajshahi Road". But in weekend, picnic buses are noticed using the Belpukur Bypass Road, where the frequency of stream of private cars, micro bus is more during the weekend. The entry of heavy vehicles (Truck) is observed more in the Belpukur Bypass Road, because of the restriction in Highway during the morning peak. The locals also suggested that heavily loaded multi-axle trucks are noticed more as the night increases. Because, during the day time, the road surface is heated up and there is enough possibility of having tire punctured. Roadway delineators are required to be established at turning point intending to provide visual aids to drivers at night and also glowing road demarcation. Motorized three wheelers, locally called as "Nosimon" are noticed only in the Bypass Road as they

have restrictions for using the highway. These Nosimons final destination is "Kharkhari Bypass" from Belpukur intersection. In lane "Intersection to Rajshahi" (IA), LOS for peak hour factor is A in working days but it becomes B in weekends indicating that the stream flow of vehicles is not constant in weekend. Again, in its opposite lane "Intersection to Rajshahi" (lB), it is LOS B for both days. Similar observations are noticed in the lanes of Bypass Road except the lane 3A (Belpukur intersection to Kharkhari Bypass) having perfect LOS A in weekends. This unstable stream flow denotes those vehicles violating the roadway accessibility restrictions for particular vehicles. This has to be monitored by the authority to avoid bitter consequences like accidents. The traffic flow behavior in Belpukur intersection of Rajshahi city is observed to be an extremely complex heterogeneous traffic having the LOS C. It means there is a constrained constant stream of vehicles within the speed limit where drivers need to pay more attention. Primarily before the study, it was assumed that there is a possibility of getting LOS A since it serves as an infamous Rajshahi- Natore-Dhaka Highway. But the study reveals LOS C because of "Belpukur intersection Natore Road". Besides, the width of the road is 15 feet per lane and along the Belpukur Bypass Road, it is 10 feet per lane which is insufficient for being a highway. This exceeds the capacity of a lane to accommodate vehicle free flow and ultimately results in with a poor V/C ratio. So, it requires to increase the effective width of both roads to have a free flow of vehicles. Right-angle mirrors as traffic aids are necessary to implement in the Belpukur intersection for avoiding unintended consequences (Kafy et al., 2018). Above all, the local government body is the sole authority that should prioritize making the required adjustments at this intersection. The way forward of the research will help transport planners and policymakers to better understand the influx of vehicles towards Rajshahi and make effective strategies and plans for it.

References

[1] A.A.K. Afshar, “Estimation of Level of Service at Signalized Intersections around the Proposed Health Campus in Etlik, Ankara,” 11th Int. Congr. Adv. Civ. Eng., pp. 21-25, 2014.

[2] E. Ben-Elia, and D. Ettema, “Rewarding rush-hour avoidance: A study of commuters' travel behavior,” Transp. Res. Part A Policy Pract. 45, pp. 567-582, 2011.

[3] S. Biswas, B. Singh, and A. Saha, “Assessment of Level-of-Service on Urban Arterials: A Case Study in Kolkata Metropolis,” Int. J. Traffic Transp. Eng. 6, pp. 303-312, 2016.

[4] S. Das, and I. Tsapakis, “Interpretable machine learning approach in estimating traffic volume on low-volume roadways,” Int. J. Transp. Sci. Technol. 9, pp. 76-88, 2020.

[5] A. Haque, “Transport situation in Rajshahi. Prep,” United Nations Econ. Soc. Comm., Asia Pacific (UN ESCAP), 2014.

[6] M.K. Hossain, M.T. Ahmed, and M.R. Islam, “Vehicle Characteristics and Roadway Level of Service of Industrial Zone: A Typical Example of Gazipur Chowrasta Intersection,” DUET J. 61, 2019.

[7] L.R. Kadiyali, Traffic Engineering and Transport Planning, Khanna Publishers, Delhi, 2003.

[8] A.A. Kafy, L. Ferdous, S.A. Poly, M. Arafat, et al., “Estimating Traffic Volume to Identify the Level of Service in Major Intersections of Rajshahi, Bangladesh,” Trends Civ. Eng. its Archit. 2, pp. 292-309, 2018.

[9] W. K. Kittelson, and R. P. Roess, “Highway capacity analysis after Highway Capacity Manual 2000,” Transp. Res. Rec., pp. 10-16, 2001.

[10] S.M.S. Mahmud, L. Ferreira, M.S. Hoque, and A. Tavassoli, “Micro-level safety risk assessment model for a two-lane heterogeneous traffic environment in a developing country: A comparative crash probability modeling approach,” J. Safety Res. 69, pp. 125-134, 2019.

[11] B. Marwah, and B. Singh, “Level of Service Classification for Urban Heterogeneous Traffic: A Case Study of Kanapur Metropolis,” Transp. Res. Circ. E-C018 4th Int. Symp. Highw. Capacit., pp. 271-286, 2000.

[12] M.V. Tom, “Capacity and Level of Service LOS,” IIT Bombay, 2019.

[13] S. Niger, “Efficiency Analysis of Public Transit Systems in Bangladesh: A Case Study of Dhaka City 103,” 2013.

[14] D. Othayoth, and K.V.K. Rao, “Investigating the Relation between Level of Service and Volume- to-Capacity ratio at Signalized Intersections under Heterogeneous Traffic Condition,” Transp. Res. Procedia 48, pp. 2929-2944, 2020.

[15] J.P. Rodrigue, “Levels of Service for Road Transportation,” The Geography of Transport Systems, 2020.

[16] N. Singh, and N. Pande, “Traffic Volume Study and Congestion,” Int. J. Eng. Appl. Sci. Tecnol. 6, pp. 307-321, 2021.

[17] S.K. Singh, and A. Saraswat, “Design Service Volume, Capacity, Level of Service Calculation and Forecasting for a Semi-urban City,” Rev. d'Intelligence Artif. 33, pp. 139-143, 2019.

[18] K.A. Tariq, H.H. Khan, S.Z. Afghan, and A. Raza, “Evaluation and Improvement of Major Intersection on Eastern Corridor of Gujranwala, Pakistan using SIDRA,” J. Eng. Appl. Sci., 2021.

[19] T. Tong, and T.E. Yu, “Transportation and economic growth in China: A heterogeneous panel cointegration and causality analysis,” J. Transp. Geogr. 73, pp. 120-130, 2018.

[20] Hasan, M. (2010). *Road Classification Practices*. https://www.researchgate.net/publication/341098728