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IMPACT OF PHYSICAL FEATURE ON TRAFFIC CONGESTION: A CASE STUDY OF KHULNA JESSORE HIGHWAY, KHULNA

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ABSTRACT

Traffic congestion has become one of the most complicated issues in Bangladesh that is increasing in an alarming rate. Khulna, one of the largest cities of Bangladesh, is facing challenges due to the congestion. The objective of this study is to investigate the impact of physical feature on traffic congestion under mixed traffic condition. To carry out the study a specific segment of Khulna-Jessore Highway (Rupsa to Shantidham) was taken as study route. A survey was conducted to assess the condition of physical features. Traffic volume was determined by manual method of volume survey with tally sheet. Finally, the volume of different mode of transport are converted in passenger car unit (PCU). Different indices (Lindley's Congestion Index and Capacity Adequacy Index) were used to measure the congestion rate at different segment of the study route showing a relation between the volumes of vehicles at design hour with the capacity of the road. A comparison among three intersection point on the study route was done to identify the most congested segment. And finally, Rupsa was found as the most congested area due to the poor condition of its physical features with narrow road width and lack of control system.

Keywords: *physical feature; volume; passenger car unit; capacity; congestion*

1. INTRODUCTION

Urbanization, the global phenomenon, is taking place at a faster rate in all over the countries of the world. As a result, in recent decades, across the urban areas of the world, both developing and developed countries are becoming automobile dominated. The demand for automobiles and infrastructure is getting high hand in hand. This issue has increased traffic congestion all over the world. Developing countries are particularly facing challenges like traffic congestion, accidents, pollution etc. in most cases (Pojani & Stead, 2015). Like other developing countries in Bangladesh, the level of traffic congestion is getting extremely high. Bangladesh is facing intense level of traffic congestion as being the most intolerable and burning issue. The traffic congestion has become a dangerous arena in the cities of Bangladesh (KDA, 2008). In major cities like Dhaka, Khulna, Chittagong, Rajshahi traffic congestion has reached in an agonising extent. Rapid and ongoing urbanization with limited resources is producing severe transport related problems in most of the cities in Bangladesh (Shamsher & Abdullah, 2012). Khulna, the third largest city of Bangladesh is now facing acute problem due to traffic congestion.

Traffic congestion on important roads is causing immense suffering to the people by retarding them to reach their destination with scheduled time. The western part of this city is facing this acute problem due to haphazard movement of traffic (The Independent, 2015). A huge number of slow moving vehicles create a huge congestion due to lack of proper management. With limited resources, infrastructures fail to provide sufficient services. Poor condition of physical features one of the major causes lying behind this failure. The collective effect of these poor physical features results in high level of traffic congestion and sufferings to the inhabitants. So, it has become essential to explore the condition and impacts of

physical features on traffic congestion. This study aims to investigate the condition of physical features and its impact on traffic congestion in mixed traffic situation.

2. LITERATURE REVIEW

A study was conducted in China investigated the effect of curb parking and effective lane width in capacity and traffic safety. Four lanes with curb parking was selected and different traffic parameters and characteristic were analysed including volume, speed, headway etc. The study was done based on Effective Lane Width and Gap Acceptance theory. The result of this study reveals that effective lane width has a significance influence. The capacity should be considered 12% less under mixed traffic. And with increase of lane width, traffic volume also increases that affect the safety (Cao et al., 2016).

A study in France also conducted to explore the effect of lane on capacity and level of service in urban motorway. The study was done by before and after comparison with implementation of a new scheme. The result concluded that capacity becomes stable with the increase of lane width. On the contrary, level of service degraded in upstream and slightly improved in downstream (Princeton & Cohen, 2011).

A study in context of Dhaka, Bangladesh has been conducted. This study points out on the fact of reduction of congestion through existing roadway conditions and features because intersections are an integrated element of traffic system and can bring effective contribution in reducing vehicular delay. For these major intersections of the city was selected. The result represents that congestion level at intersection can be reduced through flyover which reduces the waiting expectancy but reduces the travel length (Chowdhury et al., 2016).

Another study was conducted in India to assess the effect of lane width on capacity under mixed Traffic Conditions. This study describes the relationship between carriageway width and the road capacity. For capacity analysis researcher use Passenger Car Unit (PCU). Authors concluded that, the capacity of a road is increasing with total width of the carriageway and the relationship between the carriageway with and capacity a second-degree curve (Chandra et al., 2003).

Passenger Car Equivalent (PCE) or Passenger Car Unit (PCU) is a method of expressing various types of vehicles having different characteristics in a common equivalent unit which takes into account the spatial differences between vehicles. (Kadiyali, 2006).

Recent year, Level of service is become more familiar to represent the speed characteristics of highway. Level of service (LOS) is a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience (Transportation Research Board, 2016). Six LOS (A–F) are defined according to the volume and speed of vehicles-

Table 1: Level of service

Level of Service	Speed (km/h)	Volume to Capacity Ratio
A	>=80	<=0.6
B	>=40	<=0.7
C	>=30	<=0.8
D	>=25	<=0.9
E	>=15	<=1
F	<15	> 1

Source: (Kadiyali, 2006)

3. STUDY AREA AND METHODOLOGY

3.1 Study Area

Khulna the 3rd largest city of Bangladesh is connected with Jessor as well as Rajbari and Dhaka through Khulna-Jessor highway. Santidham more to Rupsa section of Khulna-Jessor highway is selected for this study purpose (Figure 1). The section is 4 km long and it is 4 lane road which laid in Central Business district (CBD) of Khulna city. Three college, one madrasa and one commercial bank, one recreational space (Jatisongho Sishu Park) are the main focal point on this road. All most all land beside the road section are used for either commercial or mixed purpose. Again, the pavement condition of the road is not convenient. This has a severe impact on the traffic circulation of the road.

3.2 Methods

The study is conducted based on primary data. The data was collected by conducting field survey from December, 2016 to January 2017. The physical feature survey was conducted to determine the impact of these features in maintaining traffic circulation. For the convenient of the study, the study route was divided into 3 section which are from Santidham more to Royal more, Royal more to PTI more and PTI more to Rupsa. By this survey carriageway width, lane width, median width, footpath, shoulder etc. were determined using measuring tape. And control system (traffic sign, traffic signal etc.) and location of control system is identified by using mobile GPS.

To assess the impact of carriageway width on traffic congestion, a volume survey was done on week days at different peak hours by manual counting method with tally sheet. An average of peak hour volume as per hour was calculated for analysis. The volume analysis procedure was conducted by assuming that there are only passenger cars in the traffic stream. For this the number of each type of vehicle was converted into Passenger Car Unit (PCU). To estimate the PCU for each type of vehicle, speed is considered as an important factor to determine the relative effect of each type of vehicle on the traffic stream in terms of the PCU.

Spot speed of different vehicles at different section were calculated by using the time that required to complete a distance of 60 ft. Stopwatch was used for determining the time (Kadiyali, 2006). The following equation (1) was used to estimate the spot speed:

$$Spot\ Speed\ = \frac{Distance}{Time\ taken\ by\ vehicle\ to\ pass\ the\ distance}(Km/hr) \quad (1)$$

Both speed and area were considered as prime variable to determine the PCU of each vehicle (Chandra & Sikdar, 2000). The standard area of each type of vehicle was used (Table 2).

Table 2: Standard area for each type of vehicle

Category	Vehicles included	Length (m)	Width (m)	Area on Ground (m^2)
Car	Car, jeep	3.72	1.44	5.39
Bus	Bus	10.1	2.43	24.74
Truck	Truck	7.5	2.35	17.62
LCV[a]	Mini bus, vans	6.1	2.1	12.81
Tractor	Tractor trailer	7.4	2.2	16.28
Three-wheeler	Three-wheeler	3.2	1.4	4.48
Two-wheeler	Scooter, motorbike	1.87	0.64	1.2
Cycle	Bicycles	1.9	0.45	0.85
Rickshaw	Pedal rickshaw/cart	2.7	0.95	2.56

[a]LCV indicates light commercial vehicle.

Source: (Chandra & Sikdar, 2000).

The following equation (2) was used to estimate PCU for each type of vehicle:

$$PCU = (Vc/Vi)/(Ac/Ai) \quad (2)$$

Using the above equation (2) the PCU of each type of vehicle at each section was estimated separately (Shown in table 3) considering the PCU of passenger car is equivalent to 1. And the counts of each type of vehicle was converted in a same unit according to the estimated PCU.

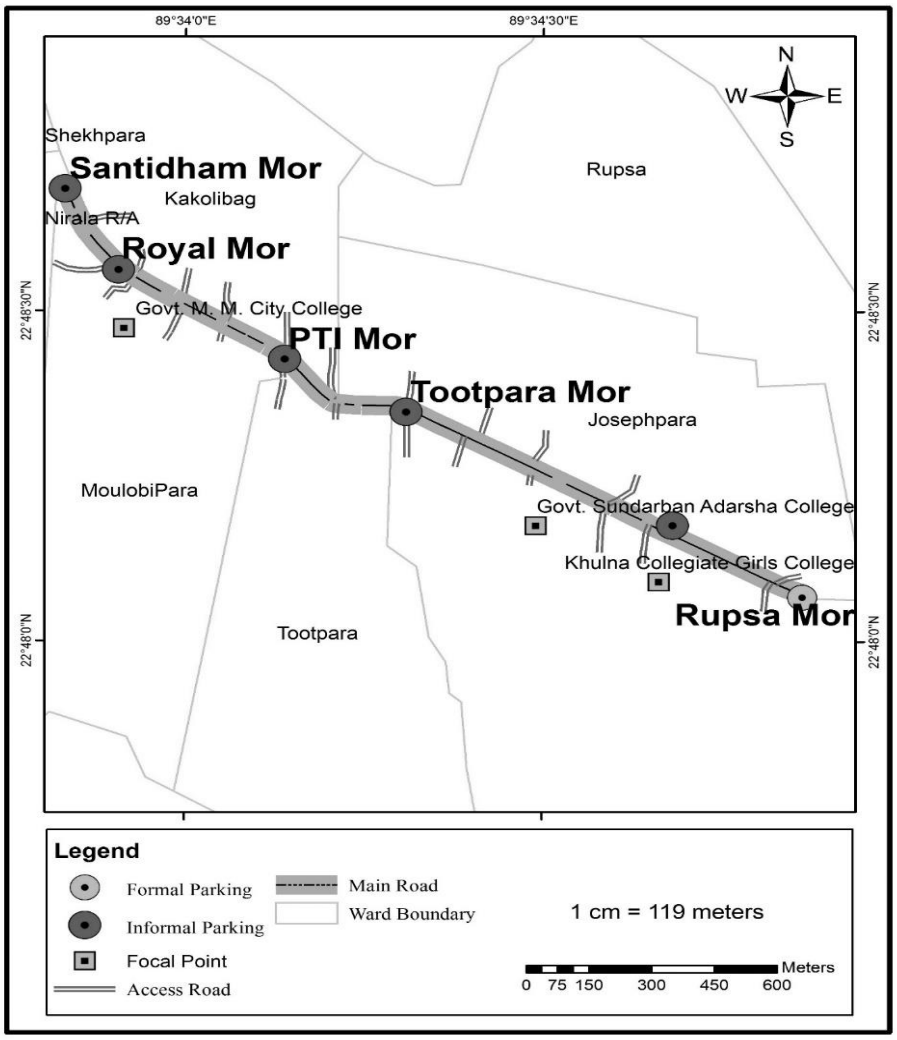

Figure 1: Study Area

Table 3: Estimation of PCU for each type of vehicle

Section	PCU					
	Large Bus	Truck	Motorcycle	Auto-Rickshaw	Rickshaw	Bicycle
Shantidham More to Royal More	6.8	4.6	0.3	1.2	1.3	0.4
Royal More to PTI More	7.3	4.5	0.3	1.8	1.4	0.5
PTI More to Rupsa More	6.6	3.9	0.3	1.6	1.3	0.5

The rate of congestion was measured using Congestion Index based on Capacity Adequacy (CAI) and Lindley's Congestion Index (LCI). CAI is basically capacity to volume ratio where

LCI is volume to capacity ratio. For both index, 1400 PCU per lane per hour was considered as capacity per lane per hour according to Indian road congress (Guidelines for Capacity of Roads in Rural Areas, 1990). The following procedure and determinant were used to estimate the level of congestion (Shown in table 4):

Table 4: The formula and determinants of indices

Indices	Procedure	Determinant	
Capacity Adequacy Index (CAI)	(Rated Volume Capacity)/(Volume During Present Design Hour)* 100	CAI>100	Good
		CAI<100	Worse
Lindley's Congestion Index (LCI)	(Volume at peak hour)/Capacity	LCI< 0.77	Good
		LCI> 0.77	Worse

Source: (Boarnet, Klm, & Parkany, 1998)

In case of CA, the value greater than 100 indicates less traffic congestion. The more the value the less the congestion is. On the contrary, for LCI, the value greater than 0.77 indicates the worst condition with higher traffic congestion.

Finally, Level of Service (LOS) was estimated. And the impact of effective lane width on volume, speed and LOS was assessed. Again, a survey was conducted to find the public perception in regard of the impact of physical features behind traffic jam. Their opinion regarding this issue was analyzed to find out the actual cause behind the over increasing traffic congestion in the study route.

4. ANALYSIS & INTERPRETATION

4.1 Cross Sectional Geometry of Road

Physical features of the road have a great impact in traffic congestion. These cross-sectional elements like carriageway width, lane width, median, and footpath have contributed in the maintenance in traffic circulation. As for study, the road from Rupsa to Santidham has been segmented into three sections, each section has variation in the condition of its cross-sectional elements.

In the section PTI more to Rupsa, the carriageway width is more than the standard (11m) allowable width (Shown in table 5). But a huge space remains unutilized which creates nuisance to the free movement of the traffic. Again, in the segment Santidham more to Royal more, head on collision has become a common incident among the slow-moving vehicles. Lane width in each segment is less than the standard (4m) (Shown in table 4). The insufficient land width not only reduces the lateral space between two vehicles but also the speed of these vehicles. It obstructs the inhabitants to reach at their destination at scheduled time.

Table 5: Cross sectional element of road (from Shantidham to Rupsa)

Section	Carriageway Width (m)	Lane Width (m)	Median (m)	Footpath (m)
Shantidham More to Royal More	10.21	3.9	N/A	0.15
Royal More to PTI More	11.43	2.9	0.4	1.7
PTI More to Rupsa More	13.41	2.9	0.4	4.9

Source: Field survey, 2016

The lane width of each segment of the road also has an irrelevance with the carriageway width. The lane width in the segment from PTI more to Rupsa was relatively low in comparison with the carriageway width. This indicates the ineffective use of the lane width. This ineffective use enhances traffic congestion with a rising level. On the contrary, the section from Santidham more to Royal more, the lane width is relatively higher than the other segment of study route. The narrow lane width in Rupsa is affecting the traffic circulation adversely in PTI more to Rupsa more segment. Along with narrow lane width, Rupsa dock also produces a huge traffic on PTI more to Rupsa more segment, results in failure to accommodate the traffics and its create long time congestion in this segment.
Control system, one of the most important physical features are not in enough number. Only one roundabout has been found at Rupsa within the overall study area. This route is not even signalized. A few markings are found on the pavement that allow two vehicles to move parallel.

4.2 Relation between Carriageway Width and PCU of Vehicles

There exists a relation between carriageway width and Passenger Car Unit (PCU) of various type of vehicle. The PCU for motorized vehicles increase with the augmentation of carriageway width. This increase in PCU has a contribution in the increment of volume level. Generally, the behaviour of non-motorized vehicles varies than the motorized ones. But in the context of Bangladesh, non-motorized vehicles show the same characteristic as motorized vehicles due to the mixed traffic condition. The effect of carriageway width on PCU for motorized and non-motorized are described below for study area.

4.2.1 The Effect of Carriageway Width on PCU for Motorized Vehicles

Considering the average standard area for each vehicle, PCU for each vehicle type increases linearly with the width of carriageway (Figure 2). This increase in PCU requires more lateral gap between two vehicles.

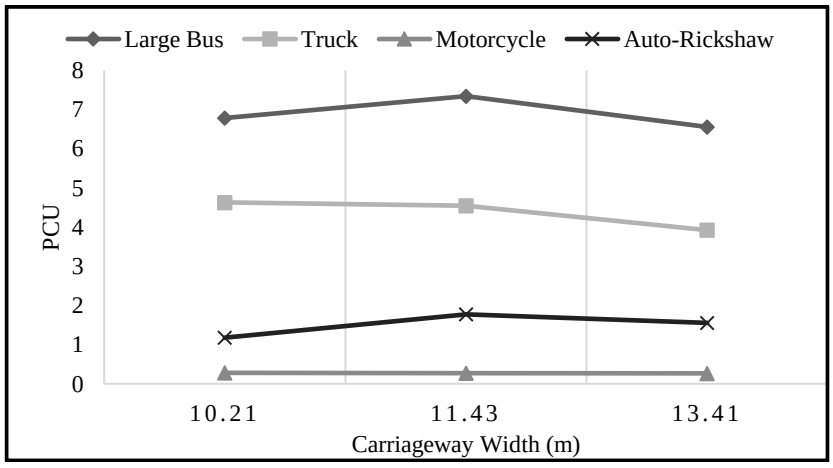

Figure 2: The Effect of Carriageway Width on PCU for Motorized Vehicles

This high value of PCU indicates a threat to the capacity of each lane. With the increasing in PCU, the volume in each lane also increases in contrast with the decreasing capacity of lane. This creates a huge congestion during peak hours. This huge volume of traffic is lessening the average speed.

4.2.2 Effect of Carriageway Width on PCU for Non-Motorized Vehicles

The same scenario of variation in PCU with lane width has been found for non-motorized vehicles (Figure 3). This is occurred because of the typical nature of mixed traffic condition

that prevails in this country. There is no separate lane or footpath for non-motorized vehicles like bicycle, rickshaws. These slow-moving vehicles contribute a major portion of congestion in peak hour of the day.

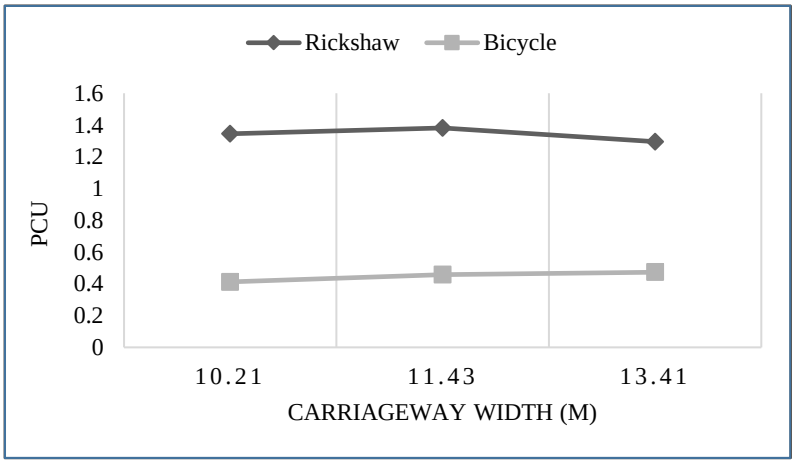

Figure 3: The Effect of Carriageway Width on PCU for Non-Motorized Vehicles

4.3 Relation between Volume and Rate of Congestion

With the increasing pressure on each lane, the congestion rate has been estimated for each segment separately using Congestion Index based on Capacity Adequacy (CAI) and Lindley's Congestion Index (LCI) (Shown in table 6). From CAI it has been found that, the most congested section of the study route is PTI more to Rupsa which occupies the widest carriageway of the whole study route. With lower width of carriageway, the segment from Royal more to PTI more has been found as the lowest congested segment. This same scenario has been found in case of Lindley's Congestion Index (LCI). According to LCI, again the section PTI more to Rupsa more has been identified as maximum level of congestion occurred in that segment.

Table 6: The value of Indices at Different Sections

Section	Carriageway Width (m)	Lane Width (m)	Capacity Adequacy Index (CAI)	Lindley's Congestion Index (LCI)
Shantidham More to Royal More	10.21	3.9	109.13	0.92
Royal More to PTI More	11.43	2.9	154.63	0.65
PTI More to Rupsa More	13.41	2.9	100.68	0.99

Source: Field Survey, 2016

These value of CAI and LCI indicate PTI more to Rupsa as most congested segment. The reason behind this congestion as the inadequate capacity of the lane width. Though this section of the study route has enough space in carriageway but this space is not utilized effectively which reduces the effective capacity of each lane. The narrow lane width fails to accommodate the huge number of traffic resulting in a rising level of congestion.

4.4 Impact of Lane Width on Volume, Speed and Level of Service

With increasing volume an inverse relation is found between volume and speed. Average spot speed for each segment of the study route has been estimated for all types of vehicle in

mixed traffic condition (Shown in table 7). The segment from Royal more to PTI more, highest average spot speed has been estimated with minimum volume of traffic. But in both segment from Santidham more to Royal more and from PTI more to Rupsa, the volume of traffic was comparatively high with lower spot speed. The lane width in these sections was insufficient to support the huge amount of traffic movement in peak hours. This creates very inconvenient to both passengers and drivers causing huge traffic congestion.

Table 7: The Relation between Volume and Speed and LOS at Different Sections

Section	Lane Width (m)	Volume (PCU/Lane/hour)	Avg. spot speed (kph)	LOS
Shantidham More to Royal More	3.9	1153	21.73	D
Royal More to PTI More	2.9	871	23.2	B
PTI More to Rupsa More	2.9	1337	22.16	E

Source: Field Survey, 2016

The rising volume of these vehicles retards the free circular flow due to lack of capacity of road to occupy the augmentation in vehicles. According to the Indian road congress the capacity per lane is considered as 1400 PCU (Guidelines for Capacity of Roads in Rural Areas, 1990). Considering the capacity, the Level of Service (LOS) has been estimated for each lane (Shown in table 6). The condition of the segment PTI more to Rupsa still seems to be in worse condition comparatively than the other sections of the study route. The LOS in this segment indicates that the volume is very close to its capacity level. Speed in this segment reduced at a level where freedom of manoeuver is extremely obstructed. On the contrary the section from Royal more to PTI more is found to be comparatively better, providing a reasonable flow with standard level of comfort and convenience. The section Santidham more to Royal more represent a limited stable flow among the whole study route. But user also face severe restrictions to maintain free flow.

4.5 Effects of Formal and Informal Parking on Congestion

One formal parking exists at Rupsa and five informal parking (Shantidham More, Royal More, PTI More, Tutpara More and in front of Khulna Metropolitan Office) is found in study area (Figure1). These informal parking create congestion at those intersections. Again, though there was space for parking at Rupsa, people found on-street parking as more convenient. This ineffective use of road width retards the free movement of both pedestrian and other users. As a result, a huge congestion occurs at Rupsa in comparison with other intersection of the study area.

4.6 User Opinion regarding Physical Features

The results of user opinion survey indicate the effects of physical features of road behind the high level of traffic congestion (Figure 4). Most of the users identify the ineffective use of road width as the main reason behind the congestion. The huge unused space at PTI more creates inconvenient for the users.

Roadside illegal shops are also blocking the effective width of the road. This causes a huge jam during peak hours of the day. Lack of separate footpath, pedestrian failed to move safely.

Again, lack of formal parking, the slow-moving vehicles prevent the motorized vehicles to maintain their free circular flow which reduces the level of service of the route. The stops randomly for boarding and departure of passengers which enhance the rate of congestion.

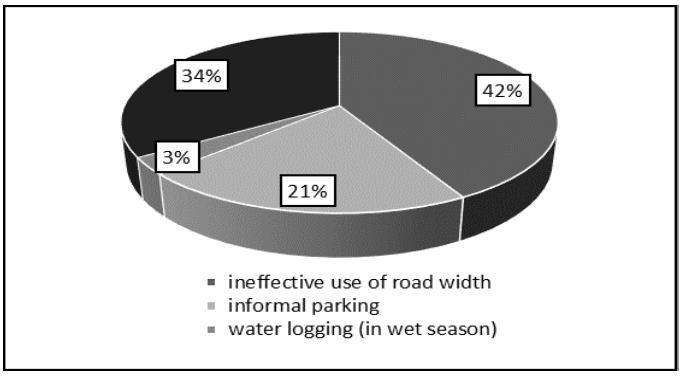

Figure 4: Causes behind Congestion (according to Users' Opinion)

5. CONCLUSIONS

The impact assessment of physical features shows a scenario which appearance is not pleasant at all. The section PTI more to Rupsa has been identified as the most congested segment. The narrow lane width is reducing the marginal error level of each type of vehicle which results in drop in speed. Due to this obstacle in free movement of traffic, the congestion is increasing at an intolerable level. Again, PCU for each type of vehicle also increased with increase of lane width which contributed in the increase in volume which resulted in congestion. A major limitation of this study as it is primary data based, it was tough enough to conduct a high-level analysis with limited source of secondary data. Besides, during survey period reconstruction project for road improvement was on going at “Royal more” which may affect per hour volume of that section. To minimize the level of congestion in the study rout, some recommendations can be suggested. Establishment of proper signs, signals, speed breakers and other control system can help to manage the congestion problem at a level. Again, the effective width of the road should be utilized in a proper way which can be helpful to improve the condition in mixed traffic.

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