Traffic Signal Design of an Isolated Intersection in Feni Town: A Case Study

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Abstract

Traffic signal is widely used for traffic controlling of urban road intersection. The capacity of urban road network depends on the effectiveness of traffic signals. Geographically, Feni is situated in most important region to contribute the national sustainable development. For this reason the population of this town are increasing day by day as well as the number of traffic volume is also increasing. There are no proper traffic management systems in this town as a result, delay is common problem at present and for future this problem will hamper on life style and sustainable socio-economic development of the town dwellers. In order to improve the present situation, it is required to establish a traffic signal design in proper way to become a sustainable town.

In this study various established equation are used and relevant data are collected in trunk road (TR) and Mizan road (MR) intersections of Feni Town. At trunk road intersection the traffic volume of first, second and third phase are 925,139 and 1088 pcu/hr respectively. At Mizan road intersection first, second and third phase traffic volume are 1136, 492 and 454 pcu per hour respectively. The cycle length of trunk road intersection is 305 seconds and Mizan road intersection is64 seconds are calculated by using the collected traffic volume data. Delay for traveling from Trunk Road Intersection to Mizan Road Intersection of Heavy Truck, Small Truck, Large Bus, Minibus, Microbus, CNG, Auto-rickshaw, Motor car, Motor cycle, Bicycle and Rickshaw are 511.00,484.50, 499.00, 442.00, 436.00, 277.50, 344.50, 394.00, 261.00, 242.00 and 395.00 seconds respectively.

Key terms: Traffic volume; traffic signal; sustainable development

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Introduction

Traffic management is necessary to reduce the travel time in transportation system of a town. Feni district is a transit town to establish the connection between the south east hilly regions to the rest of Bangladesh. The town is located beside eastern part of Dhaka-Chittagong highway.

There are so many large and small roads as SSK road, Trunk Road, Mizan road, Hospital road etc. The volumes of large and light vehicles are comparatively high as a result; the conflicts points among vehicles to vehicles and vehicles to pedestrians are very common phenomenon. So it is necessary to design a traffic signal on that intersection.

Objectives of the Study

The main objectives of this study are:

- ☐ To determine the traffic volume of the intersections
- ☐ To determine the Delay of isolated traffic system
- ☐ To reduce conflicts Points between Vehicles to vehicles and Vehicles to edestrians
- ☐ To design the traffic Signal at the study area

Due to the result of urbanization the number of population is increasing day by day also the volume of traffic in the town is increasing in the same rate. To manage such a traffic volume the manual controlling of traffic by police is not enough. We face severe traffic congestion and jam in different points of the town. It's not too early to enhance a controlled traffic signaling system to improve the living standard of the town dwellers.

Study shows that the number of traffic and the availability of road is enough till today. The triangular signal will play a vital role to reduce the travel time.

Study Area and Present Situation

The locations for carrying out the vehicular management system (controlled crossing system, traffic signal design) are decided based on the combination of land use, existing vehicles controlling system at intersections, width of road and type of intersections. Study data were collected from the following locations in the Feni Town:

- Trunk road intersection/Zero Point in Feni and
- Mizan road intersection

The study locations are chosen for considering following criteria:

The Pedestrians as well as the public traffic is enough. Entrances and exits of trunk road intersection are two ways divided and Mizan road is two ways undivided. There are traffic controlled devices and have no pedestrians crossing facilities. Present situation of trunk road and Mizan road T intersection are shown in figure 1.1(a), 1.1(b), 1.2(a) and 1.2(b).

Figure 1.1(a): Trunk road intersection point
(Source: Google Map)

Figure 1.1(b): Trunk road intersection point
(Source: Field Survey)

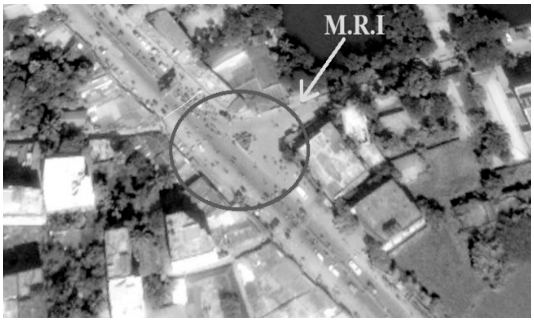

Figure1.2(a): Mizan road intersection
(Source: Google Map)

Figure1.2(b): Mizan road intersection
(Source: Field Survey)

Literature Review

Traffic Signal Studies

There are generally two types of signals in general use: fixed-time and vehicle-actuated. Another intermediate type, semi-vehicle-actuated signal with detectors on the side roads is also used (Reddy and Reddy, 2016).

Fixed-time signal: In this system, the green periods, and the cycle times are predetermined and the duration is fixed. The controllers are simple and relatively of low cost but they are not flexible. Generally, they are successfully used in linked systems. They can be set with time switches to change the settings at certain periods of the day, to adjust with different traffic conditions.

Vehicle-actuated signals: With this type of signals the green periods are associated to the traffic demands. Using detectors which are usually installed on all approaches the green period is determined. In the absence of demands, the signals will continue for an indefinite period on the phase which was served. Several low voltage electronic timers are used here. The basic technique in vehicle-actuated signal utilizes the following two basic features (Reddy and Reddy, 2016): (1) initial vehicle interval and (2) vehicle extension (passage time).

Semi-vehicle-actuated signals: In this type of signals, detectors are installed on the side roads only and the right-of-way normally rests with the main road, being transferred immediately (or at the end of a pre-set period) to the side road when a vehicle passes over the side-road detector (Reddy and Reddy, 2016)

Traffic Signal Design Concepts

The concepts of traffic signal design as they apply to traffic signal timing. The principles related to geometric design and operation are addressed in the Signalized Intersections. The elements addressed in this Chapter include (Mayor of London (2003) :

- Signal control system
- Signal phasing behavior
- Detection layout and
- How the decisions made during traffic signal design affect signal timing for isolated and coordinated operation.

Traffic Signal System Design

Traffic signals may operate in a system of intersections. The application of timing plans depends on the infrastructure available in the signal system. The typical hardware components of a full traffic control signal system is shown in Figure 2.1

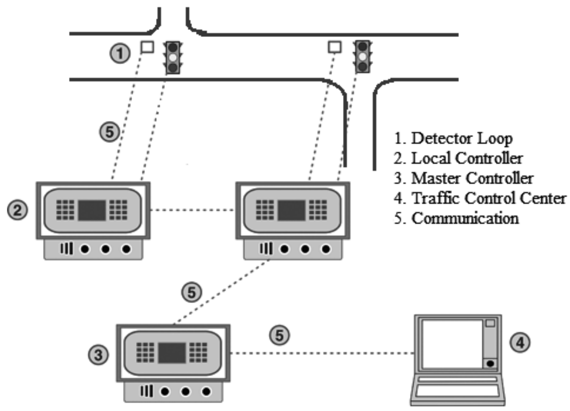

Figure 2.1: Physical components of a signal system (Source: Webster and Cobbe, 1996).

Detection: Gathering information and allocated time about the local traffic signal at each intersection, detectors are used. Detectors may also be used to collect data that can support monitoring, managing and measuring performance (Webster and Cobbe, 1996).

.**Local Controller:** The local controller operates the displays through the load switches using the signal timing provided by the user (Webster and Cobbe, 1996). The local controller implements specific strategies from field inputs or directly from the central signal system operator.

Master Controller: The master controller is an optional component of a system that facilitates communication between the "central" signal system and the local controllers for control decisions. The primary functions of the on-street master controller are to select the timing plans for a group of intersections, to process and store detector count information, and to monitor equipment operation (Webster and Cobbe, 1996).

Traffic Control Center (Signal System): The traffic control center is used for a variety of functions. The central signal system is an alternative to using a master controller and contains the operational database that stores controller data, monitors the system and allows timing and other parameters to be modified (Webster and Cobbe 1996).

Communication: Several components of the system communicate through many forms. Communication facilitates coordination between controllers.

Traffic Signal Phase Design

The signal design is nothing but involves following six major steps. They are below:

1) Phase design
2) Amber time and clearance time determine
3) Determination of cycle length
4) Apportioning of green time
5) Pedestrian crossing requirements
6) The performance evaluation of the above design.

Two Phase Signals

Two phase system is usually adopted if through traffic is significant compared to the turning movements. In Figure 2.2 non-conflicting through traffic 3 and 4 are grouped in a first phase and non-conflicting through traffic 1 and 2 are grouped in the second phase. However, in the first phase flow 7 and 8 offer some conflicts and are called permitted right turns (Mayor of London, 2003). Such phasing is possible only if the Right turning traffic movements are comparatively low than trough movement. On the other hand, if the turning movements are significant, then a four phase system is usually adopted.

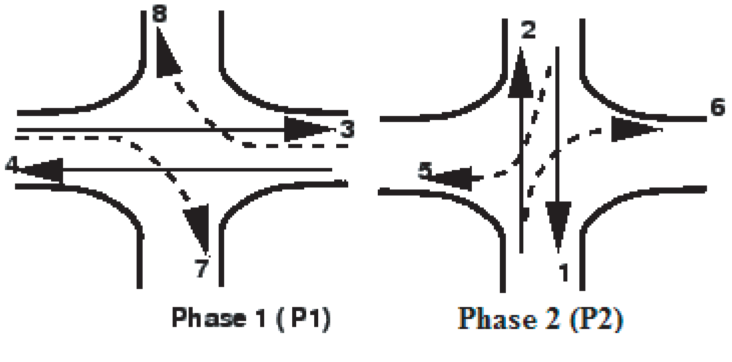

Figure 2.2: Movements in two phase signal system (Source: Mayor of London, 2003).

Three Phase Signals

Three phase signals are adopted for a three legged intersection; where there are two conflicting movements (movements 3 and 4) which are right turns for both the roads and two non-conflicting movements (movements 1 and 2) which are through movements. The phase plan for this kind of signals is shown in figure 2.3. In this study the traffic movements from Lalpol to feni university is considered first phase, traffic movements from Mohipal to Lalpol is considered second phase and traffic movement from feni university to Mohipal is considered third phase.

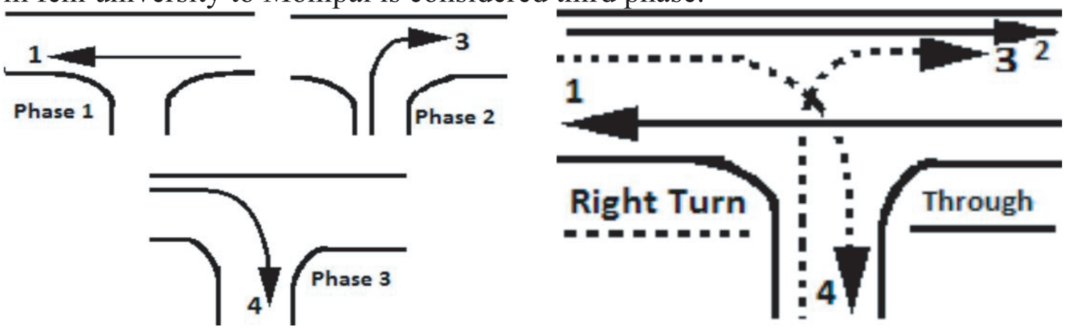

Figure 2.3: Movements in three phase signal system

Journey Speed and Delay Studies

The cost of journey depends upon the speed at which it is made. Journey speeds and delays are highly important in all highway economic studies. It is useful to evaluate congestion, capacity, and level of service (LOS) and trip assignment (Operation Feedback (2017).

Journey speed, also known as overall travel speed, is the effective speed of a vehicle between two points, and is the distance between two points divided by the total time taken by the vehicle to complete the journey including all delays incurred en-route. This speed is calculated by the following equation:

$$Journey\ Speed = \frac{Distance}{Total\ Journey\ time\ (Including\ Delays)}$$

Delay formula: The delay calculation for the Webster method is expressed as Equation

$$d = \frac{c(1-y)^2}{\{2(1-yx)\}} + \frac{x^2}{\{2q(1-x)\}} - 0.65(\frac{c}{q^2})^{\frac{1}{3}} \times X^{2+5Y} \quad \ldots\ldots(1)\ (Operation\ Feedback, 2017)$$

Where,

d = average delay per vehicle on the particular lane group of the intersection, sec/veh;

c = cycle length, sec;

q = flow, vehicles/sec;

y = proportion of the effective green with respect to cycle length (i.e. g/c)

g=is effective green time, in sec

x = the degree of saturation; (q/ys)
s= Saturation flow

Cobbe (1966) explained that the last term in the above equation gives a value which is between 5 and 15% of the average delay in cases. As a result the following equation is often used in practice to calculate an approximation of delay:

$$d = \frac{9}{10}\left[\frac{c(1-y)^2}{\{2(1-yx)\}} + \frac{x^2}{\{2q(1-x)\}}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2) \text{ (Kadiyali and Khanna, 2000)}$$

This is one of the most widely used formulas for the calculation of delays to vehicles approaching isolated intersections

Saturation Flow

Saturation flow is used to describe the constant maximum rate of discharge from the approach road and it is usually expressed in veh/hr of green time for existing intersections (Kadiyali, 2000). Saturation flow is an important consideration in traffic signal design.

The saturation flow can be calculated in different ways. It can be calculated by taking field data but it is a time consuming process. There are also many equations available for the determination of saturation flow. But the calculating the saturation flow using these equations in Bangladesh where both motorized and non-motorized vehicles run together is not satisfactory. So an empirical equation for the determination of the saturation flow developed by Hossain (2001) was used. This equation is satisfactory for Bangladesh which considers both motorized and non-motorized vehicles (Kadiyali, 2000). The equation is given below:

Saturation flow (veh/hr) = 1500 + 430*width (in meter) + 10.5*pnmv - 30*phv - 2*plt - 10*prt

Where,

Pnmv: percentage of non-motorized vehicles
Phv: percentage of heavy vehicles
Plt: percentage of left turning proportion
Prt: percentage of right turning proportion

The standard values for saturation flow according to Webster are given as in the below table.

Table 2.1 Saturation flow for widths 3 to 5.5 meters

Width in m	3.00	3.50	4.00	4.50	5.00	5.50
S (PCU/hr.)	1850	1890	1950	2250	2250	2900

The optimum signal cycle is given by

$$C_0 = \frac{1.5L+5}{1-y} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (03)\ \text{(Webster and Cobbe, 1996)}$$

$$C_0 = \frac{1.5L+5}{1-y} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (04)\ \text{(Operation Feedback, 2017)}$$

$$\mathrm{L} = 2n + R \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (05)\ (Kadiyali \text{ and } Khanna, 2000)$$

Where, L = total lost time per cycle, seconds
n= Number of phase
R =all red time

$$\mathrm{Y} = Y_1 + Y_2 + Y_3 + \ldots\ldots\ldots\ldots\ldots (06)\ (Kadiyali \text{ and } Khanna, 2000)$$

Then Green time,

$$G_1 = \frac{Y_1}{\mathrm{Y}}(C_0 - \mathrm{L}), G_2 = \frac{Y_2}{\mathrm{Y}}(C_0 - \mathrm{L}) and\ G_3 = \frac{Y_3}{\mathrm{Y}}(C_0 - \mathrm{L}) \ldots\ldots\ldots\ldots\ldots (07)$$

Conflict Points and Traffic Patterns

Traffic movements at junctions involved a numbers of conflict points between vehicles to vehicles and vehicles to pedestrians. There are nine conflicts points exist between vehicles to vehicles at T intersections where three are merging, three are diverging and three are crossing (Bo and Fusheng (2013).

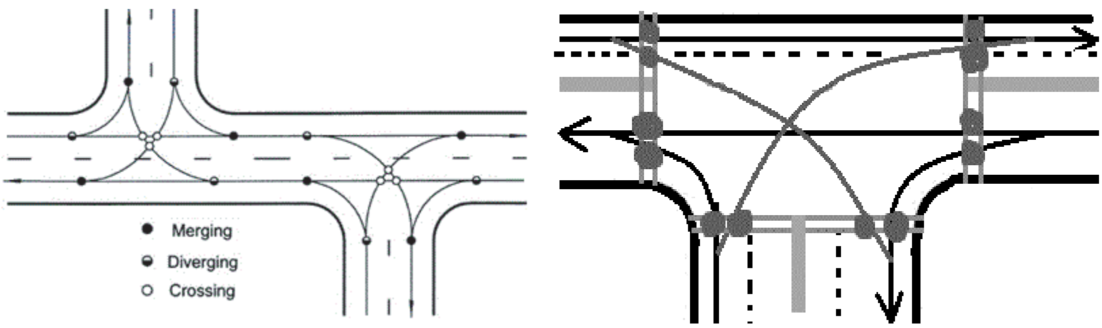

Figure 2.4: Conflicts points between vehicles to vehicles and vehicles to pedestrians (Source: field survey)

Twelve conflict points between vehicles to pedestrians at T intersections shown in figure 2.4 these points can be reduced by using traffic controlled systems as like as traffic signal (Bo and Fusheng, 2013).

At T intersection generally three traffic pattern are commonly used that is allowing free left turning movements or not. In general left turning movements are not considering in congestion at intersections. Traffic engineering always try to reduce the right turning movement by using difference types of traffic management systems. In figure 2.5 is shown the traffic crossing patterns and sequences at a t intersection.

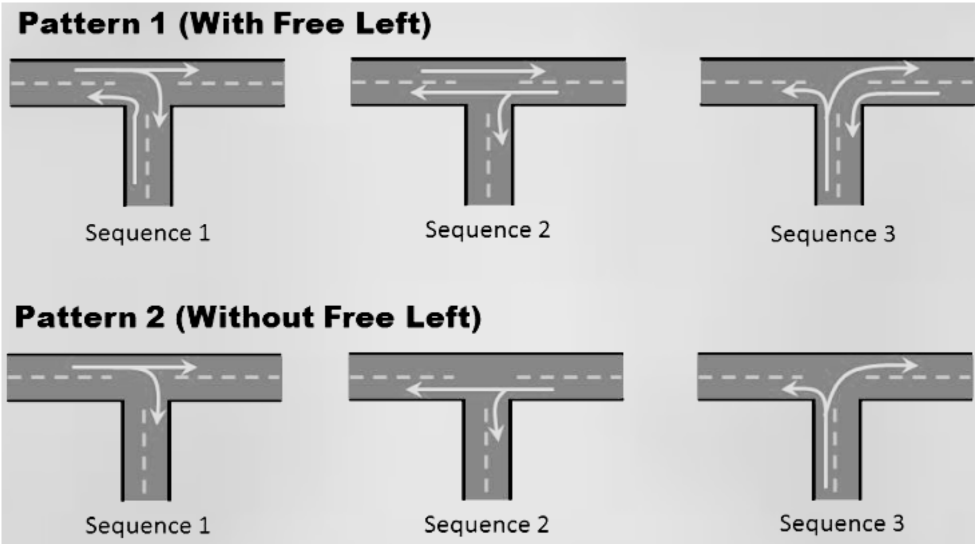

Figure 2.5: Traffic crossing pattern at T intersection (Source: IRCD, 1985)

Case Study of Feni Town

Feni is a small southern district of Bangladesh, bordering (clockwise from the north) Tripura in India, Chittagong district, the Bay of Bengal, Noakhali district and Comilla district. As of 2015, the district's estimated population stood at 1,437,371, making it the ninth-most populous district in Chittagong Division. The rapid growth of vehicular population has resulted in serious traffic congestion in Feni town. From the survey, existing traffic control systems are observed and significant numbers of physical deficiencies are identified at the selected intersections. There are no any traffic signals systems at this town; pedestrian crossing systems are not satisfactory at intersections. In this study is to prepare a plan for traffic signal design at trunk road and Mizan road intersections.

Methodology

Data collection is very constitutive to make the thesis more reliable. The data was collected in various steps using various instruments. For this research data was collected through videos. Recordings were made by interviewing pedestrians. The objectives of the research and importance of data collection were explained to them so that they give their consent. The researcher instructed the pedestrians to provide true and authentic answer. To collect the information that crosses the road at the selected area, a camera was sat up at an elevated situation. Then determined the number of various vehicles that's crossed the selected intersection. The data for present condition of traffic was gathered from the field. These data were used to calculate the delay at the present condition. The existing green period and cycle time was also determined from the field condition. The data were collected from Trunk road intersection and Mizan road intersections. Data collecting time was measured by using stop watch. Qualitative observation was done for mixed traffic behavior. Direct measurement was taken of road width and time for estimation of traffic signal planning and timing data. The collected data are shown in the result section. In the program saturation flow equation, cycle time formula and delay formula were used. To calculate the cycle time and signal time using the mathematical formula and equations stated in the literature review section. In the signal design at both intersection three phase design option are used. From this study the existing delay time and actual delay time was compared.

A video graphic survey was conducted to determine the traffic volume at trunk road intersection and Mizan road intersection. Data was collected at three times per day; morning (from9:30 am to 10:30 am), noon (from 1:30 pm to 2:30 pm) and after noon (from 4:30 pm to 5:30 pm). This video graphic survey was continuing among one week.

Data analysis, Result and Discussions

Delay Calculation

The distance between TRI and Mizan road intersection is 450 meters. Various types of vehicles use this link (from TRI to MRI) as like as Heavy Truck, Small Truck, Large Bus, Minibus, Microbus, CNG, Auto-rickshaw etc. The travel times of these vehicles are determined from field survey which is shown in table 4.1.

Table 4.1: Delay from Mizan road intersection to Trunk road intersection (Source: Field Data)

Type of vehicle	Travel		Desired		Delay in sec.
	Distance (m)	Time (sec.)	Speed (kmph)	Time (sec.)	
Heavy Truck	450	592 (9:52)	20	81.00	511.00
Small Truck	450	525 (8:45)	40	40.50	484.50
Large Bus	450	535 (8:55)	45	36.00	499.00
Minibus	450	478 (7:58)	45	36.00	442.00
Microbus	450	472 (7:52)	45	36.00	436.00
CNG	450	318 (5:18)	40	40.50	277.50
Auto-rickshaw	450	385 (6:25)	40	40.50	344.50
Motor Car	450	430 (7:10)	45	36.00	394.00
Motor-cycle	450	297 (4:57)	45	36.00	261.00
Bicycle	450	377 (6:17)	12	135.00	242.00
Rickshaw	450	530 (8:50)	12	135.00	395.00

Design speed of different vehicles is different. The desired travel time of heavy truck to be 81 seconds but actual travel time is 592 seconds so the delay is 511 seconds. Every vehicle and their desired travel (from Mizan road intersection to trunk road intersection) time and delay is shown in the table. It is huge time which is destroyed in the roads and these delay, travel time and desired time are graphically represents in the flowing figure 4.1.

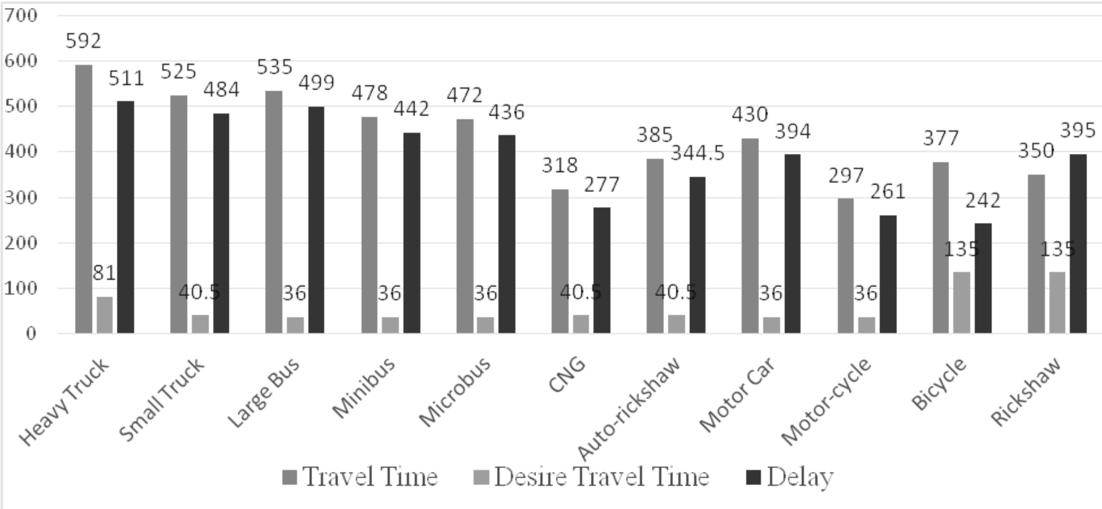

Figure 4.1: Graphical representation of delay (Source: Field survey)

Traffic Volume at Trunk Road Intersection

The maximum traffic volume from Feni University to Mohipal is 1088 PCU per hour which occurred at 4:30 pm to 5:30 pm, from Lalpole to feni university 925 PCU/hr. at 1:30 pm to 2:30 pm and Mohipal to Lalpole is 1392 PCU per hour. The data is shown in the table 4.2.

Table 4.2: Traffic volume at trunk road intersection (Source: Field data)

From		Feni University		Lalpole		Mohipal	
To		Lalpole	Mohipal	F.U	Mohipal	Lalpole	F.U
PCU/hr.	9:30 am-10:30 am	670	550	370	220	738	205
	1:30 pm-2:30 pm	837	790	790	889	1392	350
	4:30 pm-5:30 pm	930	1088	925	769	940	310

Traffic Volume at Mizan Road Intersection

The maximum traffic volume from Mizan road to Feni University is 492 PCU per hour which occurred at 4:30 pm to 5:30 pm, from Feni University to Lalpole is 1136 PCU per hour at time 1:30 pm to 2:30 pm and trunk road to Feni University is 1392 PCU per hour which occurred at from 4:30 pm to 5:30 pm. The all data are shown in the table 4.3

Table 4.3: Traffic volume at Mizan road intersection (Source: Field data)

From		Mizan Road		F.U		Trunk Road	
To		F.U	Trunk Road	Mizan Road	Lalpole	F.U	Mizan Road
PCU/hr	9:30 am-10:30 am	476	230	360	891	298	203
	1:30 pm-2:30 pm	390	407	356	1136	439	390
	4:30 pm-5:30 pm	492	392	458	1125	454	371

Cycle Length at Trunk Road Intersection

For the calculation of cycle length, saturation value, S is required, and it is taken as 3780 as the width of road 7.0 meters.

Normal flows,

q1 = 925, q2= 1392, q3= 1088.

y1= 925/3780 = 0.25, y2=1392/3780 = 0.37, y3= 1088/3780 = 0.29, Y= y1+ y2+ y3 = 0.25+0.37+0.29 =0.91

Cycle length according to Webster method is calculated using the formula

$C_0 = (1.5L+5)/(1-Y)$ where L= 2n+R = (2*3) +9 = 15 seconds.

Therefore, $C_0 = ((1.5*15)+5)/(1-0.645)$ = 305 sec

Green Time for Trunk Road Intersection

Phase 1: G1 = $(Y1/Y)$*(C0–L) = (0.25/0.91)*(305-15) =80 Seconds.

Phase 2: G2 = $(Y2/Y)$*(C0–L) = (0.25/0.91)*(305-15)= 118 Seconds.

Phase 3: G3 = $(Y3/Y)$*(C0–L) = (0.25/0.91)*(305-15)= 92 Seconds.

Considering all pedestrian time = 9 seconds, Amber time = 2 seconds for each phase = 6 seconds for three phases. Total Cycle length = 80+118+92+6+9 = 305 seconds.

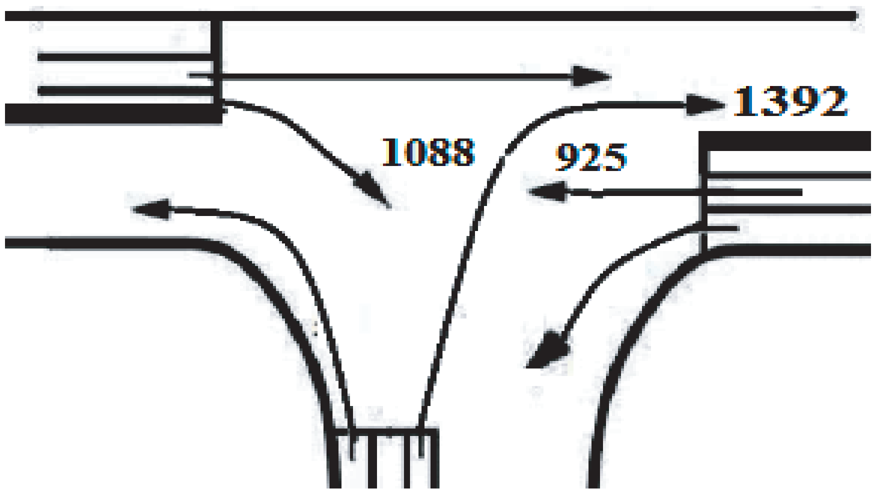

Figure 4.2: Highest PCU at different phase, Trunk road

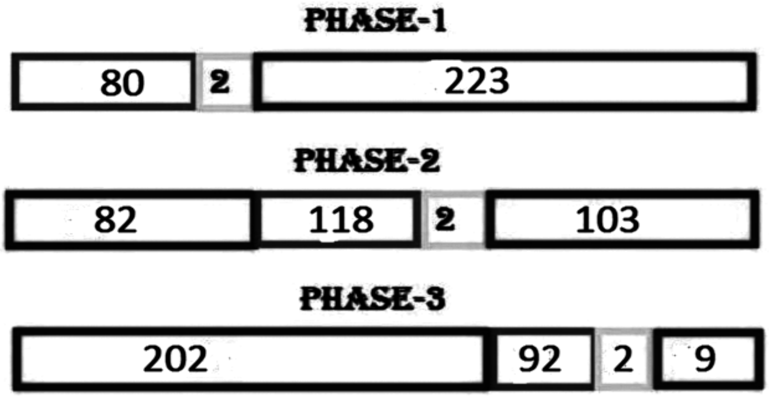

Figure 4.3: Signal Phase Diagram for Trunk Road Intersection

Cycle Length at Mizan Road

The saturation flow is taken 3780 PCU per hour for Mizan road intersection as the width of road is 7 meters.

Normal flows,

Q_1=1136, Q_2=492, Q_3=454, Y_1= Q_1/S = 1137/3780 = 0.30, Y_2= Q_2/S = 492/3780 = 0.13, Y_3= Q_3/S = 454/3780 = 0.12

$Y=Y_1+Y_2+Y_3$
=0.30 + 0.13+0.12
=0.55

Total lose Time:

$$L = 2n + R$$
$$= 2*3 + (3*3)$$
$$= 15\ sec.$$

Cycle length is calculated by using Webster method

$$C_0 = \frac{1.5L + 5}{1 - y}$$
$$= \frac{1.5*15 + 5}{1 - 0.55}$$
$$= 62\ Sec.$$

Green Time for Mizan road intersection

$$G_1 = \frac{Y_1}{Y}(C_0 - L)$$
$$\frac{0.30}{0.55}(62 - 15)$$
$$= 26\ \text{sec.}$$

$$G_2 = \frac{Y_2}{Y}(C_0 - L)$$
$$\frac{0.13}{0.55}(62 - 15)$$
$$= 12\ \text{sec.}$$

$$G_3 = \frac{Y_3}{Y}(C_0 - L)$$
$$\frac{0.12}{0.55}(62 - 15)$$
$$= 11\ \text{sec.}$$

Considering all pedestrian time = 9 seconds, Amber time = 2 seconds for each phase = 6 seconds for three phases.

Total Cycle length = 26+12+11+6+9 =**64 seconds.**

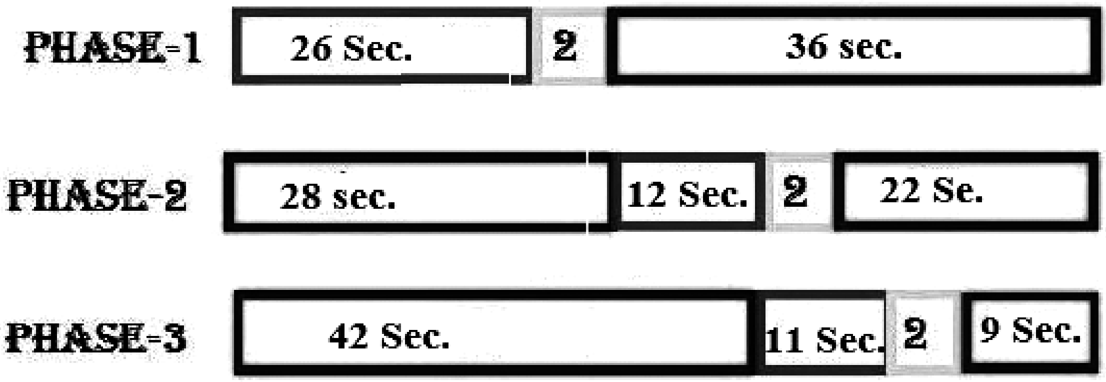

Figure 4.4: Signal Phase Diagram for Mizan Road Intersection

Results and Discussion

Traffic volume was converted into PCU per hour. Traffic volume from Feni University to Mohipal is 1088 PCU/hr. from Lalpol to Feni University is 925 PCU/hr. and from Mohipal to Lalpol is 1392 PCU/hr. at trunk road intersection. Cycle length for the Trunk road intersection is 305 seconds where green time for signal 80, 118 and 92 seconds respectively phase 1, phase 2 and phase 3at trunk road intersection. Traffic volume of Mizan road intersection is 1136 PCU/hr. from Feni University to Lalpol, 454pcu/hr. from Lalpol to Feni University and 492pcu/hr. from Mizan road to Feni University. CycFle length of Mizan road intersection is 64 seconds where phase 1 is 26 seconds, phase 2 is 12 seconds and phase 3 is 11 seconds. Desired travel time of truck from TRI to MRI is 81 seconds but present field travel time is 592 seconds. So the delay for truck is 511 seconds and for every vehicles delay time is more. By providing the following signal will reduce the travel time from Feni University to Lalpole and also other routes. It will reduce the conflicts points between vehicles to vehicles and vehicles to pedestrians as well as it will reduce the accidents frequency and intensity. Therefore, there is no necessary of traffic or community police to control the traffic volume at both intersections

Major Findings

From the field survey and data analysis, following findings are observed:

a) Traffic volume is high at trunk road intersection

b) Vehicles do not follow the traffic rules at trunk road and also Mizan road intersection

c) Pedestrians do not obey the road crossing rules at both intersections
d) Volume of Auto rickshaws and CNG are more
e) Police cannot controlled the traffic at proper way
f) Delay is more at both intersections

Recommendations

In this paper following recommendations are given:

a) The right turning at trunk road intersection must be stopped
b) Left turning channel has to construct at trunk road intersection
c) Foot over bridge has to construct at both intersections
d) Traffic controlled device has to setup instead of manual controlled
e) Advance traffic controlled system can be provide at both intersections

Limitations

There are some limitations in our research study due to different constraints as below:

- ⇨ We used video graphic method but its accuracy depends on the quality of camera.
- ⇨ This was the very first data collection of our undergraduate students.
- ⇨ Sometimes raining interrupted our data collection procedure.
- ⇨ No previous research or background data in this regard.

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