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STUDY ON PEDESTRIAN CROSSING BEHAVIOUR AT UN-SIGNALIZED INTERSECTION IN CHITTAGONG CITY

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ABSTRACT

Constant conflicts between the pedestrian and vehicle in limited space occur due to inadequate facilities for pedestrians on the existing roadway condition. Pedestrian crossing behavior is even more complex at the intersection since the vehicle has very little response time to control the vehicles in urban areas. All these issues leading towards the research work required for studying the road crossing behavior of pedestrians at urban intersections. To provide necessary infrastructure and for enhancing pedestrian safety at the un-signalized intersection a clear understanding of pedestrian crossing behavior under mixed traffic conditions is needed. Chittagong city is the second-largest city in Bangladesh. This paper attempts to analyze the general crossing behavior of pedestrians and find out the pedestrian's perception of using road crossing facilities at the un-signalized intersection in Chittagong City under mixed traffic conditions. A Field survey was completed at Agrabad intersection in Chittagong city which has four approaches. All approaches are of two way four lanes. Video observation and a questionnaire survey were conducted among the pedestrians who cross the studied area. 5472 pedestrians at Agrabad intersection have been observed through the video graphic method. A questionnaire survey has been done on 550 pedestrians at Agrabad intersection. Different parameters like gender, age, crossing patterns, educational status, and income of the pedestrian were excreted from the questionnaire survey. From this observation, it is found that 84.01% of pedestrians at Agrabad intersection do not use existing road crossing facilities. Among them, 87.16% male and 73.54% female at Agrabad intersection do not use existing road crossing facilities. The reasons for pedestrians not to use road crossing facilities are lack of awareness (40.75%), time-consuming (41.00%), unsuitable locations (7%), etc. From scrutinizing the study, it would be proposed that roadside barriers must be constructed, and the median barrier should be improved to separate the pedestrian movements from vehicular traffic. As well as, the construction of foot over bridge and the surrounding environment of the crosswalk should be improved along with people's awareness. This study can help researchers and practitioners to understand pedestrian crossing behavior at both signalized and un-signalized intersections.

Keywords: *Un-signalized intersection, Crossing behavior, Mixed traffic conditions.*

1. INTRODUCTION

Due to high population density, rapid urbanization, and lack of adherence to traffic regulations by both drivers and pedestrians, traffic accidents involving pedestrians have become a major safety problem all over the world, particularly in developing countries. Lack of adherence to traffic regulations at pedestrian crossings particularly by drivers creates an example in which pedestrians may become bold and force approaching vehicles in the traffic stream to break in order to gain priority at the pedestrian crossing. On the other hand, pedestrian crossings with heavy pedestrian flow are likely to cause an unacceptable vehicular delay.

There has been extensive research on pedestrian behavior including estimation of accident risks in various environments (Lassarre et al., 2007), the effects of land use on pedestrian safety (Wedagama et al., 2006), the differences between the behaviors of young and old pedestrians (Oxley et al., 1997), and the resulting injury outcomes associated with accidents (Derlet et al., 1990). The World Health Organization estimates that nearly half of global fatalities are vulnerable road users (WHO, 2009). In an investigation, results show that pedestrians are found at fault in 59% of the crashes, drivers in 32%, and both are found at fault in 9% (Hoque, 2004). Another paper has been found, Foot-travelers who expend more time waiting to cross from one side of the street to the median are likely to have a greater risk of ending the waiting time than when they cross from central refuge to the other side of the street (Hamed, 2001). The location of pedestrian crossing facilities also plays an important role in crash occurrences and crash-related injuries. In Israel a detailed analysis of pedestrians' accidents in 2006-2007, with an emphasis on the infrastructure characteristics involved, was performed; it was found that 75% of the fatalities and 95% of the injuries occurred in urban areas, the majorities of cases occurring on-road sections (not at the junction). When a pedestrian crossed the road, about 80% of the accidents took place and the majority of them at non-crosswalk locations or at non-signalized crosswalks (Gitelman et al., 2012). It has also been found around 38.2% of the crashes occur at non-crosswalk locations, while proportionately more 61.8% of the pedestrian accidents occur at non-crosswalk locations (Kim et al., 2008).

In view of different studies, it has been found that many studies have been done for other countries, but few studies have been done for Bangladesh. No study has been done in the context of crossing behavior of the pedestrian in Chittagong city. The overall objective is to study the behavior of pedestrians when they crossed the road. The following main objectives have been set for this study:

- to identify the general crossing behavior of pedestrians,
- to find out the pedestrians' perception of using road crossing facilities, and
- to suggest improvement measures.

2. METHODOLOGY

Research methodology is a systematic way to solve a problem and it refers to what kinds of methods are applied or performed for research. It is a science of studying how research is to be carried out. This research is prepared by field survey (Questionnaire Survey and Video Observation) methods to identify the general crossing behavior of pedestrians and find out the pedestrians' perception of using road crossing facilities.

2.1 Research Instruments

Instrumentations refer to the tools that are used for data collection as well as interpretation. The instruments are used in the research according to the purpose of the research. The data was collected through questionnaires and videos. Mobile phones as a tape recorder, computer, internet, calculator, reference books were used to gather and interpret information.

2.2 Data Collection Procedure

Data was collected through videos and a questionnaire survey. In the questionnaire survey, interviews were made on the basis of age, gender, educational status, occupation, monthly income, and knowledge level of crossing facilities. The interviews were taken in formal and informal settings. The objectives of the research and the importance of data collection were explained to them so that they can give their consent. Pedestrians were instructed to provide a true and authentic answer. In case of any difficulty in understanding the questionnaire, the researcher was there to help them out. To collect the information at the selected area, a camera was sat up at an elevated place. Then the number of pedestrians who are used existing road crossing facilities and who are not determined through video graphic survey.

2.3 Data Analysis Procedure

Data analysis refers to the fact of analyzing data obtained from the pedestrians. After collecting data, they were checked, verified, cleaned and finally edited. Respective tables and graphs were prepared as required. And pedestrian responses were cross-checked. In this way, it has been tried to find out whether they had given the true answer because if they didn't, their responses would contradict. Data from different videos were also analyzed and compared in the same way. The tabulated and transcribed data were analyzed carefully and critically and then interpretations ware made accurately. All the data were analyzed in terms of the central research questions and objectives. Both qualitative and quantitative methods were used for analyzing them.

2.4 Study Area and Period

The City of Chittagong making is the second-largest city in Bangladesh. According to the Bangladesh Bureau of Statistics (2014), Chittagong has a population of more than 2.5 million. In this study, data collection was carried out at the Agrabad an un-signalized intersection as shown in the following figure. A video graphic survey data was recorded for one hour from each approach and 5472 pedestrians have been observed at Agrabad intersection. A questionnaire survey was done randomly selected respondent pedestrians during the period of August 15-25, 2018. The questionnaire data were collected from 550 nos. pedestrians at Agrabad intersection. The sample has been collected in two categories- (i) pedestrians who obey the rules and (ii) pedestrians who violate the rules.

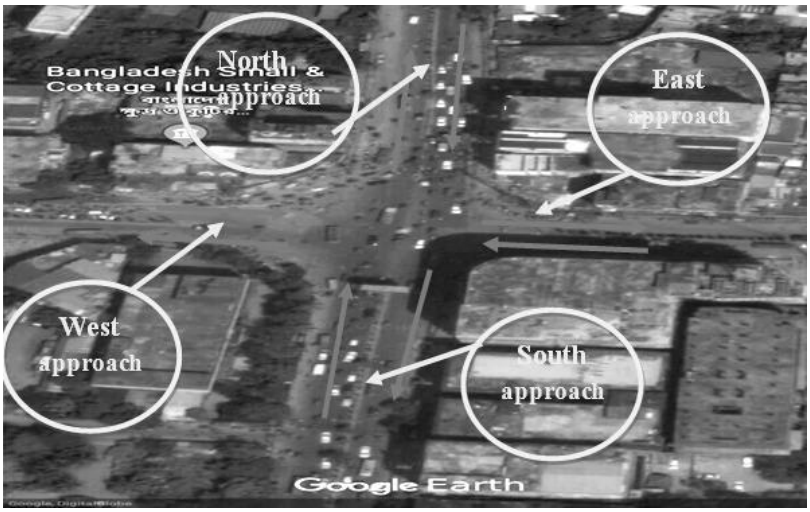

Figure 1: Agrabad Intersection (Google earth view)

3. DATA ANALYSIS AND INTERPRETATION

Data analysis and interpretation is the most important task of the work. The success of this study totally depends on the accuracy of the data analysis and interpretation. In this work, to analyze the collected data, graphical representations have been used.

3.1 Video Graphic Data at Agrabad Intersection

Initially, 5472 pedestrians are followed by a video graphic survey at Agrabad intersection, to determine the road crossing behavior of the pedestrians. Table-1 reveals that only 15.99% of pedestrians were following pedestrian crossing rules. Among them, 12.44% of males and 26.46% of females do not follow rules.

Table 1- Total Pedestrian and Their Behaviour at Agrabad intersection

Type		Agrabad Intersection	
		Total	**Results (%)**
Gender	Male	4206	76.86
	Female	1266	23.14
Total	Follow Rules	875	15.99
	Do not follow Rules	4597	84.01
Male	Follow Rules	540	12.84
	Do not follow Rules	3666	87.16
Female	Follow Rules	335	26.46
	Do not Follow Rules	931	73.54

3.2 Questionnaire Survey at Agrabad Intersection

The questionnaire survey on the basis of age, gender, educational status, occupation, monthly income, and knowledge level of crossing facilities has been done among the 550 pedestrians. Among them, 350 pedestrians were taken from road crossing rules violated group and 200 pedestrians were taken from road crossing rules obeyed group. From the questionnaire survey, the following demographic characteristics in pedestrian behavior are observed.

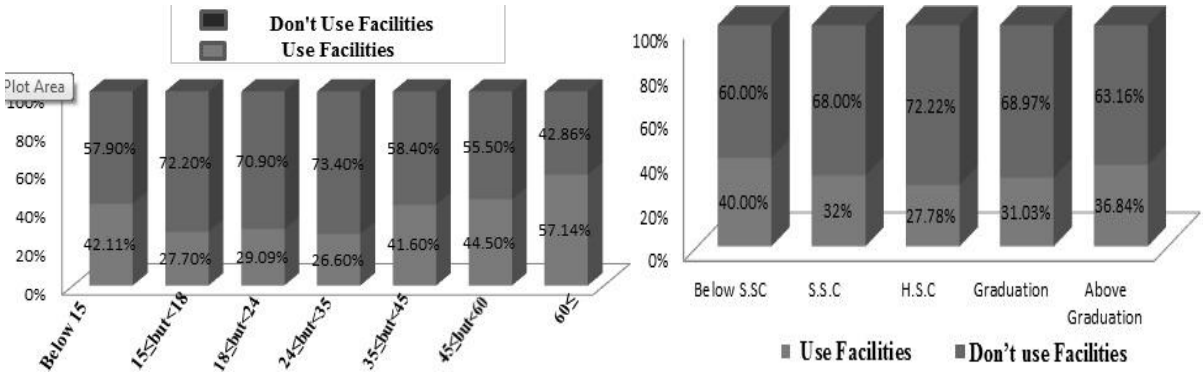

Figure 2: (a) Violation of existing rules in road crossing due to age group; (b) Violation of existing rules in road crossing due to education.

Fig. 2(a) shows that most of the rules violated group is 24-35 years old people. 73.40% of pedestrians do not obey the road crossing rules whose age is 24-35 years. 57.14% of pedestrians obey the road crossing rules whose age is above 60 years and 70.90% of pedestrians do not obey the road crossing rules whose age is 18-24 years. Fig. 2(b) shows that the group below S.S.C level pedestrians obey the traffic rules more, 60% of pedestrians have followed road crossing rules. Most of the rules violated group is the pedestrians who are studying at higher secondary certificate (H.S.C) and the value is 72.22%.

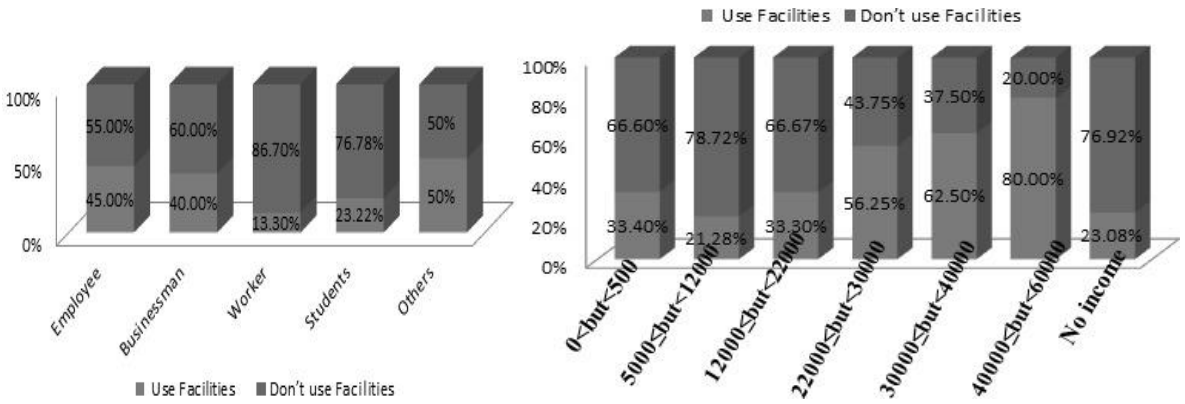

Figure 3: (a) Violation of existing rules in crossing according to occupation; (b) Violation of existing rules in crossing due to income (in BDT)

Fig.3(a) shows that 55% of employees obey the road crossing rules, but 86.70% of workers and 60% of businessmen do not follow the road crossing rules. Maximum students who come from various educational institutions do not use the zebra crossing. From research, it has been found that 76.78% of students do not use existing road crossing facilities at this intersection. Temporary workers who work beside the road, fully violence to the traffic rules and maximum time they cross the road for any purposes. Fig. 3-(b) shows that 80% of pedestrians obey the road crossing rules whose income is around 40,000 to 60,000 BDT per month. 66.67% of pedestrians are not using the road crossing facilities whose income rage is 30000 to 40000 BDT per month.

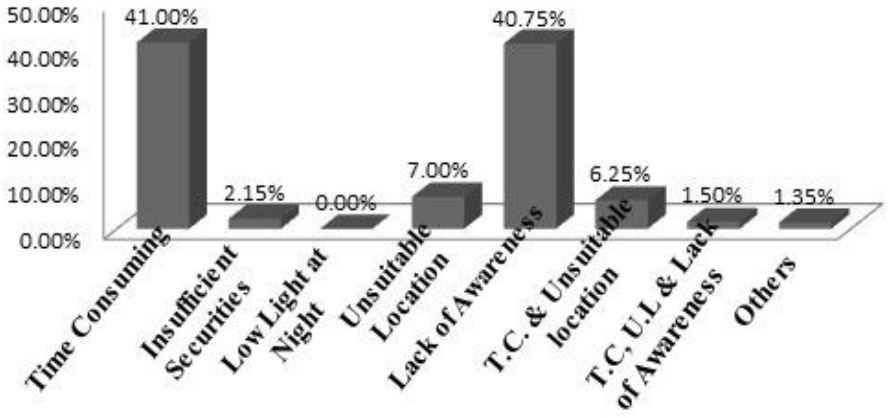

Figure 4: Causes for not using existing facilities during crossing the road (Field survey)

From the video graphics survey, we have known that most of the pedestrians (84.01%) of the selected area are not using the road crossing facilities. The possible reasons for not using the pedestrian's road crossing facilities identified from the field investigation. Based on a questionnaire survey it has been found that lack of awareness has been identified as the topmost reason for not using road crossing facilities. Fig. 4 shows that 41% of pedestrians assumed that obeying the road crossing facilities is time-consuming (T.C.). Lacking awareness is another important factor that discourages the pedestrians to use the road crossing facilities; 40.75% of pedestrians do not use the road crossing facilities due to lack of awareness. But only 7% of pedestrians assume that the crossing facilities are not properly placed and they violate the road crossing rules due to unsuitable location (U.L.) of crosswalk. The lighting problem is not found in the survey.

A zebra crossing is a type of pedestrian crossing used in many places around the world. The minimum width for a Zebra pedestrian crossing is 2.4 meters (Hamed, 2001). Fig- 5(a) & (b) shows that rules for constructing zebra crossings in all approaches of the studied intersection are not maintained properly. And, no pedestrian guardrails and pedestrians' barriers observed in all approaches of the

intersections. According to Bangladesh Road Transport Authority (2008), drivers must be able to see the various traffic signs from at least 75 meters away so that they have time to read the message and act on it. Unfortunately, traffic signs are not properly placed. Interruption due to illegal parking and business in front of pedestrians crossing ways has also been observed.

Figure 5: (a) Roadway marking conditions; (b) Parking on zebra crossing at Agrabad intersection

Figure 6: (a) Illegal parking & (b)Footpath condition & hawkers at Agrabad Intersection

It is very interesting that 100% of pedestrians make-believe violating the road crossing system is risk although they do not use the existing road crossing facilities. 79% of pedestrians know road crossing rules, only 21% of pedestrians are uneducated about road crossing systems. It is very interesting that 72% of pedestrians faced difficulties due to not using existing road crossing facilities at Bangladesh intersection shown by Fig. 5.

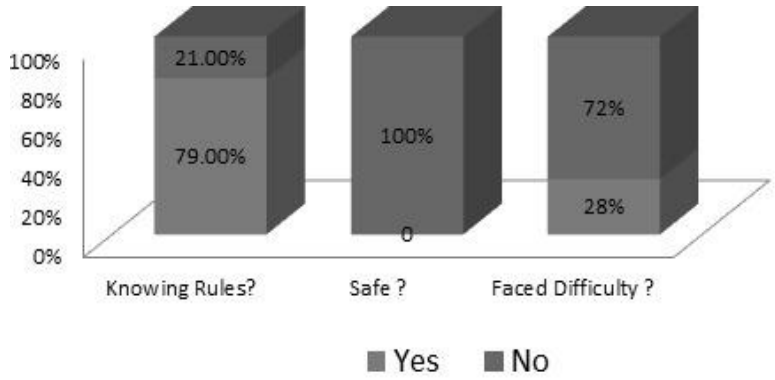

Figure 5**:** Pedestrians Opinions (Field Survey)

4. CONCLUSIONS AND RECOMMENDATIONS

From this research, some conclusions can be made out based on some parameters. At first, the studied area has shown that 41% and 40.75% of pedestrians violate the rules due to time-consuming and lack of awareness respectively whereas 79% of pedestrians know the road crossing rules. Again, male pedestrians (87.16%) more violate the rules comparatively than female pedestrians (73.54%). Besides, only 29.09% of young people obey the rules whose age limit is 18 years to 24 years. Further, educated and rich people more conform to the rules (36.84%) who have at least a graduation degree. On the other hand, below the S.S.C level, 40.00% of people only follow the rules. 7% of pedestrians assume that the crossing facilities are not properly placed, and they violate the road crossing rules due to the unsuitable location of the crosswalk. Moreover, 80.00% of pedestrians use facilities whose salary about 40000 to 60000 BDT.

To acquire more detailed information about pedestrian traffic violations, the research presented here studied the behavioral characteristics of pedestrians and the factors that affect their behavior at unsignalized intersections. Though some pedestrians are following the existing system they are facing so many problems in using the recommended system. These problems include mainly a lake of safety, security, comfort, and cleanliness, etc. Moreover, there is a lack of awareness among the pedestrians and the drivers. So the identified problems and the preference should be considered while proposing a new road crossing system whether it is zebra crossing, underpass crossing or overpass crossing. And the pedestrian issue should be integrated into the transport planning process to ensure safe, secure and convenient pedestrian movement in Chittagong city.

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INTERSECTION DESIGN AS A ROUNDABOUT

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ABSTRACT

The vehicle ownership is increasing daily with the population boom of Bangladesh. The traffic scenario is also moving along with this alternation. In the swiftly evolving global of transportation engineering, the roundabout is quickly gaining recognition as an alternative to a signalized intersection. The number of roundabouts in the U.S. has risen to kind of 3,700 during the last 20 years. Due to common use, there has been a need for detailed study to better apprehend the characteristics of roundabouts and its performance on transportation networks. Sustainability-related benifits of roundabouts are of particular interest. Most of the countries widely adopted roundabouts as an alternative of signalized intersection wherein applicable due to its convenience for operation with lesser conflict points. Roundabouts are designed to control traffic flow smartly at the intersections without using the stop signs or traffic signals. Roundabouts are received more attention increasingly due to the advantages of accident-decreasing and efficiency-increasing. The capacity of a roundabout is the key parameter to check the performance of the roundabout. The capacity of the roadway roundabout depends on the flow at different legs approaching the roundabout. The performance of roundabouts in terms of delays, queues and saturation index typically depends on entry capacity. We surveyed several peak hours at Tiger-Pass intersection (which is one of the busiest intersections of Chittagong city) to design this signalized intersection as roundabout. This paper evaluates a signalized intersection as an alternative geometric design to a multi-lane roundabout. This paper also discusses briefly the possible benefits after the conversion of an intersection into a roundabout. This study will give us the benefit to find the intersections where authority should build more roundabouts.

Keywords: *Intersection, Roundabout, Entry capacity.*

1. INTRODUCTION

According to the Bangladesh Bureau of Statistics (2014), Chittagong has a population of more than 2.5 million and it is developing gradually over time. Rapid urbanization increases the number of vehicles on the road section extensively in our country. The road traffic in the Tiger-pass intersection is solely heterogeneous containing vehicles. In the road transport network, the traffic junctions is considered to be the most complex and the most challenging points where several traffic streams intersect. If traffic junctions with circular flow of traffic (the so-called roundabouts) are compared with traditional at-grade urban road junctions with or without traffic lights, it may easily be decided that properly dimensioned and designed roundabouts greatly increase the level of efficiency. Moreover, during their total lifespan, they reduce the vehicle waiting time at road junctions, the total time of travel, fuel consumption and the length of travel, while also lightening harmful impacts on the environment due to the release of exhausted gases. In addition from an economic standpoint, such intersections bring plentiful benefits such as lower cost of construction, lower land purchase costs and installation of equipment (illuminated traffic signs in particular), less costly maintenance, and lower losses generated by congestions due to excessive traffic load. Besides, the level of traffic safety grows significantly when roundabout-type intersections are used.

"A roundabout is a type of circular intersection or junction in which road traffic is permitted to flow in one direction around a central island, and priority is typically given to traffic already in junction" (Robinson, 2000). The main types of roundabouts are Grade Separated, Mini, Normal, Compact, Signalized, and Double Roundabouts (the last being a combination of Mini, Compactor Normal Roundabouts).

The traffic capacity of the roundabout depends on several factors which include the geometry of the roundabout, the diversity of vehicles, and driver behavior. Usually, the priority of movement at roundabouts is for the circulating flows; therefore the approaching traffic must wait and look for a gap in the circulating flow. There is a need to evaluate roundabouts with different characteristics, such as intersection demand level, traffic demand patterns (e.g., turning movement ratios), and geometric characteristics (e.g., entrance angle, exit angle), and pedestrian volumes.

The aim of this study is to improve the existing condition of the "Tigerpass intersection" of Chittagong city and to find out the dimensions to convert this rotary intersection to a roundabout. The study tends to find out the solution for all busiest intersections like Tigerpass intersections. Researchers, Planners, Policymakers will get ideas about the congestions and solutions along with one of the most important intersections of Bangladesh. The study will also help transport engineers as there will be explanations of possible all benefits.

The history of roundabout and in particular its evolution from the old traffic circles and rotaries built in the first half of the 20th century. Dahl et al. (2012) found that the rate of decreasing in the observed capacity with an increase in the circulating flow was lower at the roundabouts.

One study showed that non-signalized roundabouts aresafer than traditional intersections (Turner, 2011). Perdomo et al. (2014) scrutinized factors affecting pedestrian crossing behavior and found that the existance of pedestrian crossings, crossings location, vehicular speed, pedestrian islands, signage, number of traffic lanes and traffic volumes all affect the pedestrians' willingness to cross at roundabouts. Hels et al. (2007) investigated roundabouts are familier to result in fewer traffic accidents than traditional intersections. However, this is to a lesser degree true for bicycles than for vehicles. One of the first studies on vehicle safety at roundabouts in North America was performed by Montonen, who conducted a crash study using data from roundabouts both on national and municipal roads. The results showed that on national and municipal roads with roundabouts the accident rate was 26% and 23% while the injury accident rate was 4% and 4% respectively (Montonen, 2008). Many studies mainly focused on vehicle safety at roundabouts which all conclude that when

intersections are converted to roundabouts the safety benefits are tangible (Jensen, 2013). One simulation study in 2001 modeled 25 signalized intersections in Burlington, Vermont as roundabouts using the software SIDRA (Redington, 2001). The author estimated a 250,000 yearly reduction in fuel use, when signalized intersections were converted to roundabouts; which amounts to 61,000 tons of CO_2 saved per year. Roundabout features such as signage and advance warning play an important role in determining driver performance when navigating the roundabout. It has been observed that single-lane roundabouts perform better safety-wise compared to multilane roundabouts (Wankogere, 2014). Roundabouts are linked with a 30% to 50% reduction in the number of injury accidents. Fatal accidents are reduced by 50% to 70%. Effects on property damage accidents are highly uncertain, but in three-leg intersections, an increase often will occur (Elvik, 2003).

2. METHODOLOGY

2.1 Overview

The first phase of this study involved the selection of a suitable location. We selected the Tigerpass intersection for its convenience in collecting geographic data and the intersection plays a significant role in Chittagong city. Throughout the second phase, geographic and vehicular data of the intersection were collected. In the third phase, after data collection the data will be analyzed to determine the capacity of each entry lane, entry flow rate, circulating and existing flow rate to calculate central island, splitter island, and sight distance. As a final product of this study, we will convert the existing intersection to roundabout and will present its possible benefits for sustainable transportation.

2.2 Survey & Data Collection

2.2.1 Geographic Data Collection

As per our selected area, we collected its geographic data or features by a total station. The dimensions of existing roadway width, splitter islands, footpaths, and current land-use patterns are considered while conducting the survey Finally, we made an Existing Dimension Drawing of Tigerpass Intersection (selected study area) to make all of its features visible which will help to a workforce of the whole procedure. The Dimension Drawing is given below.

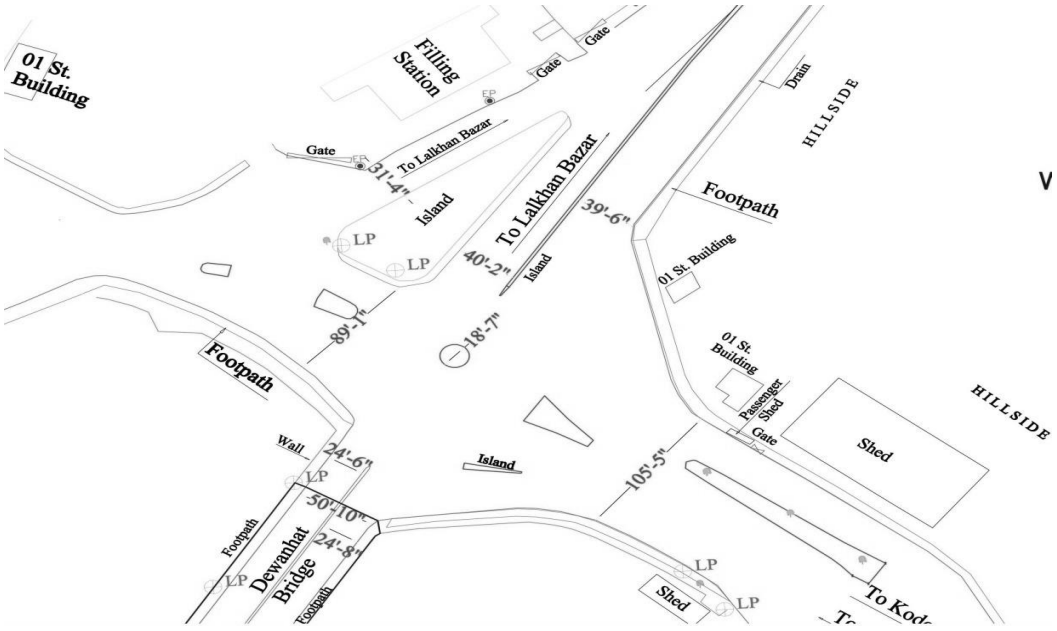

Figure 1: Dimension Drawing of Tigerpass Intersection

2.2.2 Vehicular Data Collection

The vehicular data has been collected using a video camera. For a particular amount of time, a video has been captured and data is later collected by rewinding. In addition to traffic volume, it is possible to obtain other traffic parameters from the captured video. It is possible to cross-check data and ensures quality. In this study, traffic volume was calculated by manual counting for the one-hour duration on a typical peak day. Peak 1-hour traffic data was collected along all directions for every hour at that time. Finally, add them together to show the volume with percentage details in the result and analysis section.

The date of data collection was 12th June 2018 and the time was from 5.00 pm to 6.00 pm. We set several sets of cameras at suitable points of the intersection. After filming one hour, we had found the overall composition of different vehicle categories, showed in Table 1. From the video clip, we had also determined flows in veh/hr. Table-1 also reveals that there are 81% of motorized and 9% of nonmotorized vehicles.

Table 1- Overall Composition of different vehicle categories

Serial No.	Vehicle Category	Flow (veh/hr)	Composition (%)
1	Cycle	121	3
2	Rickshaw	242	6
3	Motor Bike	616	16
4	CNG	826	22
5	Tempu	134	4
6	Human Howler	259	7
7	Car	1003	26
8	Mini Bus	102	3
9	Bus	287	8
10	Mini Truck	86	2
11	Large Truck	73	2
12	Pick up	40	1
Total		3790	

InTable-2, distribution from each entry lane to other lanes as well as shown. It has been ovserbed that there is no flow from Ambagan to Kodomtoli and Ambagan to Dewanhat due to the restriction in entry. From Figure-1 it can be seen that there is no restriction from Ambagan to Lalkhan Bazar as there is a connecting lane.

Table 2- Vehicle per hour Distribution from Four Entry Lane to Other Lanes

From	To	Flow (Veh./hr)	Total Flow (Veh./hr)
Lalkhan Bazar	Dewanhat	534	1275
	Kodomtoli	395	
	Ambagan	346	
Kodomtoli	Ambagan	346	976
	Dewanhat	316	
	Lalkhan Bazar	314	
Dewanhat	Lalkhan Bazar	585	1265
	Ambagan	226	
	Kodomtoli	454	
Ambagan	Lalkhan Bazar	274	274
	Kodomtoli	0	
	Dewanhat	0	

3. DATA ANALYSIS AND INTERPRETATION

3.1 Assembling Traffic Data

This includes obtaining the data relating to periods that are relevant for analysis and which may vary depending on the nature of the side, converting typical crossroad turning movements into roundabout entry and circulating flows and converting heavy commercial vehicle flows to passenger car units. Figure-3 shows a typical turning movement diagram by collected survey data, and Figure-4 shows the typical turning movement diagram converted to roundabout flows. And maximum circulating capacity of 1353 veh/hr has been found at the Ambagan approach and estimated by adding the entry flows which were contributing to the circulating flow (New Market to Lalkhan Bazar= 314 veh/hr, Dewanhat to Lalkhan Bazar= 585 veh/hr, and Dewanhat to New Market= 454 veh/hr).

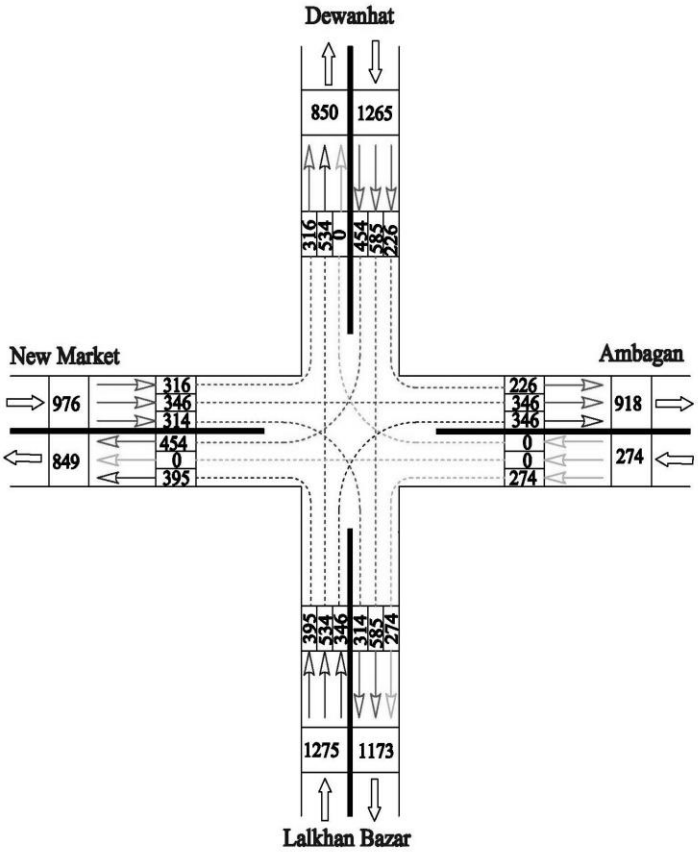

Figure 3: Typical turning movement diagram.

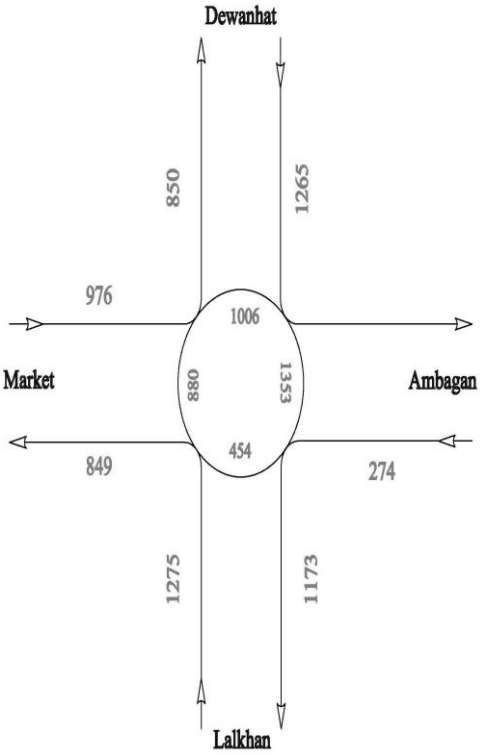

Figure 4: Typical turning movement diagram showing entry and circulating flow.

3.2 Determination of the Number of Entry and Circulating Lanes

The number of entry lanes will generally be determined from the number of lanes on the approach carriageway. However, an entry may be widened to provide additional lanes, particularly where turning movements are heavy. It is usually assumed that the number of circulating lanes will equal the number of entry lanes at any approach. However, a single lane approach may be provided at a multi-lane roundabout. According to the roundabout design guideline: state of maryland department of transportatbn state highway administration, Figure-5(a) is a plot of entry flows against circulating flows and provides a quick means of assessing the acceptability of a single or multi-lane roundabout. From that figure, we get the required number of two entries and circulating lanes for the Tigerpass intersection. Figure-5(b) is a plot of entry flows against circulating flows it has been found that the value of the inscribed diameter of the roundabout is a minimum 40 m.

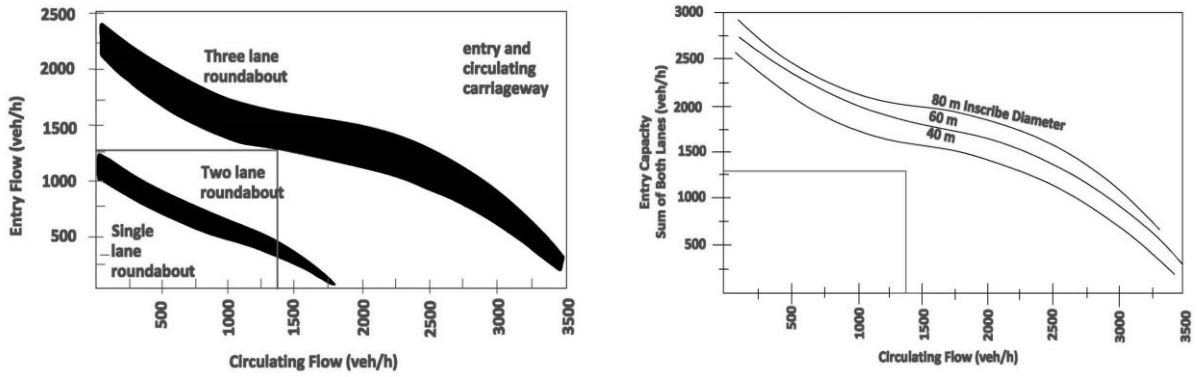

Figure 5: Diagram of Entry flow vs Circulating flow: (a) to determine the number of entry and circulating lane; (b) to determine the inscribed diameter of the roundabout.

3.3 Determination of the Dimension of Central Island

As the inscribed diameter has been selected 45m (150ft), from Table: 3 (Robinson, 2000, p. 150), Minimum Circulatory Lane Width is 9.8m (32ft) and Central Island standard diameter is 25.4m (86ft).

Table 3: Minimum circulatory lane widths for two-lane roundabouts (Robinson, 2000, p. 150)

Inscribed Circle Diameter	Minimum Circulatory Lane Width*	Central Island Diameter
45 m (150 ft)	9.8 m (32 ft)	25.4 m (86 ft)
50 m (160 ft)	9.3 m (31 ft)	31.4 m (103 ft)
55 m (180 ft)	9.1 m (30 ft)	36.8 m (120 ft)
60 m (200 ft)	9.1 m (30 ft)	41.8 m (140 ft)
65 m (215 ft)	8.7 m (29 ft)	47.6 m (157 ft)
70 m (230 ft)	8.7 m (29 ft)	52. 6 m (172 ft)

*Based on 1994 AASHTO Table III-20, Case III(A) (4). Assumes infrequent semi-trailer use (typically less than 5% of total traffic). Refer to AASHTOfor case with higher truck percentage.

3.4 Splitter islands

Splitter islands have been provided on all roundabouts, except those with very small diameters at which the splitter island would obstruct the visibility of the central island. Their purpose is to provide shelter for pedestrians (including wheelchairs, bicycles, and baby strollers), assist in controlling speeds, guide traffic into the roundabout, physically separate entering and exiting traffic streams, and deter wrong-way movements. Additionally, splitter islands can be used as a place for mounting signs. Figure 6 (Robinson, 2000, p. 157) shows the minimum dimensions for a splitter island at a multi-lane roundabout.

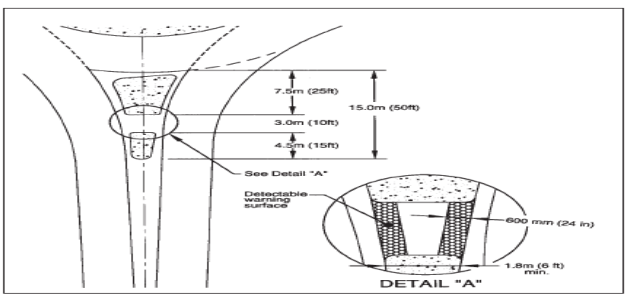

Figure 6: Standard dimensions of minimum splitter island (Robinson, 2000, p. 157).

3.5 Final Layout

After following all of the standards, we have converted Tigerpass intersection into the roundabout as the following figure by keeping the connecting lane from Ambagan to Lalkhn Bazar. And It has been computed that there is no need for land acquisition.

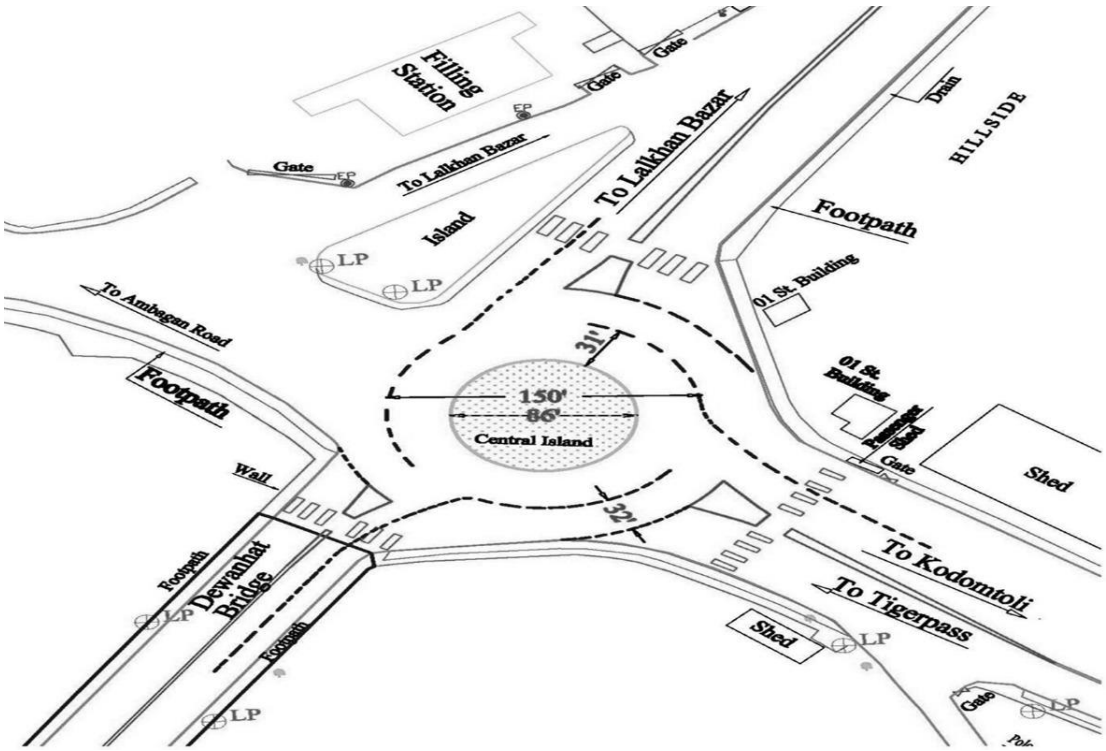

Figure 7: Final dimensional layout of Tigerpass roundabout as per standard design.

4. CONCLUSIONS

Roundabout is an efficient feature in the roadway system for vehicles crossing the intersections smoothly without making any congestion and without halting vehicles for a quite amount of time. Many intersections are now adopting to have a roundabout for traffic management and control. This study was intended to design a roundabout in Tigerpass intersection based on current entry flow. Before design, all existing geometric and vehicular data has been collected with precision and perfection. For the highest of the four entry flow (1275 Veh. /hr), the roundabout has been designed to have two-lane with a minimum inscribed circle of 40m. For the final design, a two-lane roundabout having an inscribed circle of 45m (150ft) diameter has been selected. Thus the circulatory lane width and central island diameter have been found 9.8m (32ft) and 25.4m (86ft) respectively.

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EFFECT OF WASTE BONES AND GGBS AS MODIFIER FOR BITUMEN IN CONSTRUCTION OF FLEXIBLE PAVEMENT

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ABSTRACT

Bitumen has been modified for the past several decades using various additives, including synthetic polymers, various types of rubbers etc. This type of modification improves structural and engineering characteristics as a binder as well as its adhesion capability with the aggregate. In this experiment, bones and GGBS were chosenas additives. Generation of waste bones (from fertilizer factories) and GGBS (from various factory wastes) may be managed for using it as a modifier. They both have cementitious characteristics and are expected to provide good binding and waterproofing characteristics. Marshall Stability test was performed here to obtain various Marshall Parameters and to observe the changes from standard specifications. Also the effects of GGBS and bones were individually observed to have a better understandings. The bitumen content, bones and GGBS content were changed in suitable percentage to determine optimum bitumen content and average optimum bone and GGBS content. The design matrix was combined as such that only one parameter was variable and other parameters were fixed. The experiment result was that the stability and flow increased and decreased respectively to a considerable amount. Also, the air void percentage was within limits. VMA and VFB analysis suggest that adjustment is required as their percentage was below the minimum limit. Finally a design mix was achieved where all the parameters gave the best possible result for this experimental setup. It is concluded that the additives had some positive impact on bitumen and were able to enhance the mix design properties to some extent.

Keywords: *Waste bones, GGBS, Stability, Flow, Design-mix.*

1. INTRODUCTION

1.1 General

Progression of roads, structures, socio-economical standards, etc. define the condition of a country. To ensure the maintenance of this progress, the network system plays a vital role and the best network system is roadway network. A flexible pavement has different parts such as wearing course, base, subbase, subgrade etc. Bitumen is mainly used in wearing surfaces with aggregates and it is one of the most critical layers. As the wearing surface gets in direct contact with vehicles, it must be capable of withstanding abrasion, wear and tear due to heavy traffic load and also to prevent excessive entrance of water so that the layer beneath the surface is not highly damaged. Generally, bitumen is used worldwide for this wearing surface because of its binding and waterproofing quality. Bitumen production is economical, easily available, it can undergo recycling and recycled product can be used again for road construction, its physical and rheological properties bring versatilities to road construction and its low melting point makes it easy to work with. Also, bitumen is available in different grades suitable for different conditions which made it a popular material for road construction worldwide. Despite having such advantages, it also has drawbacks. The most common problems are various cracking, rutting and formation of potholes. One of the major causes of these problems is the faulty mix design of wearing courses. The susceptibility of bitumen to climate changes cannot be overlooked also. That's why maintaining bituminous pavements with utmost care is a challenge no matter where in the world because the traffic load is increasing in an alarming rate and frequent maintenance has become quite costly. The possible solution is to create a sustainable road network which is why various experiments are being conducted to modify bitumen to produce long-lasting effects.

Cliff Ellis et. al., (2004) researched on the effect of GGBS on bitumen. They had previously done some works related to this and those suggests that adding cementitious binder such as GGBS may enhance certain properties of bitumen emulsion mixtures. The results of their experiments showed that the inclusion of GGBS may enhance stiffness and strength development in high humidity conditions. S. Shahba et. al., (2017) investigated the effects of GGBS with SBS on the strength properties on bitumen. Modified bitumen and asphalt mixtures were evaluated based on the penetration test, Marshall Stability, etc. According to their results, the mixture of GGBS and SBS can be used to modify porous bitumen mixtures which will either improve or will not change their properties. This test also showed that using two additives simultaneously has strengthened bitumen mixture properties such as Marshall strength and uniaxial compression strength. A notable recent work which involved modifying bitumen with bone glue was done by Hashim Raza Rizviet et. al., (2014) which included mixing bone glue with bitumen mixture as waste bone glue has somewhat cementitious characteristics. In this study, a new kind of bitumen modifier derived from animal wastes, such as bones, hides, and flesh commonly known as Bone Glue was studied. This biomaterial which is a by-product of food and cattle industries is very readily available in developing countries. Their experiment showed a significant reduction of cost in bitumen mixture, a quality improvement of the mixture and also the whole process was quite environment-friendly which may be considered as a sustainable solution.

1.2 Objectives

- The main focus of this experiment is to observe the strengthening effect of both GGBS and waste bones as additives, as both of the materials has binding quality and they are waste products which make them easily accessible.
- To observe whether the improvement of Marshall stability of the bitumen mix in different mixing ratio is possible.
- To obtain optimum value of the bitumen mix design.
- To understand whether the experiment was able to provide results involving different parameters within standard or specified value.

2. METHODOLOGY

Marshall Method of mix design is the most popular method to determine the optimum bitumen content. Marshall Test method will be held for the performance analysis of Bones and GGBS mix with the standard bituminous mix. The Marshall test procedures have been standardized by the American Society for Testing and Materials (ASTM) and published as ASTM D1559. The method is applicable only to hot mixtures using penetration grades of asphalt cement and containing aggregates with a maximum size of 1 in. (25mm) or less (Paul H.Wright and Karen K. Dixon, 2004).This method best reproduces the field condition of wearing course. In this experiment medium type design (50 blows per side of the specimen) is used to simulate medium traffic volume and compaction. In this experiment, there are three variables which are bitumen content, bones content and GGBS content. All the variables are taken in three proportions to observe the performance within the range. For bitumen, chosen proportions are 4.5%, 5%, and 5.5%. For bones and GGBS content chosen proportions are 5%, 10% and 15%. From related previous works, it is observed that expected optimum lies within the range.

In this test, at least three specimens for each combination of aggregates and mixing bitumen content were prepared. The bitumen was of penetration grade 70. All the aggregates used were oven-dried. Around 64% of coarse aggregate, 31% of fine aggregate and 5% of mineral filler stone dust in proportion chosen for the mix design. Bones and GGBS of design proportion and bitumen content chosen for the sample preparation of design mass, of around 1216g (for 5% bitumen) to ensure a theoretical density of 2.4-2.5 g/cc for the cylindrical samples. The aggregate of design quantity in correct proportion was mixed with design bones and GGBS in a hot pan which was stirred uniformly to give a homogeneous mix at a temperature of 105-110oC. The weighed bitumen for a sample was added to the heated aggregated mix. The bitumen was heated to a liquid state and mixed well with the aggregate to get a homogeneous state mixture at 105-110o C. The specimen was compacted with 50 blows to each side of the cylindrical sample mounted on a standard mold assembly with a standard Marshall hammer that has a circular tamping face 98.4 mm (3.88 in.) in diameter and a weight of 4.5 kg (10 lb.) with a free fall of 457mm (18 in.) to get the Marshall compaction specimen. The compacted specimen was allowed to cool down to room temperature before the extraction of the sample. Then it was placed on a smooth level surface until ready for testing. Normally specimens are allowed to cool overnight.

The stability of materials for the design of Marshall bitumen requires that a number of tests are performed on the materials. The stability-flow test measures the maximum load resistance and corresponding deformation (or flow) of a standard test specimen when subjected to a load by a standardized test procedure. Marshall method of analysis is undertaken to record the stability, flow, and others the volumetric performance of all the samples. Stability and flow values are directly accessible from the gauge reading of the Marshall apparatus. Formulas based on materials properties are used to record the volumetric properties of samples like air voids (V_a), voids in the mineral aggregate (VMA), voids filled with asphalt (VFA), effective asphalt content (P_{be}), Bulk Specific Gravity (G_{sb}), Effective Specific Gravity (G_{se}), Aggregate content(P_s), Asphalt content(P_b) etc.

The formula used in this experiment for bitumen properties are given below:

$$G_{mb} = \frac{W_a}{W_s - W_w} \quad (1)$$

$$G_{mm} = \frac{P_{mm}}{\frac{P_s}{G_{se}} + \frac{P_b}{G_b}} \quad (2)$$

$$P_s = 100 - P_b \quad (3)$$

$$P_{mm} = 100 \quad (4)$$

$$G_{se} = \frac{P_{mm} - P_b}{\frac{P_{mm}}{G_{mm}} - \frac{P_b}{G_b}} \quad (5)$$

$$G_{sb} = \frac{P_1 + P_2 + P_3}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \frac{P_3}{G_3}} \quad (6)$$

$$\%V_a = 100\frac{G_{mm} - G_{mb}}{G_{mm}} \quad (7)$$

$$\%VMA = 100 - \frac{G_{mb}P_s}{G_{sb}} \quad (8)$$

$$\%VFA = \frac{\%VMA - \%V_a}{\%VMA} 100 \qquad (9)$$

The limits of the Marshall parameters namely stability, flow, air voids, VFA, VMA are as follows: -

Table 1: Limiting values of Marshall Parameters: (For medium traffic)

Marshall parameters	Limiting values
Stability, N (lb.)	5338 (1200)
Flow, 0.25mm (0.01 in.)	2 to 4
Percent air voids	3 to 5
Percent voids filled with asphalt(VFA)	65 to 78

Source: (Paul H.W and K. Dixon, 2004)

For the analysis of the samples, six graphs are prepared namely:

(1) Unit weight vs. Percent AC by wt. of mix (where AC indicates Asphalt Content equivalent to bitumen content),
(2) Percent air voids vs. Percent AC by wt. of mix,
(3) Marshall stability vs. Percent AC by wt. of mix,
(4) Percent VMA vs. Percent AC by wt. of mix,
(5) Flow (1/100) in. vs. Percent AC by wt. of mix,
(6) Percent VFA vs. Percent AC by wt. of mix.

The shape of the curves help to determine whether the samples are giving results within acceptable range. The standard shape of the specified six graphs look like this:

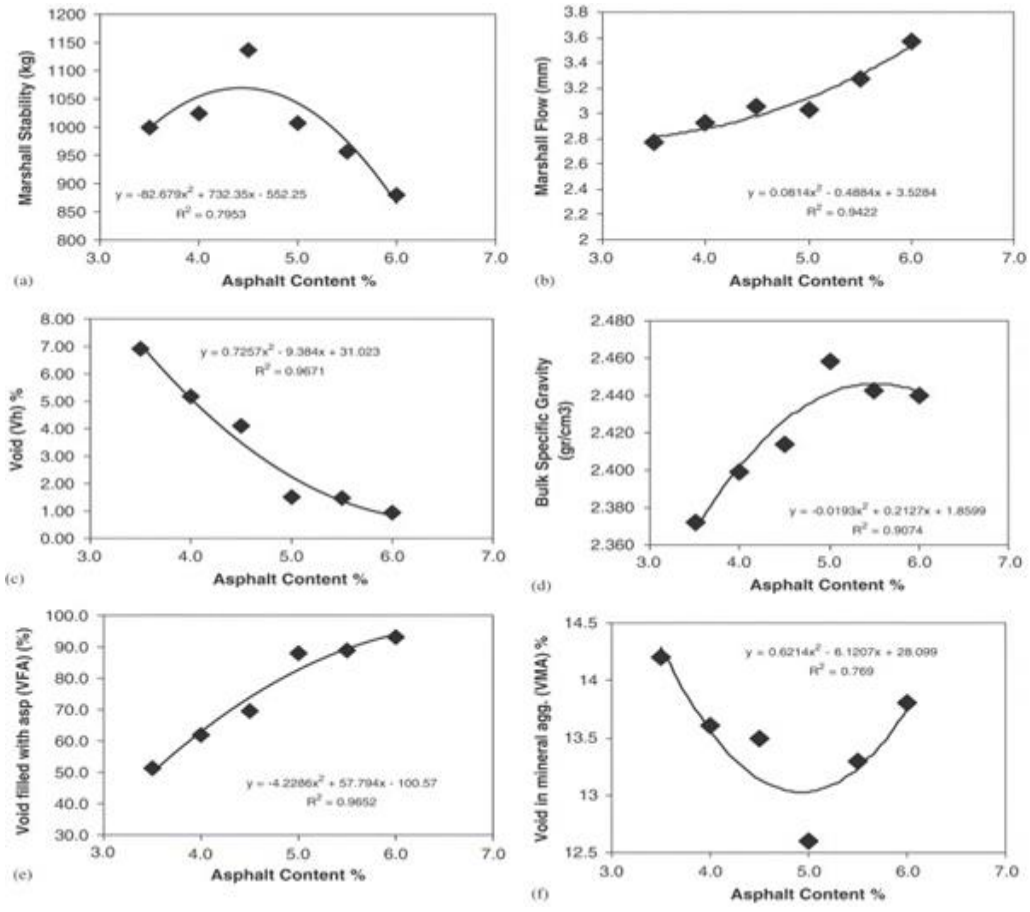


Figure 1: Test property curves for hot-mix design data by Marshall Method
Source: (Paul H.W and K. Dixon, 2004)

To analyze the performance of bones and the GGBS mix, the Marshall method is applied extensively. Among the three variables namely bitumen content, bones content and GGBS content, two variables are kept constant at a time and the other is changed and the sample is analyzed by the Marshall method of analysis. Here the analysis of optimum binder content for each mix (of bones and GGBS) is derived and corresponding values of stability, flow, air voids, VMA, unit weight, and VFA are recorded.
The samples were prepared according to this experimental design:

Table 2: The bones and GGBS combination of three design proportions with three proportions of bitumen content (70 penetration grade) give 18 sample for this experiment

Bitumen Content	Bones	GGBS
4.5%	5%	10%
	10%	
	15%	
	10%	5%
		10%
		15%
5%	5%	10%
	10%	
	15%	
	10%	5%
		10%
		15%
5.5%	5%	10%
	10%	
	15%	
	10%	5%
		10%
		15%

Here, % of Bitumen (of Total Mix), P_b for different percentage is 4.5% = 54.42 gm, 5.0% = 60.79 gm, 5.5% = 67.22 gm.

Specific Gravity

C.A. (1 inch - #8) (G_1): 2.68 (ASTM C-127)
F.A. (#8 - #200) (G_2): 2.68 (ASTM C-128)
M.F. (Passing #200) (G_3): 2.77 (ASTM D-854)
Bitumen (G_b): 1.02 (ASTM D-5)

3. RESULTS AND DISCUSSION

At first the penetration test was done to see the changes in bitumen.

Table 3: Penetration test result:

	(%)	Penetration Result
Bones (%)	5	67.33
	10	63.68
	15	63
GGBS (%)	5	65
	10	64.33
	15	65.68

From Table 3, it is clear that the additives were able to decrease the penetration which also means the consistency of bitumen somewhat decreased. The lower the consistency, it becomes more suitable for warmer countries because it gives less scope of deformation or rutting. In hotter areas, lower penetration

grades area unit most well-liked to avoid softening whereas higher penetration grades like 180/200 area unit utilized in colder areas to forestall the prevalence of excessive brittleness.

All the test sample were made for medium traffic (for sample compaction, 50 blows per face) specification for Marshall Test and will be analysed for medium traffic also. After acquiring all the data from the test and the value of air void, VMA, VFB, by the equations 7, 8, 9 respectively.
The Marshall parameters of the tested specimen are given below:

Table 4: Marshall Analysis data obtained from samples:

Specimen No,	Bitumen Content (%)	Bones (%)	GGBS (%)	Air Void (%)	Unit Weight (pcf)	VMA (%)	VFB (%)	Stability (kN)	Flow (mm)
1	4.5	5	10	3.93	155.613	11.267	65.157	6.727	3.23
2		10		4.398	154.849	11.703	62.424	6.837	3.21
3		15		4.788	154.2171	12.063	60.312	6.447	3.34
4		10	5	4.950	153.954	12.213	59.469	6.658	3.28
5			10	4.829	154.149	12.102	60.094	6.932	3.17
6			15	4.792	154.209	12.067	60.288	6.898	3.22
7	5	5	10	3.892	156.450	11.257	65.427	6.933	3.18
8		10		4.011	156.257	11.367	64.715	7.362	2.87
9		15		4.168	156	11.512	63.792	7.382	2.88
10		10	5	4.207	155.936	11.549	63.565	7.835	3.2
11			10	4.050	156.192	11.403	64.481	7.007	3.1
12			15	4.089	156.128	11.439	64.251	7.146	2.98
13	5.5	5	10	4.058	156.965	11.433	64.504	7.785	2.95
14		10		4.099	156.898	11.471	64.267	8.243	2.89
15		15		3.860	157.289	11.250	65.689	8.367	2.87
16		10	5	4.531	156.192	11.869	61.829	7.877	2.95
17			10	4.452	156.320	11.797	62.259	8.011	2.9
18			15	4.413	156.385	11.761	62.479	7.967	2.92

After these data were obtained, total 36 graphs were plotted for individual sample using the data from Table 4. Also 12 graphs were plotted which included the individual parameters against the various percentage of bitumen content and the individual performance of waste bones and GGBS. This was done to obtain optimum bitumen content for various parameters, and average optimum bone and GGBS content for best possible results. This whole extensive analysis result can be summarized as below:

Table 5: Summary of Parameter Analysis:

	Minimum	**Maximum**
Flow Value	2.87 mm for both 5% bitumen, 10% GGBS and 10% bones and 5.5% bitumen, 10% GGBS and 15% bones.	3.34 mm for 4.5% bitumen with 10% GGBS and 15% bones
Comments on Flow Value	• Optimum bitumen content based on flow analysis is 5.5%. • Average optimum bone content is 12.5% • Average optimum GGBS content is 10%	
Stability Value	6.447 kN for 4.5% bitumen, 10% GGBS and 15% bones	8.367 kN for 5.5% bitumen with 10% GGBS and 15% bones
Comments on Stability Value	• Optimum bitumen content based on stability analysis is 5.5% • Average optimum bone content is 15% • Average optimum GGBS content is 10%	

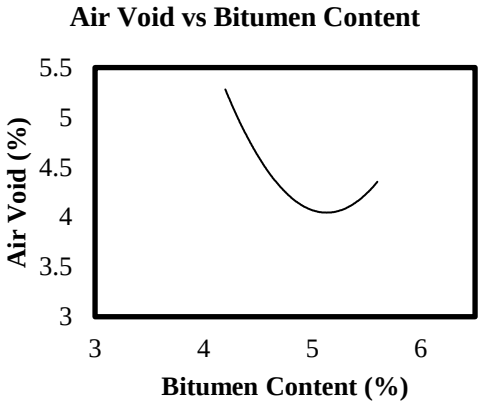
Air Void Value	3.86% for 5.5% bitumen, 10% GGBS and 15% bones	4.95% for 5.5% bitumen with 5% GGBS and 10% bones
Comments on Air Void Value	• Optimum bitumen content based on air void analysis is 5.5% • Average optimum bone content is 15% • Average optimum GGBS content is 10%	
VMA Value	11.25% for 5.5% bitumen, 10% GGBS and 15% bones	12.213% for 4.5% bitumen with 5% GGBS and 10% bones
Comments on VMA Value	• Optimum bitumen content based on air void analysis is 4.5% • Average optimum bone content is 10% • Average optimum GGBS content is 5%	
VFB Value	59.47% for 4.5% bitumen, 5% GGBS and 10% bones	65.43% for 5% bitumen with 10% GGBS and 5% bones
Comments on VFB Value	• Optimum bitumen content based on air void analysis is 5% • Average optimum bone content is 5% • Average optimum GGBS content is 10%	
Unit Weight Value	153.95 pcf for 4.5% bitumen, 5% GGBS and 10% bones	157.3 pcf for 5.5% bitumen with 10% GGBS and 15% bones
Comments on Unit Weight Value	• Optimum bitumen content based on air void analysis is 5.5% • Average optimum bone content is 15% • Average optimum GGBS content is 10%	

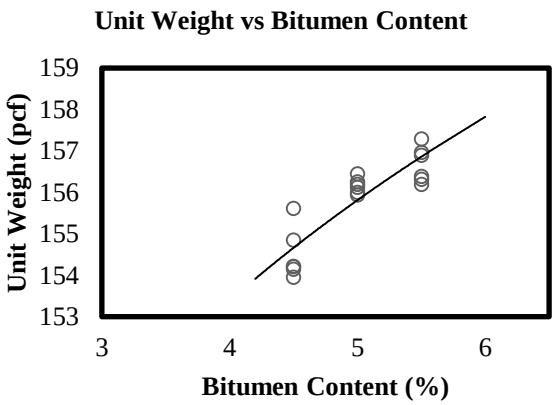
Table 6: Comparison of best possible experimental value with Table 1 for medium traffic:

Parameters	Standard Values	Experimental Values	% Decrease/Increase
Stability (kN)	Minimum 5.3 kN	Max. 8.367 kN	57.86% Increase
		Min. 6.45 kN	21.7% Increase
Flow (mm)	Maximum 4 mm	Min. 2.87 mm	28.25% Decrease
		Max. 3.34 mm	16% Decrease
Percent Air Void (%)	Maximum 5%	Min. 3.86%	22.8% Decrease
		Max. 4.95%	1% Decrease
VFB (%)	Minimum 65%	Max. 65.7%	1.1% Increase
		Min. 59.47%	8% Decrease
VMA (%)	Minimum 17%	Max. 12.2%	28.23% Decrease
		Min. 11.25%	34% Decrease

The Marshall parameters were individually analysed. From Table 6 it was observed that the flow decreased to 28.25%. This means that the experiment was able to successfully decrease the flow to a considerable amount. Flow gives a general idea about the deformation corresponding to the load-carrying capacity of the design mix meaning it is such a point where the load begins to decrease. For a considerable good design, always a lower value of flow is expected, as the higher value indicates too much deformation under specific load and weather conditions. In this experiment, the optimum bitumen content based on flow was 5.5% as the flow decrease rate is higher. From Figure 2 it seems that GGBS gives better results at 4.5% bitumen content while bones give better results at 5% and 5.5% bitumen content. Stability measures the maximum load resistance of bitumen mix design. A higher value suggests that the mix design has a higher load capacity. Observing Table 4, it is seen that stability increases in most cases. Especially, for 5.5% bitumen and 10% GGBS with corresponding bones variable gives a good result. Considering the minimum and maximum values from Table 6, the value has increased by 57.86% of the standard value. Though the test was carried out for medium traffic, some of the values reached the minimum stability requirement for heavy traffic. The optimum bitumen content based on stability analysis was 5.5%, and average bones and GGBS optimum content was 15%

and 10% respectively (Table 5). Also (Figure 2) it seems that GGBS gives better result at 4.5% bitumen content while bones gives better results at 5% and 5.5% bitumen content which is similar to flow results and it gives the most obvious indication that with increasing stability the flow decreases as the relationship between stability and flow is reversely proportional. This was attributed to the specific gravity of additive which is less than that of bitumen. This serves to penetrate between particles and enhanced the interlock of aggregates, which increases the stability and decreases the flow value. It should be emphasized that the design range of air voids (3 to 5 percent) is the level desired after several years of traffic. This is a very important parameter regarding the design as more air voids indicates higher permeability to water and air which causes heavy damage to waterproof and the consequence of this situation is a mix that hardens prematurely, becomes brittle and cracks at an early age or the aggregate ravels out of the mix because of the loss of asphalt adhesion. Again if the air void is less than minimum prescribed value than there is no space for future compaction leading to rutting. Still from Table 6, it is notable that the air void did not surpass or fall behind the prescribed limits. Moreover, the experiment was able to decrease the air void up to 23%, though some of the results show values reaching almost 5% air voids. The optimum bitumen content based on air void was 5.5% which means in this bitumen content the specimen had fewer air voids but not less than the minimum specified value. VMA is a representation of the voids in the mineral aggregate which also includes air voids and the effective bitumen content. For the different percentages of variables, it gives different results. Especially from observing Table 6 the VMA value decreases from the minimum standard value considerably up to 34% which is not desired. So this parameter should be thoroughly investigated further. VFB represents the voids filled with bitumen. In this experiment, the VFB results were slightly unsatisfactory. Maximum values are below the minimum specific requirement and some value was just at the threshold of the minimum requirement (at least 8% decrease from Table 6). This indicates that most of the voids were not filled properly. This may happen due to the variety of mixture and compaction throughout the experiment. Though unit weight does not have any specific limit for this test, it gives an idea about the relationship between the specific gravity of aggregates and voids. Good compaction gives maximum unit weight with fewer voids. In this experiment, from Table 5, 5.5% bitumen content showed maximum unit weight.





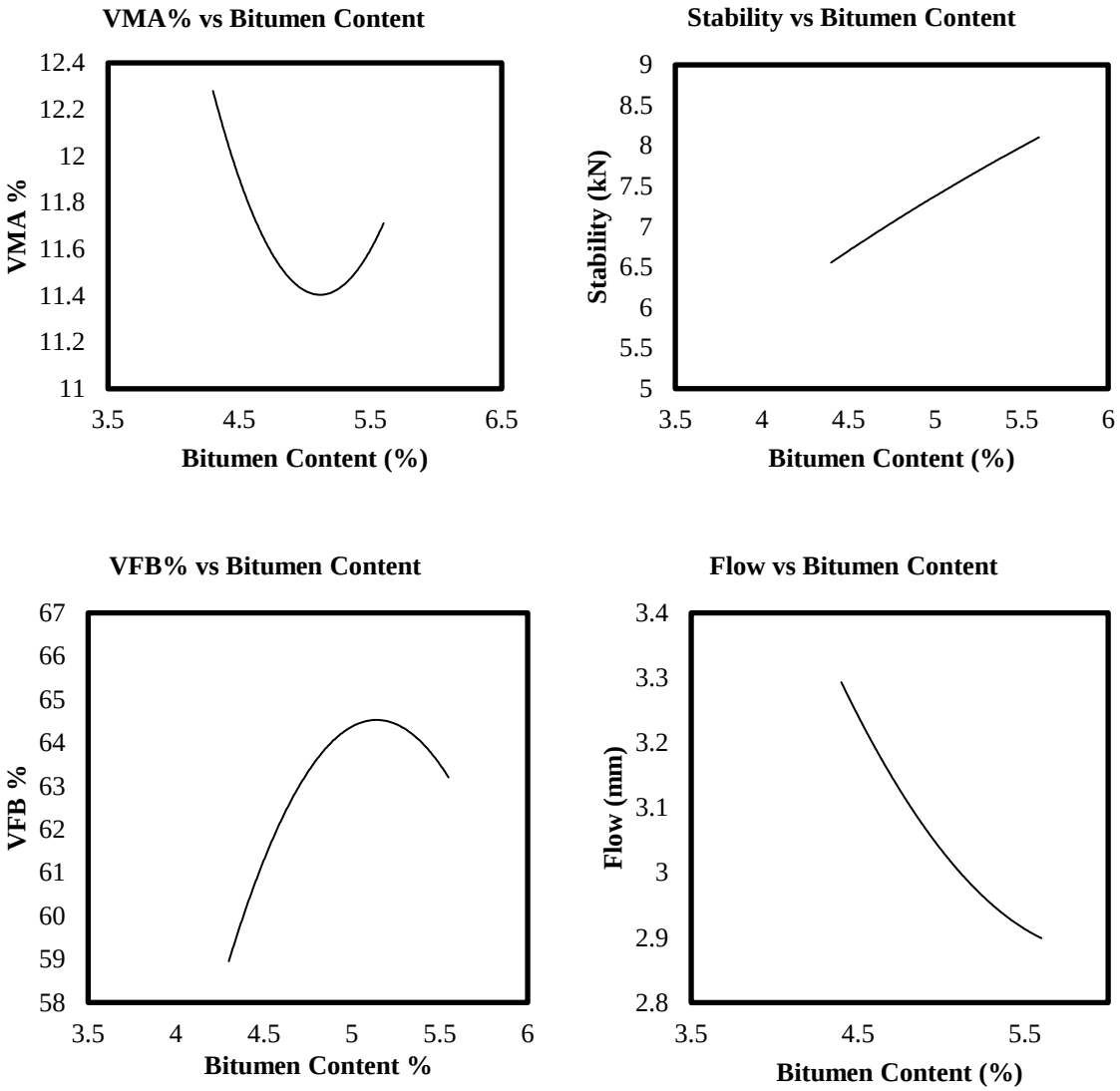


Figure 2: Marshall Method curves obtained from using data from Table 4.

If we compare Figure 1 and Figure 2, the obtained Marshall Test property curves followed the general behavior pattern quite similar to the standards except for the stability and flow curve. Generally, the stability and flow decreases and increases respectively with increasing bitumen content. But in the obtained result stability kept increasing and the corresponding flow kept decreasing. This phenomenon only indicates that the optimum bitumen content may be higher in modified bitumen content than generally used. Mix design is a compromise of many factors. The bitumen content that provides the best overall performance in addition to passing the previously discussed conventional criteria would be considered the design value. In this experiment, VFB and VMA criteria were slightly fluctuating, but other parameter results were very satisfactory, especially flow and stability of the samples.

4. CONCLUSIONS

The overall summary of the experiment is:

- The addition of the additives successfully increased the stability and the best result include 57.86% increase and decreased the flow rate up to 28.25% which is highly desired for a sustainable and long-lasting pavement surface. This result was expected for high volume traffic

but was achieved only using medium volume traffic specification which indicates that more amazing results can be obtained with these additives using high traffic volume specification.

- Most of the good results for different parameters were obtained for 5.5% bitumen content and so it is the optimum value for this design.
- The air void was within the standard limit which is also desired for long-lasting pavement design. Except for VMA and VFB, all other parameters gave desired results with the addition of GGBS and waste bones.
- Some slight adjustments in the mix design involving the aggregate size is required to obtain desired VMA and VFB as the value was slightly fluctuating.

This experiment was an initial step to see the effects of the two additives over bitumen and the result show that these additives have positive effect over mix design.

ACKNOWLEDGEMENTS

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EFFECT OF NON-MOTORIZED TRANSPORT (NMT) ON ROAD SEGMENT FROM NOTUN RASTA TO B. N. SCHOOL AND COLLEGE, KHULNA

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ABSTRACT

On the zeitgeist of twenty-first century urbanization is a conspicuous consequence of intensifying urbanization. Being the third largest city as well as a major economic and industrial hub, transportation system of Khulna plays an indispensable role in the economy of Bangladesh. Effect of Non-motorized transport on the performance of urban transportation on a road segment of Khulna city is assessed in this study. A road segment Notun Rasta to BN School and College is taken as study area. The existing overall road traffic scenario is seen first, then performance parameters like traffic volume, speed etc. to know congestions and travel time, delay, travel cost etc. for traffic condition is perceived to see whether NMT has good influence or not. Travel pattern analysis (mode choice, trip length etc.), transport mode shares, volume study, speed study, level of service, traffic flow analysis, and congestion index analysis etc. are done to see the effect of NMT. Data is collected by reconnaissance survey, physical feature survey, user opinion survey, volume and speed survey. Low congestion rate, problems requiring traffic demand, traffic flows, problems due to merging and diverging were identified. The analysis of operational and physical features of NMT provides a diagram on the fixed facilities, control system and support system of the area. The result depicts that the congestion level is very low, easy bike is the most preferred vehicle in the area, in off peak and peak hour the spot speed was highest for motor bike that is a motorized vehicle. The NMT shows low spot speed in the area. Free flow with low volume and high speed for NMT is vivid. There are several recommendations for improving the condition. Such as on street and off street parking provision, round about road pattern, shoulder, separate bicycle lane etc. are to be addressed properly to amalgamate both privileges of motorized and non-motorized transport.

Keywords: *NMT, Urban transportation, Performance parameters, Travel pattern, Congestion.*

1. INTRODUCTION

Non-motorized transport is a cheap and handy way of transportation. However, around the world the aftermaths of modernization has not only made its use capricious (Wu & Lam, 2003; Zhang & Hu, 2004) but also has made the traffic flow heterogeneous (Hossain, Adhikary, Ibrahim, & Rezaur, 2005). Khulna one of the prominent industrial cities of Bangladesh (Hossain, Adhikary, Ibrahim, & Rezaur, 2005) with population density of 26287 per square km (KDA, 1999). In Khulna 13360 non-motorized vehicles are plying (Hossain, Adhikary, Ibrahim, & Rezaur, 2005) on the roads. Urban transportation system is quite complex having different modes of auto mobile dominated transports (James, 2006). Nevertheless, there are plethora of non-motorized transports such as bicycle, walking, cart etc. are widely used in Asian countries (Pendakur & Pardo, 2007). Non-motorized transport plays a vital role in Khulna city (Hossain, Adhikary, Ibrahim, & Rezaur, 2005) and it is assessed in this study. Travel pattern analysis, moving observer surveys in peak and off peak hour, level of service analysis etc. are scrutinized though dogged perseverance in this study.

Numerous studies had been conducted through the world regarding non-motorized transport in urban area. In a study in Delhi, non-motorized transport in Peri-urban areas are seen in a study. NMT is used only for utilitarian trips in Delhi where there is no assigned infrastructure for NMT (Arora, 2013). Bicycles area described as captive users in the city (Arora, 2013). Besides the peak hour for NMT is different from peak hour for MT (Arora, 2013) and forward collision warning system is a crying need (Mohan, Tsimhoni, & Flannagan, 2009) to ameliorate the situation as accidents occur frequently. In case of integrated land use and transportation system, NMT is included in a study by Waddel et. Al., 2002. They have implemented integrated land use and transport model that is potentially a sensitive model and the major public policy interests are addressed here that is getting more heed by the state (Waddell & Nourzad, 2002). Non-motorized transports are seen as a mode that hardly meet the fast needs of an area fully, nonetheless, walking and cycling has always prevailed to be acceptable solution for many accessibility problems (Litman, 2009). In Malaysia an investigation took place where NMT is seen to be sustainable transport. The use of NMT e.g. cycling and walking both reduces carbon emission and exhorts healthy lifestyle as well as a physical activity (Yazid, Ismail, & Atiq, 2011). Pedestrian flow characteristics in Khulna city is assessed in a study that found the free-flow speeds of were lower in Khulna than other Asian and Western countries (Nazir, Adhikary, Hossain, & Ali, 2012). They observed that the free-flow speed and densities are found proportional to each other (Nazir, Adhikary, Hossain, & Ali, 2012). Moreover the increase in road friction increases the jam density (Nazir, Adhikary, Hossain, & Ali, 2012).

2. METHODOLOGY

2.1 Study Area

Road segment from Notun Rasta More to B. N. School and College had been selected as study area as it not only connects Khulna city with other adjacent cities but also is one of the busiest road segments that connects easily with the city centre. Outer city Bypass road plays an important role in transportation of goods and passenger in Khulna district. The study area starts from Notun Rasta More and goes through Outer City Bypass road then takes a left turn to road no 23. The section is approximately 1.5 Km. With growing pollution and environmental degradation, cities are in dire need of transports that generates less amount of carbon and its derivatives. Therefore, non-motorized transport is a great option so, its effect is assessed on this important road segment.

2.2 Survey and Data Collection

To assess the effects of Non-Motorized Transport (NMT) on the performance of urban transportation in Khulna City, the field data was collected. 120 questionnaire surveys were conducted after stratified sampling. Among them 70 people were passer-by (including drivers, students and people who went to office regularly) and 25 people were the store keepers in the area. The rest were the residents of the

area who used the segment almost daily. The survey was conducted both during peak and off peak hours to get requires information. Based on the survey response income, mode choice etc. analysis had been done.

2.3 Traffic Performance Parameter Analysis

2.3.1 Volume Analysis

Manual Counting Method would be conducted to count volume of the traffic on two-week days at five different times (Three peak times & two off-peak times) in each day. Manual Counting Method was applied.

Average Daily Traffic (ADT): The volume during a given time period divided by the number of days in that time period and expressed in terms of vehicle per day (vpd).

$$ADT = \frac{\text{Volume of days } (> 1\text{days and} < 1\text{year})}{\text{Number of days}} \text{vpd}$$

(Source: Gurcharan Sing)

Normally 30 minutes are surveyed for volume analysis. After counting the vehicles, the data is converted into PCU (Passenger Car Unit). Passenger Car Unit (PCU) was calculated by using the following table-

Table 1: Vehicle Type

Vehicle Type	PCE	Vehicle Type	PCE
Bicycle	0.2	Passenger Car	1.0
Motorcycle	0.3	Truck/Mini Bus	2.0
Auto-Rickshaw/Tempo/Human Hauler	0.5	Large Bus	2.5
Rickshaw/Van	0.8	Pushcart	4.0

The PCU value that can be found after calculating is multiplied by two for converting PCU/hour. Then the total value is divided by two for converting the PCU/lane/hour.

2.3.2 Spot Speed Calculation

Spot speed could be used to design the geometry of road like horizontal and vertical curves, super elevation etc. Spot speed was calculated by this equation-

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

2.3.3 Moving Observe Method

Flow of the vehicles and mean journey time are calculated by the moving observed method. The total number of vehicle overtaken and overtaking is also found through this survey. Flow of the Vehicles

$$Q = \frac{X+Y}{Tg+Tw}$$

Where,
X = No of the vehicles with speed by the observer travelling
Y = No of the vehicles with speed which overtake the travelling when traveling with stream the number vehicle overtakes correspondence
Again,

$$\text{Mean Journey Time, } T = Tw - \frac{Y}{q}$$

$$\text{Mean Journey Speed} = \frac{Distance * 60}{Mean\ Journey\ Time}$$

$$\text{Running Speed} = \frac{Distance * 60}{Running\ Time}$$

2.3.4 Traffic Density

Traffic density is defined as the number of vehicles occupying a unit length of roadway. Analysts can easily obtain the relationship between traffic density and average distance headway from the following equation:

$$K = \frac{5280}{\bar{d}}$$

Where:
K=density (vehicles per lane-mile)
$\bar{d}$=average distance headway in a single lane (feet per vehicle)

2.3.5 Level of Service:

Volume to capacity ratio is calculated volume divided by design capacity 1400 PCU/lane/hour according to (DITS, 1994). Level of service was measured from the table of corresponding measure and corresponding level of service.

Table 2: Performance Measures and Corresponding Level of Service

	Level of Service	Speed (Kph)	Volume to Capacity Ratio
A	Free Flow, with low volumes & high speeds	>= 80	<= 0.6
B	Reasonably free flow, but speeds beginning to be restricted by traffic conditions.	>= 40	<= 0.7
C	Stable flow zone, but most drivers restricted in freedom to select their own speed	>= 30	<= 0.8
D	Approaching unstable flow, drivers have little freedom to maneuver	>=25	<= 0.9
E	Almost unstable flow, volumes reach near at the capacity of the highway	>=15	<=1
F	unstable flow may be short stoppages	<15	>1

2.4 Different traffic performance measurement Index

2.4.1 Congestion Index

It is computed by using the formula (C – C0) / C0 where C is the total travel time and C0 is the free flow time. Free flow travel time can be defined as the time taken to travel the distance when the traffic density is nearly zero.

$$\text{Congestion index} = \frac{(C - C0)}{C0}$$

If the value of (C – C0) / C0 is near zero it will indicate very low levels of congestion and if the value is greater than 1 than it means road is highly congested.

3. ILLUSTRATIONS

3.1 Travel Pattern Analysis

Travel pattern is influenced by some factors e.g. Trip length, Trip purpose, Mode choice, Travel time on NMT, Travel cost on NMT, Preferable vehicle, Frequency of Using Routes etc. Travel pattern is explained below:

3.1.1 Mode Choice Behaviour of the Respondents

The figure 1 represents the mode choice of the people in the study area. Mahindra, easy bike, private car and bus are available motorized vehicle in our site. As easy bike is mostly available in our site so 39 % people prefer easy bike, 23% prefer Mahindra. And 3% use motor bike. The percentage of using trips by private car is 19%, Non-motorized vehicle like Cycle, Rickshaw are attainable for general public 9%use Non-motorized vehicle. &7% for Rickshaw and 2% for cycle. About 2% make their trips on foot they prefer walking rather than using any mode for their trip. Most of the people prefer easy bike and Mahindra because the cost is lower rather than another available vehicle.

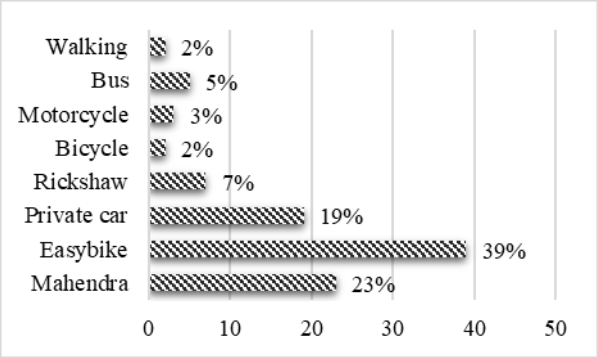

Figure 1: Mode Choice behavior of the respondents

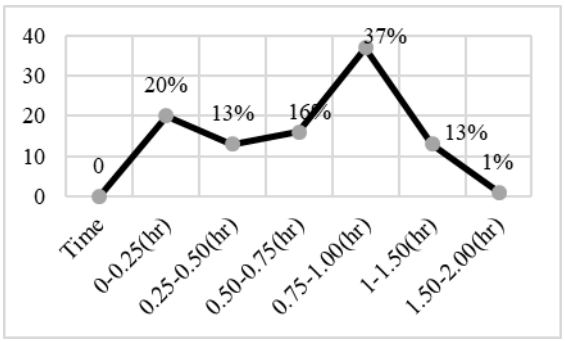

Figure 2: Travel time on NMT

3.1.2 Travel Time on NMT

The following figure 2 refers to the percentage of people's travel time period in NMT. From the figure we can easily see that, there is no percentage of people who do not travel in NMT. The most percentage of people travelling in NMT is 37 and the time duration is 45 minutes to 1 hour. About 20 percent of people's travel time in NMT is 15 minutes. . The best possible reason of the above chart, as the people who travel in that specific route are "Students" and "Drivers". Their travel time is normally high because they have to travel to their desired destination and according to the availability and lower travel cost of "Easy Bike", the percentage of using this particular transport mode is very high.

3.1.3 Travel cost on NMT

The table 3 shows the relation between people's income level and most preferable vehicle mode. From the table we can easily see that, the most percentage of people belong in the group of less than 5000-taka income's people which is 59 percent whose preferable vehicle mode is "Walking" and "Easy bike", some also like travel in "Mahindra" and "Bus". There is about 20 percent of people whose income is above 25000-taka and the preferable vehicle mode for that group is "Private Car" and also "Walking", "Mahindra". The percentage of people within the income group of 5001 to 10000 taka is about 13 percent and the transport mode are "Bus". They also interested in "Walking", "Mahindra", "Easy Bike", "Private Car", "Bus" The best possible reason could be, lower income people always try to travel within lower travel cost vehicles. Like other studies e.g. (Hassan, Sarkar, Uddin, & Rahman, 2016), from mideum income group most of the trips are generated in the study area.

Table 3: Income VS Preferable Vehicle

The table 4 provides us the relation of different occupation holding people's frequency of using that particular road. From the table we can see that, the most percentage of people using that road is 25 and they belong in the occupation group of "Drivers" and the frequency of using that particular road is "Several Times a Day".

Table 4: Occupation vs Frequency of Using Routes

Occupation	Frequency of Using This Route				
	Once A Day	Several Times in A Day	Once A Week	Various Time	Occasionally
Govt. Service	3	16	3	4	2
Private Service	9	2	4	0	7
Student	16	3	0	12	2
Driver	2	25	10	5	6
Housewife	2	3	2	2	1
Total	32	49	19	23	18

3.2 Performance Parameter Analysis

3.2.1 Spot Speed of the Study Area:

In weekdays at peak and off-peak hour different vehicles have different spot speed. Figure 3 shows the difference of spot speed in peak and off-peak hour for a specific vehicle. This study concentrates more on NMT so if NMT is seen first it is clear that spot speed of by-cycle is the most amongst all the NMT. But with peak and off-peak hour spot speed of rickshaw changes more. At peak hour spot speed is 10.82. At peak hour the speed is less because a large number of vehicle ply at peak hour with great speed specially motorized vehicles. So, at peak hour spot speed of rickshaw is reduced as a result of high competition with motorized vehicle. Spot speed of motorbike is the most at both peak (43.85km/hr.) and off peak (44.06km/hr.) hour.

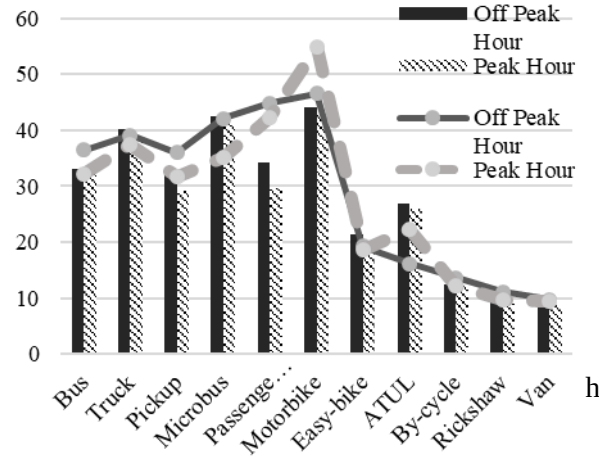

Figure 3: Spot speed of different vehicles on week days & weekend in both peak and off-peak hour in the Study Area.

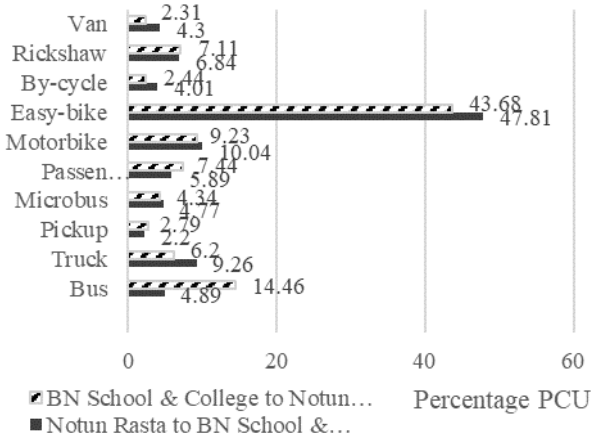

Figure 4: Volume of different vehicle for trip from Notun Rasta to B.N School and college and vice versa.

Income Level	Most Preferable Vehicle				
	Walking	Mahindra	Easy bike	Private Car	Bus
<5000	14	3	34	0	8
5001-10000	4	5	2	1	13
10001-15000	2	8	5	0	2
25000+	3	1	0	20	0
Total(percentage)	23	17	41	21	23

3.2.2 Vehicle Volume in the Study Area

For trip from Notun Rasta to B.N school and college and again reverse trip form B.N School and College to Notun Rasta for each vehicle type volume is shown in figure 4. For easy-bike volume is the most for both the trip. But from Notun Rasta to B.N school and college trip has more volume (47.81). Basically, this route has easy-bike as main transport mode. Students of this school and the patients and their relatives use these two trips. They prefer easy-bike because of availability and low cost. volume of van is lowest (2.31 and 4.3) in each the direction from B.N school to Notun Rasta and Notun Rasta to B.N School.

3.2.3 Fluctuations of Volume at Different Time in Two Direction (both weekdays and weekends):

For five separate time intervals at both the direction from B.N School and College to Notun Rasta and Notun Rasta to B.N School the fluctuation of volume is shown in figure 5 bellow:
From Notun Rasta to B.N School and College at 8:30 to 9:00 am the volume is the most. But for B.N School to Notun Rasta trip the volume is highest at 5:30 to 6:30 am. But the fluctuation is conspicuous at 8:30 am to 12:30 pm and 12:30 to 6:30 pm for both the direction. This is for week days in both directions that is for Notun Rasta to BN Scholl and college is 519.91 and for other trip is 503.82.

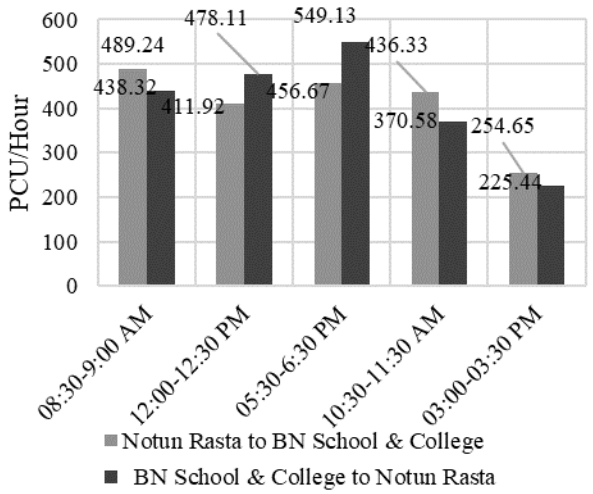

Figure 5: Fluctuations of Volume at Different Time in Two Direction (Week day)

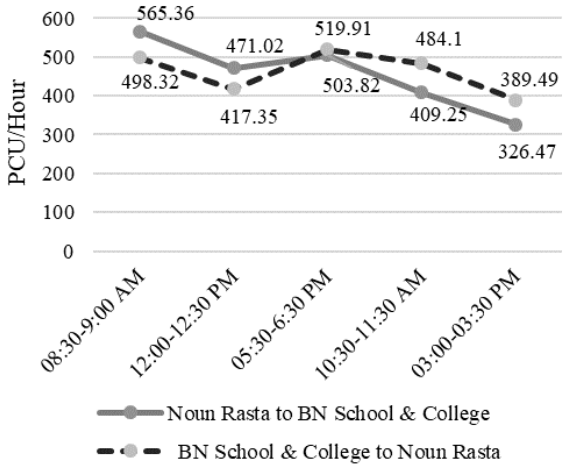

Figure 6: Fluctuations of Volume at Different Time in Two Direction (Weekend)

For weekend days the fluctuation is not so heavy as week days. Figure 6 shows at 5:30 to 6:30 from BN school to Notun Rasta the volume is maximum i.e. 549.13 and for the opposite direction the volume is maximum at 8:30 to 9:00 am and that is 489.24. So along with the trip direction the volume fluctuates with respect to time. For a specific time, interval, the graph shows that the values differ for volume.

3.2.4 Level of Service:

The value of level of service for this site tells the level is A; that means congestion is not seen here. Free and spontaneous flow exists in the two sections. Volume is low and the speed is high. For low volume NMT can be increased but for high speed of motorized transports the condition becomes risky.

Table 5: Level of Service

Intersection Pont	Time	Volume to Capacity Ratio	Range	Level of Service	
				Level	Service
Notun Rasta	Peak	.18	<= 0.6	A	Free flow, with low volumes and high speeds
	Off peak	.13	<= 0.6	A	
B N School and College	Peak	.17	<= 0.6	A	
	Off Peak	.16	<= 0.6	A	

3.2.5 Moving Observer Survey:

For the two directions the rate of flow is different, from Notun Rasta to BN School and college the flow is greater than the opposite direction. That means here interruption is less. Mean journey time and mean running time is less for this direction. This also implies that the flow towards this direction is better.

Table 6: Moving Observation

Section	Rate of Flow (PCU/Hour)	Mean Journey Time (min)	Mean Journey Speed(KPH)	Mean Running Time(min)	Mean Running Speed(KPH)
Notun Rasta to BN School & College	531.2	3.04	33.52	2.66	38.34
BN School & College to Notun Rasta	210	4.34	30.53	3.86	36.42

3.2.6 Moving Observer Survey from Notun Rasta to Gollamari more

Table 7: Moving Observation of Some Sections in Khulna City

Vehicles	North Bound		South Bound		Flow PCU/hr.
	Mean Journey Speed	Running Speed	Mean Journey Speed	Running Speed	
Notun Rasta-BN School and College	30.53 kmph	36.42 kmph	33.52 kmph	38.34 kmph	531.2
BN College- KPC	28.64 kmph	30.33 kmph	37.64 kmph	43.64 kmph	652.6
Khulna Public College-KMC	10.82 kmph	11.54 kmph	19.24 kmph	20.14 kmph	743.8
KMC- Sonadanga	11.34 kmph	11.79 kmph	9.66 kmph	11.34 kmph	651
Sonadanga-Gollamari	26.34 kmph	40 kmph	31.76 kmph	84.71 kmph	560
Notun Rasta to Gollamari more	21.53 kmph	26.01 kmph	26.36 kmph	39.63 kmph	628

The table 7 shows for all the links mean journey speed and running speed in case of inflow and outflow. In case of mean journey speed Notun Rasta to BN school and college shows the greatest value in case of north bound. But in south bound BN School to KPC has greatest mean journey speed. In case of running speed Sonadanga to Gollamari has the greatest running speed in south bound. This shows the difference in running and mean journey speed that leads to difference in mode choice. Flow of Notun Rasta to BN School and college is the least. So, less flow would encourage NMT s they have

lower speed. Whereas from Khulna Public College to KMC has greatest flow. It will discourage NMT as flow is basically of motorized vehicles for their low cost and high speed.

3.2.7 Occupancy of Different Vehicle of the Study Area

Figure 7 represents the occupancy data for different vehicles. Average occupancy of bus is seen to be the most. In the section of Notun Rasta-BN School and College, bus is not a prominent vehicle. But Easy-bike is the mostly used vehicle in this study area, so in the converted number of vehicle of occupancy is the most for easy-bike.

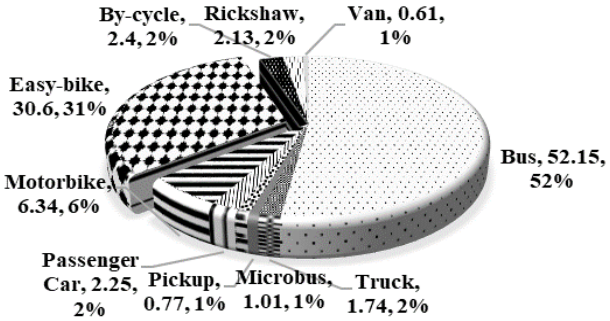

Figure 7: Occupancy of Different vehicle

Average occupancy of easy-bike is 2.2. As the converted value is the greatest, it proves people of this rout prefers easy-bike. Basic reason is its low cost and availability. A horizontal bar chart shows the average occupancy for different vehicles. This is simply the representation of the table above.

3.3 Congestion Index

3.3.1 Notun Rasta to BN School and College

Total Travel Time = 3 min 5 sec
Free Flow Travel Time = 2 min 42 sec
So, Congestion Index = 0.14

3.3.2 BN School & College to Notun Rasta

Total Travel Time = 3 min 20 sec
Free Flow Travel Time = 2 min 45 sec
So, Congestion Index = 0.21
So it is vivid that the congestion level is low in the study area.

4. CONCLUSIONS

Non-motorized vehicle is the salient mode by which individuals of every single monetary class can reach their destinations. It is averred that the satisfactory level is very low. Because most of the section of road has no footpath, median, signal and shoulder which create congestion in the road and also reason for accidents. Both side of the road land use is developing on the basis of commercial use. There is no formal parking and it creates congestion. Notun Rasta More is the most congested space of the study area. Congestion Index shows that the congestion level is low. From volume study the problems requiring traffic demand, traffic flows, problems due to merging and diverging were

identified. Different analysis methods are used in this report regarding volume study which can be used for further policy imposing or changing. Some recommendations are made bellow:

- ✓ There 152 sq. ft. on-street parking lots is available in Notun Rasta to BN School and College area that is used for illegal commercial activity resulting in illegal on-street parking. Congestion is the aftermath of such reduction in road width.
- ✓ There is no safe road crossing provision for the pedestrian in the study area. So, it is very dangerous for the pedestrian to cross the intersection point of the road like Notun Rasta more, BN School and College more etc. A foot over- bridge can certainly ensure safety requirement of those sections.
- ✓ Plethora of slow moving transports create immense congestion due to lack of proper management (Tasnim & Khan, 2018). A separate lane for non-motorized transport would be a lucrative measure to promote usage of NMT. However, with such narrow road it is not possible for the road section. If government acquires space, such initiative can be taken to increase usage of NMT.

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IMPROVEMENT OF URBAN TOURISM: ANALYZING THE FACTORS OF TRANSPORTATION NETWORK FOR VISITORS IN CHATTOGRAM, BANGLADESH

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ABSTRACT

Transportation has been recognized as part of the country's development through communication. But transportation facilities for tourists have been disregarded in most of the developing countries . Existing transportation system of Chattogram city in Bangladesh doesn't provide enough facilities and safety. Domestic and overseas visitors use Chattogram as a transit point to reach their recreational destination of four tourist cities; Rangamati, Khagrachari, Bandarban and Cox's Bazar. Since no public transport facilities are provided, it is creating an adverse effect on the tourists and the transport sector. As the number of tourists growing every year, urban tourism should be planned as per people's demand and tourist attraction. For this study literature review, field survey, disclosed existing condition, data collection, data analysis, questionnaire, findings and discussion, and recommendation have been done. By following these steps origin and destinations, terminal facilities, vehicle condition and fitness, highway capacity and conditions, tourist satisfaction data have been collected. This paper provides the improvement of urban tourism of Chattogram city through proper transport planning. It also overviews the present condition of urban tourism and tourist experience in this city. Proper planning in tourist transportation in Chattogram needs to be developed by providing geometric design, widening highways, construction of bypass road, tourist facilities and better sight distance.

Keywords: *Urban tourism, Transportation planning, Factors, Improvement, Visitors.*

1. INTRODUCTION

Transportation connects various destination with people. Tourism can be defined as travelling to various destinations. Transportation plays a vital role in tourism. With the growing development of transportation, tourism has expanded. Culpan (1987, p 546) defined transportation as important ingredients of the international tourism system acknowledging that land, air , sea modes are important with the availability of support service like fuel stations, repair centre and hotels for land travel. Transportation planning is defined as planning required in the operation, provision and management of facilities and services to provide safer, faster, economical, convenient movement of goods and people. Chattogram is the prime tourist destination of Bangladesh which connects hill districts and Bay of Bengal. But the transportation facilities for tourist in these routes are inadequate. These routes play vital role in tourism sector of Bangladesh. For a tourist area, an well planned transportation system is an essential infrastructural bridge between tourist origin and destination place. Chattogram is used as a transit point for visitors. People of different destinations interchange transportation modes here. But the transportation facilities are unwholesome for visitors. The fitness of buses are not good. Lacking of leg space, comfortable seats are evident. Terminals do not provide enough facilities like seating, public toilet for both male and female, locker room for baggage, prayer room, emergency medical facilities, vehicle repair and parking facilities. After analysing all factors this study was conducted. The purpose of this paper is to increase accessibility to tourist districts. Also analysing road network and development proposals, increasing terminal facilities, vehicle fitness improvement is suggested in this study. It will encourage visitors and enhances their comfort. Also tourism sector can be developed by implementing these suggestions.

2. METHODOLOGY

Methodology means the procedure in which the study is accomplished. It is the combination of some necessary steps to fulfill the study. A methodology has been selected for analyzing and improving the transportation network of the study area. Design strategies are based on these key features described below:

- Literature review
- Field survey
- Disclosed the existing situation
- Data collection
- Data analysis
- Questionnaire
- Findings and Discussion
- Recommendation

2.1 Literature Review

Literature review on improving and analysis transportation network have been collected from previous research works, articles and newspapers

2.2 Field Survey

Field surveys were conducted to collect information on 27 may, 9 June, 14 July, 8 September 2019 onwards. The surveys were conducted in Bahaddarhat bus terminal, Oxygen junction , Shah Amanat Karnaphuli Bridge area of Chattogram.

2.3 Disclosed the Existing Situation

On field survey disclosed the existing situation in the selected areas. Existing vulnerable conditions of transportation networks are noted.

2.4 Data Collection

Various data have been collected in regard to the study. Existing area plan from Chittagong Development Authority (CDA) and on field survey. Some secondary data are collected from research work, papers and projects.

2.5 Data Analysis

After collecting all data and information analysing of data is conducted. Existing conditions were judged, problems were identified. Comparing the existing data proposals are given.

2.6 Questionnaire

To conduct the study a questionnaire is prepared in a systematic way. It helps to collect information and suggestion from occupied people in this area.

2.7 Findings and Discussion

This study conducts some discussion on the problems of the transportation network. They are:

- Origin and Destinations
- Vehicle condition and fitness
- Terminal facilities
- Highway capacity and conditions
- Tourist satisfaction

2.8 Proposal

Proposals are given after judging the existing transportation condition.

3. STUDY AREA

In Study area A, Boddarhat Bus Terminal is the biggest bus terminal of Chattogram. This bus terminal connects Cox's Bazar and Bandarban hill districts. It also includes buses of South Chattogram
In Study area B, Oxygen Bus station which is the prime route for two hill districts Khagrachari and Rangamati.

In study area C, Shah Amanat Bridge bus station (locally known as notun bridge bus terminal), which is the connection bus station of Boddarhat bus terminal. Includes buses of Cox's Bazar, Bandarban and South Chattogram.

Figure 1: Study area A, B, C (From left to right) (Source: Google Map, 2019)

4. FINDINGS AND DISCUSSIONS

4.1 Origin and Destination

Route 1 (Chattogram to Cox's Bazar):

Cox's Bazar having the largest sea beach in the world is the prime tourist attraction around Bangladesh. Direct bus services available here are Marsa transport, Soudia Paribahan, S.alam. Also some local bus services are also available in this route. This journey takes three to four hour. Some buses provide hotel break in mid time.These are direct closed door service having ac and non ac facilities every hour. Also there are some other local transport companies in this route.

Route 2 (Chattogram to Bandarban) :
There are only two major bus companies that are servicing; Purbani and Pubali. Also some local bus services are available but inadequate in number. It takes almost three and half an hour to reach there. The buses don't provide any hotel breaks.

Route 3 (Chattogram to Rangamati) :
One bus operator is providing service in this route; Paharika super service. Others are some local bus operators. It takes around two and half an hour to reach. The buses don't provide any hotel break.

Route 4 (Chattogram to Khagrachari) :
Shanti paribahan is servicing in this hill route. They have bus trips every hour. They provide twenty minutes hotel break in this three to four hours journey.

Table 1: Bus Service Information (Source: On field Survey, July 2019)

Route	Bus Operator	Counter Location	Bus Type	Hotel Break Location	Number of Buses
1	Marsa	Bahaddarhat, Notun Bridge	Direct/ Non ac	No break	90+
	Soudia	Cinema palace,Dampara, Bahaddarhat, Notun Bridge	Direct/ Non ac	Chakaria	70+
	S.alam	Cinema palace, Dampara, Bahaddarhat, Notun Bridge	Direct/ Non ac	No break	50+
	Relax Transport	Bahaddarhat, Notun Bridge	Direct/ Non ac/ Ac	Chakaria	20+
2	Purbani	Bahaddarhat, Notun Bridge	Direct/ Non ac	No Break	20+
	Pubali	Bahaddarhat, Notun Bridge	Direct/ Non ac	No Break	15+
	BRTC	Bahaddarhat	Direct/ Ac	No Break	10+
3	Paharika	Oxygen	Direct/ Non ac	No break	20+
4	Shanti Paribahan	Oxygen	Direct/Non ac	Matiranga	30+

4.2 Terminal Facilities

Bus terminal facilities are included in the following table.

Table 2: Terminal Facilities (Source: On field Survey, July 2019)

Facilities	Bohaddarhat	Oxygen	Notun Bridge
Loading and Unloading	Yes	No	No
Servicing and Repair	Yes	No	No
Parking	No	No	No
Toilet	Yes	No	Yes
Locker room	No	No	No
Medical Service	No	No	No
Cafeteria	No	No	No

4.3 Vehicle Condition and Fitness

The condition of buses of Cox's Bazar route is comparatively good. The bus operator replaces old buses almost every two years. Tourists get adequate comfort in the journey. The bus condition of Bandarban route is not that good. Inadequate leg spaces, fans and suspension don't provide better comfort to the tourist. The bus condition of Khagrachari routes is also same as Bandarban route. The buses running in the roads are minimum 5 to 7 years old. In Rangamati route the condition and fitness of buses are comparatively low. It creates a hectic situation for tourists.

4.4 Highway Condition

Table 3: Highway Condition (Source: On field Survey, August 2019)

Route	Length (K.M.)	Condition	Traffic Congestion
1	142	Good, Curves	High
2	71	Good	Average
3	71	Average	Low
4	115	Good, Hilly	Low

4.5 Highway Capacity

Using the formula,

$$C = \frac{1000 \times v}{s}$$

Where, C = Capacity of single lane vehicles per hour
v = speed (km/h)
S = Average centre to centre spacing of vehicles (meter), When they follow one behind the other on a queue or space headway (m)

Thus, Capacity depends upon speed and spacing.
Numercially, Spacing, S= Sg+L
Again, Sg = 0.278v.t
Where, Sg= Space gap(head to rear) between vehicles.
L= Average Length of vehicles
V= speed (km/h)
t= Total reaction time of driver equally assumed equal to 0.70 to 0.75

Assume, Vehicle speed for routes are,
Route 1, V= 80 km/h
Route 2, V = 70 km/h
Route 3, V= 75 km/h
Route 4, V= 65 km/h

After putting the values,Capacity per hour is found,
Route 1, C=3137
Route 2, C=2966
Route 3, C=3048
Route 4, C=2876
(Source : Khanna, S.K. & Justo, C.E.G. (1991). *Highway Engineering)*

4.6 Tourist Satisfaction

There are questionnaire data collected from survey sites from people of different ages. They were asked these questions on the aspects of bus terminals.

People age : 26 years – 45 years
Gender : Both male and female
Occupation : Service Holder, Businessman, Housewife, Student, Worker

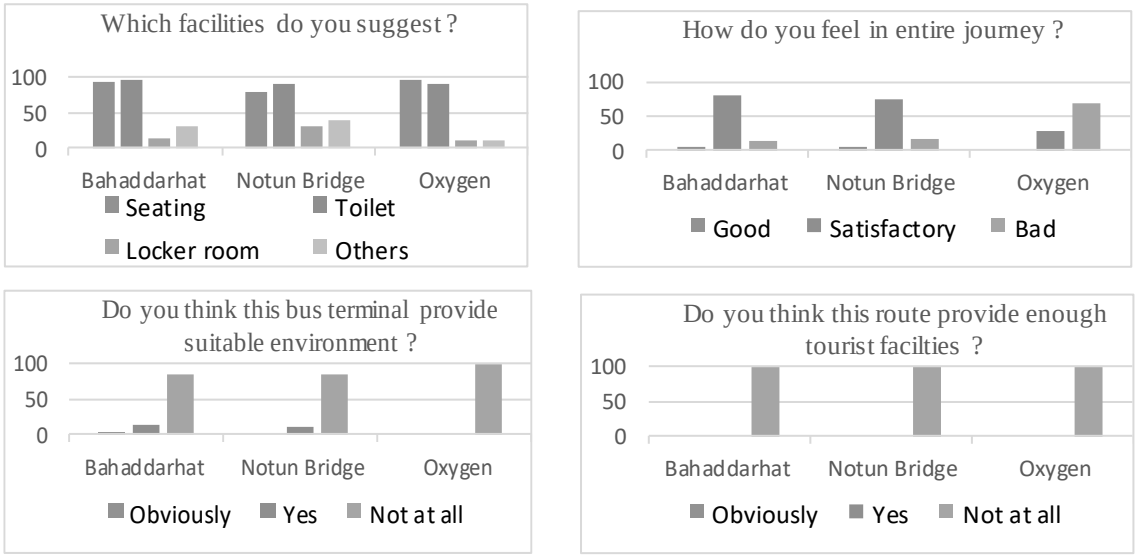

Figure 1: Different locations facilities and feelings

5. PROPOSALS

Some proposals are given in this study. The proposals are based on literature study and collected data from on field survey. These proposals will reduce existing problems by maintaining standard dimensions on road network. Also, terminal facilities are proposed as per tourist demand.

USER SURVEY QUESTIONNAIRE ON TOURIST SATISFACTION

Name: Age: Sex: Occupation:
Terminal Name:

We are from Chittagong University of Engineering & Technology (CUET) . We are conducting a research based on tourist facilities for visitors of Chattogram. The purpose of this research is completely academic. Please complete this questionnaire with specific regard to the above enquiry, by placing a cross to above .

In the appropriate box.

1. Do you think this bus terminal provide enough suitable environment?
☐ Obviously ☐ Yes ☐ Not at all

2. How do you feel in entire journey?
☐ Good ☐ Satisfactory ☐ Bad

3. Do you think this route provide enough tourist facilities?
☐ Obviously ☐ Yes ☐ Not at all

4. Which facilities do you suggest ?
☐ Seating ☐ Toilet ☐ Locker room ☐ Others(Please mention).....

Figure 2: Questionnaire form

5.1 By Pass Road Construction

Construction of bypass road will reduce traffic congestion inside Chattogram city. Already constructed Potiya bypass has reduced congestion on Chattogram to Cox's Bazar highway. Bypass for Rangamati and Khagrachari route should be constructed. Already proposed outer ring road from

Potenga to Shah Amanat Bridge for passing the buses of Cox's Bazar and Bandarban should be implemented as soon as possible.

5.2 Road Widening

Existing two lanes highway should be increased to four lane highway. With the increasing number of tourist and local people, the roads are getting congested by vehicles of inter district and long route vehicles. Width of roads should follow some standard dimensions as these roads pass by plain land and mountain terrain. A table is given below about standard roadway width.

Table 4: Road Width Dimension (Source: Khanna, S.K. & Justo, C.E.G. (1991). *Highway Engineering)*

Road Classification	**Roadway width (meter)**	
National and State Highway	Plain and Rolling terrain	Mountain and steep terrain
Single lane	12	6.25
Two lane	12	6.25

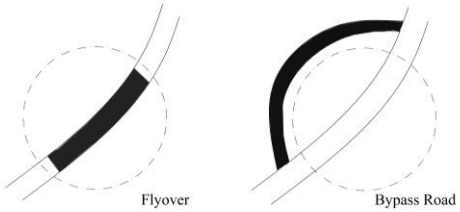

Figure 3: Road Widening Examples

5.3 Control of traffics

Vehicular traffics, reckless driving should be controlled. These four highways already consist of hill terrain with slope and curves. Every year road accidents occurred due to over speed and reckless driving. For hilly terrain permissible vehicle speed should be less than the standard.

5.4 Maintaining Sight Distance

Enough sight distance must be provided for drivers in each lane. The length of the carriageway should be visible to a driver both horizontal and vertical planes.

5.5 Improvement of Terminal Facilities

The three terminals should be improved with passenger and tourist facilities. Providing parking space, loading and unloading yard, different toilet and washroom for male and female, Locker room facilities. Moreover, the security system should be engaged in these terminals. These facilities will improve the urban tourism network.

5.6 Maintenance of Vehicle

Vehicles are the prime concern for comfort in transportation network. Old buses should be replaced. Available buses should be maintained properly. Also, the number of daily trips on these routes should be increased with more number of buses.

6. CONCLUSIONS

With these recommendations Chattogram can be a prime urban tourism destination in Bangladesh. So, its present public transportation system needs a well approached improvement to meet its need for daily passengers and the tourists. Necessary steps should be taken by the concerned authority to

implement the proposals. It will attract urban tourism and will improve the transportation network of these routes.

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FORECASTING AIR FREIGHT TRANSPORTATION DEMAND USING LOG-LINEAR MODEL FOR SOCIO-ECONOMIC FACTORS

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ABSTRACT

Forecasting freight transport demand is of critical importance since investment efficiency is greatly influenced by the estimation performed. In this current study, Log-Linear Models have been developed individually for inbound, outbound and total freight transportation demand in Australia for finding the combined effect of various socio-economic variables in freight movement. Log- linear model is chosen due to its capability of modelling non-linear effects. Data of exogenous variables has been collected from Australian Bureau of Statistics (ABS). Selected independent socio-economic variables are population, GDP, total goods exported, total goods imported, import and export price index and consumer price index. Socio-economic variables are chosen in such a way that the overall model has a good-fit. All the three models have adjusted R-square values greater than 0.95 and standard error within 0.1 indicating goodness of fit and good correlation within the variables. Elasticity analysis is done here. From the elasticity analysis it is found that, Import-Export Price Index (IE-Index) and Consumer Price Index (CPI) have positive elasticity greater than 2 which emphases that the air freight movement is very elastic with respect to IE-Index and CPI. Value of elasticity for GDP is 0.126 for total freight movement, 0.62 and 0.625 for inbound and outbound air freight movement respectively indicating that air freight movement is mostly a necessity for industrial growth in Australia. Negative low value of elasticity(-0.22) for Inbound freight movement is found for the variable of total goods imported which can be described as the fact that capacity of air-freight movement is not unlimited, so with the increase of total imported goods, it doesn't significantly increase the freight movement, rather alternative modes induce negative sign on elasticity value. Such result indicates that a cross-elasticity model may perform even better in the prediction of freight movement demand.

Keywords: *Freight transportation, Log-linear model, Elasticity, Socio-economic factors.*

1. INTRODUCTION

Freight transportation is different from transportation of passengers and their modelling requires different factors. When the transportation of freight is made by air cargo, forecasting becomes more complex. There is very limited study on air freight transportation demand modelling. Totamane et. al. (2014) used Potluck Problem approach to propose a multi-producer/multi-consumer solution for predicting the cargo demand of a specific airline in a given route. Each airline is considered as a producer and the users of air cargo services as consumers, no explicit communication with other producers/airlines was assumed. They mainly used data of different routes of North American Region as training data and proposed a new capacity plan. They modelled the problem using some of the generic predictors, such as time-varying functions, holidays, weekends, and so on. Additional predictors, such as industrial output, industrial growth, GDP, and so on, were considered but not found to make a significant overall difference.

Air freight has become increasingly important for transporting goods on Australia's international routes, largely due to the fact that Australia is a large island nation which lies far from densely populated business centres such as Singapore, Hong Kong, London, Paris, New York and Los Angles and that movement of freight by sea on Australia's international routes is time consuming. Goods that are moved by air are mostly light and high value goods requiring urgent delivery. In 2009-10, a total of 798100 tons of international air freight passed through Australian airports. It included 318600 tons of outbound air freight and 479500 tons of inbound air freight. About seventy per cent of the outbound air freight volume was uplifted at Australia's two major airports, Sydney and Melbourne (Hamal, 2011).

This study focusses on identification and collection of data from Australian Bureau of Statistics (ABS) of exogenous variables which may have direct influence on the demand data for forecasting the demand model of freight transport. The objective of this study is to develop a Log-Linear Demand Model to predict the combined effect of different socio-economic variables, identify the elasticity and determine the most influencing variables for determining the demand. Explanation of elasticity that are found from log linear regression of the variables is also done here.

2. METHODOLOGY

For forecasting transportation demand in Australian freight movement, raw data is taken from Australian Bureau of Statistics (ABS). Data set contained total Australian yearly freight movement statistics for the year 1985 to 2016. These were used to form a log-linear model. Regression analysis result showed elasticity of selected independent variables.

2.1 Selection of Variables

This modelling has two types of variables. One is dependent variables and other one is independent variable. The values of dependent variables depend on the values of independent variables. The dependent variables represent the output or outcome whose variation is being studied by the means of elasticity. Here, the dependent variables are Inbound, Outbound and Total Air Freight Movement for total Australia. Independent variables are population, GDP, total goods exported, total goods imported, import and export price index and consumer price index. Here, the independent variables are socio-economic factors. The variable consumer price index is a measure of changes in the purchasing-power of a currency and the rate of inflation. This variable is only considered for the model of forecasting total freight movement. Here, such socio-economic variables are selected which showed good fit in the model. Table 1 shows input data for regression analysis taken from Australian Bureau of Statistics.

Table 1: Input Data for Regression Analysis

Year	Inbound Air Freight (Tonnes)	Outbound Air Freight (Tonnes)	Total Air Freight (Tonnes)	Total goods exported ($ million)	Total goods imported ($ million)	GDP ($)	Population	Import and Export Price Index
1985	118,478	112,523	231,002	32807	34149	11452.66	15,901,000	66.0
1986	106,914	141,825	248,739	33768	36515	11379.52	16,139,000	77.3
1987	120,716	167,215	287,931	38942	38193	11643.95	16,395,000	84.5
1988	145,316	163,567	308,884	42562	43338	14283.38	16,687,000	86.8
1989	179,556	168,284	347,839	47021	51216	17838.36	16,937,000	79.0
1990	174,933	182,106	357,039	50712	50216	18249.29	17,170,000	83.1
1991	171,628	188,074	359,703	54316	49772	18865.34	17,379,000	88.9
1992	186,343	219,704	406,048	58265	56064	18616.32	17,557,000	85.3
1993	197,719	257,017	454,736	62648	62760	17681.15	17,719,000	93.9
1994	240,976	279,622	520,598	64675	69053	18102.32	17,893,000	99.0
1995	247,681	301,244	548,925	71800	77619	20384.67	18,120,000	94.1
1996	265,490	317,333	582,823	76944	77902	21944.16	18,330,000	97.3
1997	302,764	344,082	646,846	87099	85038	23551.22	18,510,000	91.0
1998	302,643	329,265	631,908	88976	97277	21365.98	18,706,000	96.7
1999	335,268	346,247	681,515	86705	101774	20561.48	18,919,000	102.0
2000	332,095	347,915	680,010	110283	118916	21690.92	19,141,000	99.2
2001	289,661	350,461	640,121	123412	119927	19517.84	19,386,000	114.8
2002	305,095	340,831	645,926	119633	129835	20081.82	19,605,000	113.1
2003	313,619	297,592	611,210	108695	132223	23465.39	19,827,000	108.0
2004	383,423	293,070	676,493	118178	143769	30472.38	20,046,000	94.4
2005	414,431	294,238	708,668	140462	158730	34016.71	20,312,000	94.8
2006	440,678	306,050	746,728	165320	181365	36118.28	20,628,000	97.0
2007	452,850	308,998	761,848	169925	194674	40991.98	21,016,000	97.0
2008	451,321	304,152	755,474	222795	232312	49664.69	21,476,000	94.8
2009	405,210	309,146	714,356	198343	204735	42743.00	21,866,000	114.8
2010	492,036	314,365	806,402	231699	219953	51874.08	22,172,000	97.0
2011	521,483	316,989	838,472	262895	241145	62245.10	22,527,000	96.1
2012	541,205	328,900	870,105	249386	257534	67635.32	22,942,000	100.6
2013	524,642	354,153	878,795	262957	255940	67708.69	23,322,000	99.7
2014	515,061	383,722	898,783	267287	264381	62099.61	23,673,000	104.9
2015	506,112	472,736	978,848	250881	275885	56408.34	24,013,000	105.2
2016	502,586	514,058	1,016,643	258078	267035	49755.32	24,127,159	107.7

2.2 Regression Analysis

Considering different variables stated in section 2.1, log linear regression analysis is done. Log-linear regression model is chosen because it capable of modeling nonlinear effects. Again, coefficients themselves directly represent the demand elasticities with respect to the different explanatory variables. The form of log linear regression analysis is shown in equation (1) to (3).

$$Ln\ (Inbound\ Air\ Freight\ Movement) = \beta_0 + \beta_1 ln\ (Population) + \beta_2 ln\ (Total\ Goods\ Imported) + \beta_3 ln\ (Total\ Goods\ Exported) + \beta_4 ln\ (GDP) + \beta_5 ln\ (Import\text{-}Export\ Index) + \epsilon \quad (1)$$

$$Ln\ (Outbound\ Air\ Freight\ Movement) = \beta_0 + \beta_1 ln\ (Population) + \beta_2 ln\ (Total\ Goods\ Imported) + \beta_3 ln\ (Total\ Goods\ Exported) + \beta_4 ln\ (GDP) + \beta_5 ln\ (Import\text{-}Export\ Index) + \epsilon \quad (2)$$

$$Ln\ (Total\ Air\ Freight\ Movement) = \beta_0 + \beta_1 ln\ (Population) + \beta_2 ln\ (Total\ Goods\ Imported) + \beta_3 ln\ (Total\ Goods\ Exported) + \beta_4 ln\ (GDP) + \beta_5 ln\ (Import\text{-}Export\ Index) + \beta_6 ln\ (Consumer\ Price\ Index) + \epsilon \quad (3)$$

Here, variables are shown in parantheses. β's are regression analysis co-efficient, ϵ's are error terms.

Total goods exported and total goods imported are specified in million dollars, GDP is specified as dollars per capita. Remaining parameters are specified as values.

2.3 Elasticity Analysis

The variation in demand in response to a variation in price is called the price elasticity of demand. It may also be defined as the ratio of the percentage change in demand to the percentage change in price of particular commodity. When the price elasticity of demand for a good is perfectly inelastic, changes in the price do not affect the quantity demanded for the good. When the price elasticity of demand for a good is relatively inelastic ($-1 < Ed < 0$), the percentage change in quantity demanded is smaller than that in price. When the price elasticity of demand for a good is unit (or unitary) elastic ($Ed = -1$), the percentage change in quantity demanded is equal to that in price. When the price elasticity of demand for a good is relatively elastic ($-\infty < Ed < -1$), the percentage change in quantity demanded is greater than that in price. Regression analysis done in section 2.2 yields to the values of β (regression co-efficient) for corresponding variables assigned. These β values are analyzed if those are in elastic or inelastic in nature as stated above.

3. DATA ANALYSIS

From the regression analysis, forecasting model is formed and adjusted R-square values are checked.

3.1 Forecasting Model

Result from regression analysis is shown in table 2.

Table 2: Result from regression analysis

Variables	INBOUND	OUTBOUND	TOTAL
Intercept (β_0)	30.31	-37.8215	27.46
Population (β_1)	0.37	-0.417	1.44
Total Goods Imported ($) ($\beta_2$)	-0.22	0.153	0.426
Total Goods Exported ($) ($\beta_3$)	0.71	1.34	0.06
GDP($) ($\beta_4$)	0.62	-0.625	-0.126
Import Export Index (β_5)	2.11	2.53	2.3
Customer Price Index (β_6)	------	------	3.04
R Square	0.995	0.989	0.951
Multiple R	0.9974	0.995	0.97
Adjusted R Square	0.994	0.987	0.950
Standard Error	0.038	0.038	0.105
Observations	32	32	32

Adjusted R Square value indicates good-fit for all the three models. The standard errors found are all within 0.1, which also indicates the good correlation among the data.

Using the regression co-efficients shown in table 2, equations (1) to (3) can be written as shown in equations (4) to (6)

Ln (Inbound Air Freight Movement) = 30.31+ 0.37ln (Population) – 0.22ln (Total Goods Imported) + 0.71ln (Total Goods Exported) + 0.62ln (GDP) + 2.11ln (Import-Export Index) (4)

Ln (Outbound Air Freight Movement) = -37.82 - 0.417ln (Population) + 0.153ln (Total Goods Imported) + 1.34ln (Total Goods Exported) - 0.625ln (GDP) + 2.53ln (Import-Export Index) (5)

Ln (Total Air Freight Movement) = 27.46 + 1.44ln (Population) + 0.426ln (Total Goods Imported) + 0.06ln (Total Goods Exported) - 0.126ln (GDP) + 2.3ln (Import-Export Index) + 3.04ln (Consumer Price Index) (6)

3.2 Elasticity

Regression co-efficient values from table 2 is used to explain elasticity of a socio-factor with its corresponding model.

3.2.1 Import-Export Price Index

Import and export price indexes measure changes in the price of goods and services in international trade. From table 2, it is found that IE- Index has positive elasticity greater than 2 for all the three models, these emphases that the air freight movement is very elastic with respect to IE-Index. It indicates that if IE-index varies the number of freight trips will vary significantly. Import Export Price Index has overall positive effect on air freight movement.

3.2.2 GDP

GDP is a key performance indicator of a nations economy. From table 2, it is found that regression coefficients for inbound, outbound and total freight movement is 0.62, -0.625 and -0.126. Value of elasticity for GDP is very low and almost same in all cases. This indicates that air freight movement is mostly a necessity for industrial growth. Gross Domestic Product (GDP) per capita has inelastic effect on demand.

3.2.3 Population

From table 2, for independent variable popuation, it is found that regression coefficients for inbound, outbound and total freight movement is 0.37, -0.417 and 1.44. Elasticity value greater than one indicates increase in population has larger increase in freight movement. More people require more goods i.e. more freight movement. The effect of population is positive in case of Inbound and Total Air Freight movement but negative in case of outbound movement. If we consider inbound and outbound freight movement individually, both are inelastic range.

3.2.4 Total Goods Imported

From table 2, it is found that regression coefficients for inbound, outbound and total freight movement for total goods imported is 0.22, 0.153 and 0.426. Value of elasticity for total goods imported is very low and almost same in all cases. This indicates that air freight movement is mostly a necessity for industrial growth. Negative low value of elasticity for Inbound freight movement for total goods imported can be described as the fact that capacity of air-freight movement is not unlimited, so with the increase of total imported goods, It doesn't significantly increase the freight movement , rather alternative modes induce negative sign on elasticity value.

3.2.5 Total Goods Exported

From table 2, it is found that regression coefficients for inbound, outbound and total freight movement for total goods exported is 0.71, 1.34 and 0.06. Total goods exported have positive elasticity of 1.34 as

it directly emphases the outbound Air freight demand. It has inelastic behavior or no change of behavior on inbound Freight Movement. Total goods exported has overall positive effect on air freight movement.

3.2.6 Consumer Price Index

A measure of changes in the purchasing-power of a currency and the rate of inflation is termed as consumer price index. From table 2, it is found that regression coefficients for total freight movement for this variable is 3.04. Here it can be seen that CPI has very high elasticity with Air Freight Movement. It has a value greater that 3 indicating high dependency of air freight on the CPI.

4. CONCLUSIONS

From this study, it is found that for maximum variables (population, GDP, Total Goods Imported and Total Goods Exported), freight movement is inelastic nature. These result shows similarity with the study of Totamane et. al. (2014) where they found that industrial output, industrial growth, GDP don't make a significant overall difference. International Trade Expense (Import and Export Price Index) is the most effective variable for freight movement according to this analysis and very elastic in nature for inbound, outbound and total freight movement. Introducing cross-elasticity analysis for these socio-economic factors can help to replicate the actual scenario in a better way.

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TRANSPORTATION SAFETY IN THE INLAND WATERWAYS OF BANGLADESH: CHALLENGES AND MITIGATION OPTIONS

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ABSTRACT

Inland water transport is one of the most popular modes of transport in Bangladesh. It allows very easy access to any region of the country and is also cheaper than the other modes of transport. The aim of the study is to investigate the contemporary safety issues related to inland water transportation in Bangladesh. The statistical analysis is conducted based on the inland waterway accident data collected from the Department of Shipping and Bangladesh Inland Water Transport Authority (BIWTA). The study considers 268 accidental events during the period of 2005 to 2017 in which 438 vessels were involved. The analysis reveals that collision (57.8%) is the leading cause of inland water transport accidents. A major finding of the study is that cargo vessel is the dominant type of vessels responsible for the accidents. Besides most of the cargo vessels are foundered after the accidents. It has also been found that the major portion of the overall casualty is the fatality. The average fatality per accident ratio is high for the accidents related to stormy weather and overload & stability failure. Besides, most of the fatalities are involved in collision accidents. Dhaka to Barishal route has been found to be the most vulnerable waterway route in Bangladesh. During the study, it is found that many important factors and parameters of the accidental event are not reported properly due to a significant deficiency in the accident reporting system. Based on the analysis a number of recommendations have been put forward to mitigate the accidents in the inland waterways of Bangladesh and improve the safety situation.

Keywords: *Bangladesh, Inland waterway, Accidents, Passenger vessel, Transportation safety.*

1. INTRODUCTION

Bangladesh is bestowed with numerous rivers and canals that are extended all over the country. This blessing from nature has allowed her to form an extensive inland water transport network throughout the breadth and length of the country. Despite the improvement of roadway, railway & airway transportation sectors, the inland water transport still plays a significant role in the transportation of a huge number of passengers and a significant amount of cargoes of the country. However, the safety situation of this vital mode of transport is disappointing to all. Every year many people are killed, some others are injured and reported missing due to accidents in the inland waterway. In the most recent decades, a number of catastrophic inland water transport accidents have been the depressing news for the whole world. At times these accidents have caused harmful effects on the environment. An investigation committee is formed by the government after each accident to identify the vital causes behind the accident and to generate some recommendations to stop such a loss in the future. Despite making significant efforts, the safety situation of the inland waterway is not improving and accidents are taking place in each year.

The prime objective of the study is to perform a statistical analysis based on the accident data of inland water transport accidents. The nature & type of accidents, involvement of types of vessels, types of casualties, location of accidents & eventual condition of vessels after the accidents are analyzed in this study. Based on the findings of the study a number of recommendations are put forward that can mitigate the accidents and thereby safety can be ensured in the inland waterways of Bangladesh.

2. LITERATURE REVIEW

A number of studies have been carried out to address the safety issue of the inland waterways of Bangladesh. However, due to the inadequacy of accident data & information, the numbers of in-depth studies on maritime transportation safety are very few.

A study by Chowdhury (2005) was involved in the application of Geographical Information System (GIS) to reveal that most accidents occur during fair weather & good visibility condition. The study, therefore, concluded that human factors are highly responsible for the inland water transport accidents in Bangladesh. Awal (2007) stated that there are four main factors that are responsible for the maritime accidents of Bangladesh. These factors are related to vessel design, operating environment inside the vessel, education & enforcement, and human error. A study by Awal (2008) revealed that passenger vessels & cargo vessels contribute significantly to the total number of fatalities of inland water transport accidents. Rahman & Rosli (2014) proposed the concept of elevator operation to mitigate the accidents due to the overloading of the passenger ships of Bangladesh. Hossain et al. (2014) developed a fault tree as a tool for collision & grounding-type accidents and analysis of accident data to identify the hazardous chain of events. Islam et al. (2015) investigated the causes behind the water transport accidents in Bangladesh. The study concluded that the most combined form of occurrence of maritime accidents in Bangladesh is overloading combined with inclement weather. Uddin & Awal (2017) analyzed the inland water transport accidents from 2005 to 2015 to reveal that the numbers of accidents increase & decrease in a periodic manner which resembles a wave shape form. A study by Probha (2017) revealed that cargo vessels and passenger vessels mainly contributed to the accidents in the inland waterways of Bangladesh during the period of 2008 to 2015. Another important finding of the study is the average casualty per accident & average fatality per accident ratios are higher in the waterways in comparison to the roadways & railways. Raiyan et al. (2017) applied Event Tree Analysis method to analyze the maritime accidents of Bangladesh. The study concluded that the number of accidents can be reduced considerably if the problem of poor visibility when the vessel is overloaded can be solved.

3. ACCIDENT DATA COLLECTION AND METHODOLOGY

The data of inland water transport accidents have been collected from the Department of Shipping and Bangladesh Inland Water Transport Authority (BIWTA). This study considers 268 accidents during the period of 2005 to 2017 in which 438 vessels were involved. These accident data are usually documented in a textual form and there is no standard database to maintain these vital data & information. Many important technical parameters like types of vessel, time of accidents, names of rivers or canals etc. are found missing for many accidents. Furthermore, the exact location of accidents including latitude & longitude, route of accidents, dimensional characteristics (viz. length, breadth, depth & draft etc.) of the vessels, number of passengers or weight of cargo carried by the vessels before accidents etc. are not found to be recorded in those reports. Therefore, it has been observed that the current documentation system mainly focuses on legal issues rather than technical issues. As a result extraction of the technical information from these reports has been a burdensome task for this study. The Microsoft Excel software has been used for statistical analysis of the accident data and the results are presented in graphical form.

4. ANALYSIS

4.1 Annual Distribution of Accidents and Casualties

The annual distributions of accidents and casualties in the inland waterways of Bangladesh are illustrated in figure 1. The annual distribution of inland water transport accidents suggests that the number of accidents follows a random pattern i.e. it fluctuates considerably over the years. The numbers of accidents remain above ten except the years 2013 & 2016. Besides, after the year 2010, the number of accidents remains below twenty-five; although it exceeds this figure in 2017 which is a very alarming issue. It is also observed that number of fatalities is comparatively higher than the number of injured & missing people i.e. fatality constitutes a greater portion of overall casualties. The annual distribution of fatalities shows that the trend of fatalities over the years follows the almost similar pattern to the trend of the number of accidents except the years 2005 & 2012.

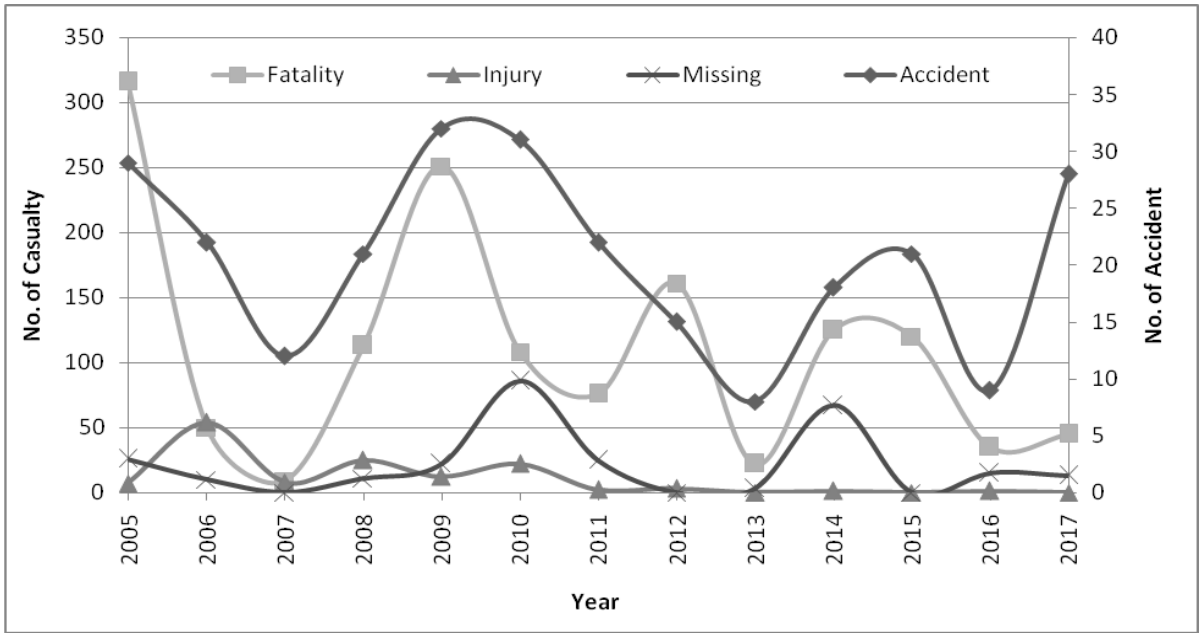

Figure 1: Annual distribution of accidents and casualties in the inland waterways of Bangladesh

During the analysis, it has been found that the high number of fatalities occurs mainly due to the accidents involving the passenger vessels. A single accident involving the passenger vessels has caused the death of more than a hundred people which is really a shocking issue. The number of injured people remains considerably lower in comparison to the number of fatalities. During 2006 the

number of missing people is above fifty. Apart from this year, the number of injured people is less than fifty throughout the mentioned range of years. During the years 2010 & 2014, the number of missing people has been found to be higher than any other year. An important fact needed to be discussed here is that the missing people are usually not found alive after the accident; rather their dead bodies are sometimes recovered after some days of the accident. Therefore, the numbers of missing people are reported based on recovering their dead bodies. In fact, they can be considered as killed in the accident.

4.2 Annual Distribution of Accidents and Their Types

The annual distribution of number of accidents on the basis of accident types is illustrated in figure 2. It is observed that the collision of vessels dominates over all types of accidents. The shape of this curve for collision accidents is almost similar to the curve of overall accidents as shown in figure 1. The most probable reason behind such a huge number of collision accidents may be the operation of vessels by the unskilled operators & crews. Besides, the non-availability of the sufficient number of navigational aids on the waterway routes may be a significant causal factor. The occurrences of other types of accidents follow a random pattern over the years.

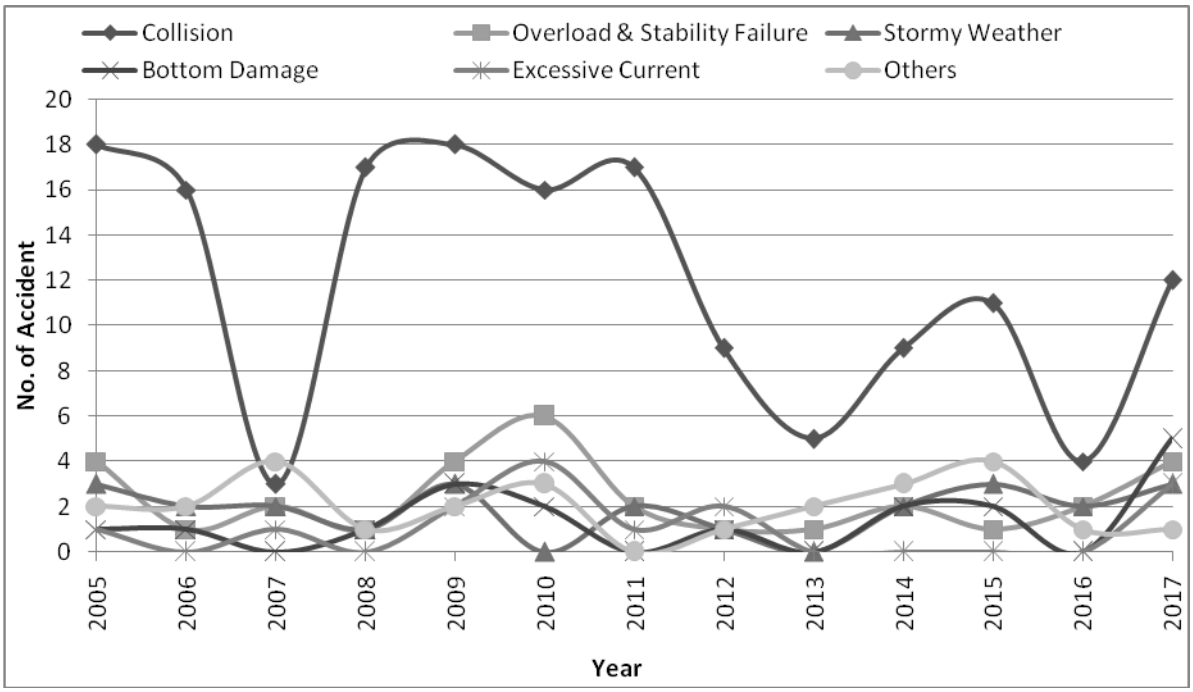

Figure 2: Annual distribution of the number of accidents on the basis of accident types

4.3 Accident Types and Associated Fatalities

To identify the type of accidents that is highly responsible for the occurrence of a major portion of fatalities it is needed to distribute the number of accidents and associated fatalities based on the type of accidents. Figure 3 illustrates such a distribution to reveal this vital fact. It is observed that the numbers of accidents in the inland waterways of Bangladesh mainly occur due to collision (57.8%). Moreover, the number of fatalities involved in the collision accidents is also higher than any other types of accident. Therefore the mitigation of collision accidents will obviously reduce the number of accidents and associated fatalities in the inland waterways of Bangladesh. However, the number of fatalities involved in stormy weather and overload & stability failure is considerably higher with respect to the number of accidents; that is the ratio of average fatality per accident is higher for these two types of accident than any other types of accidents. This is due to the fact that the vessels usually capsize in these types of accidents and the people inside the vessels become unable to save their lives. The fatalities involved in the bottom damage, excessive current & other types of accidents are insignificant with respect to the overall fatalities.

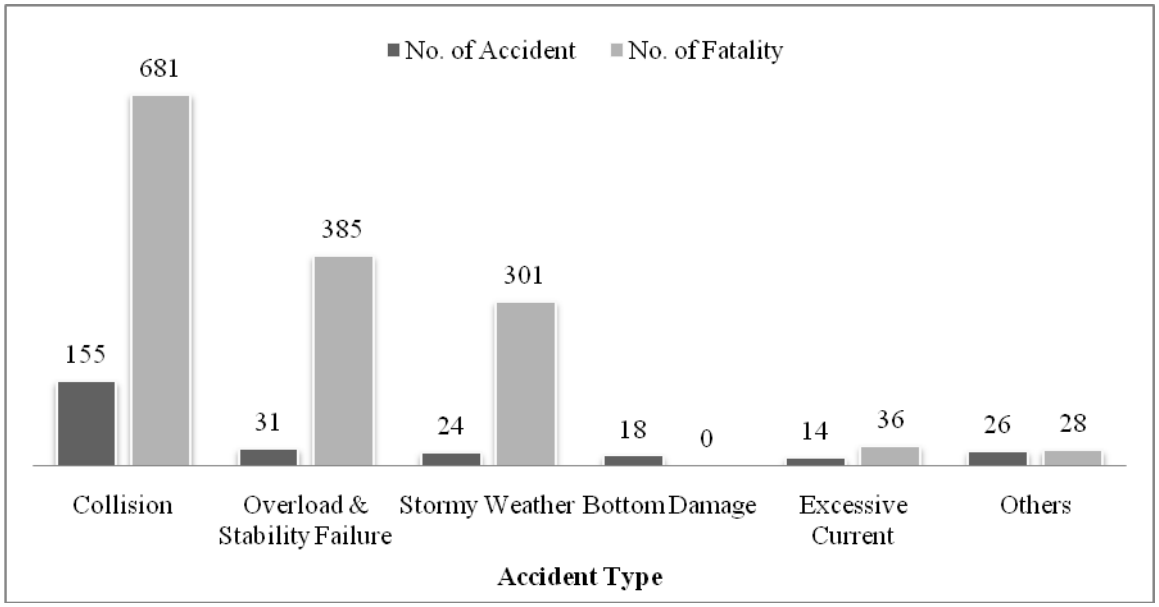

Figure 3: Distribution of accident types and associated fatalities

4.4 Location of Accidents

The district-wise distribution of inland water transport accidents is illustrated in figure 4. It is observed that most of the accidents have occurred in the districts located in the southern zone of Bangladesh. The primary mode of transport in this zone of the country is the inland water transport. However, the occurrence of accidents remains as a great threat to the people those who travel by the waterway. Barishal, Chandpur, Munshiganj, Dhaka & Narayanganj are the noteworthy districts for occurrence of accidents which is under the renowned waterway route of the nation named as Dhaka to Barishal. The Meghna is the major river of this route that connects the major portion of the southern zone to the central zone of the country through the waterway. Apart from these districts, Chattogram, Khulna & Shariatpur are also notable districts for the occurrence of accidents.

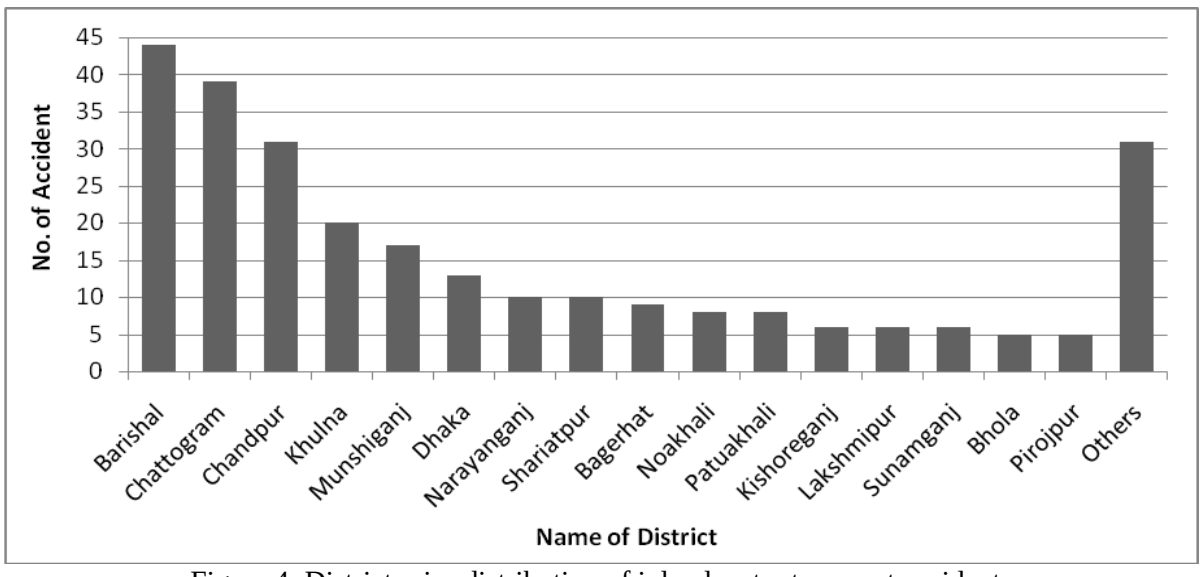

Figure 4: District-wise distribution of inland water transport accidents

4.5 Involvement of Vessel Types in Accidents

The distribution of types of vessel involved in the inland water transport accidents is shown in figure 5. It is revealed that most of the accidents take place due to the involvement of the cargo

vessels (28%). Apart from this, passenger vessels also share a considerable percentage (23%) in the accidents. The accidents involving oil tanker (5%) sometimes has caused a detrimental effect on the natural balance due to spillage of oil from the damaged ships. Trawlers & country boats are generally made for carrying a low volume of cargo together with carrying few numbers of passengers occasionally. The main purposes of using these boats are not specifically mentioned in the accident report form maintained by the government authorities. Therefore it is very hard to categorize these boats into a particular vessel type. The most important fact is that the types of 32% vessels are not mentioned in those reports. As a result, it has created a serious barrier for this analysis as the actual percentage of involvement of the vessels is not revealed from this section of the analysis. This drawback should be removed by improving the maritime accident investigation & documentation process.

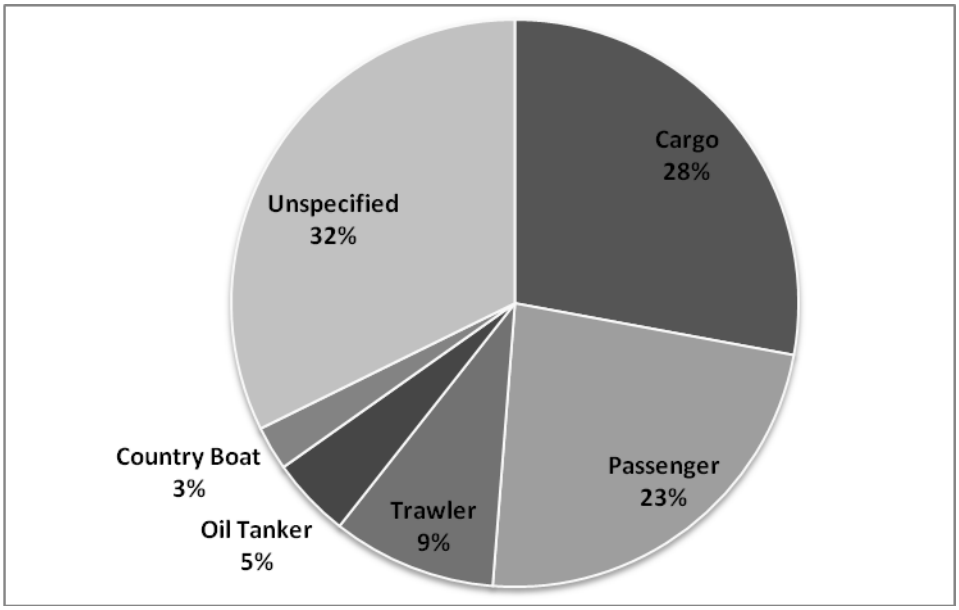

Figure 5: Distribution of vessel types

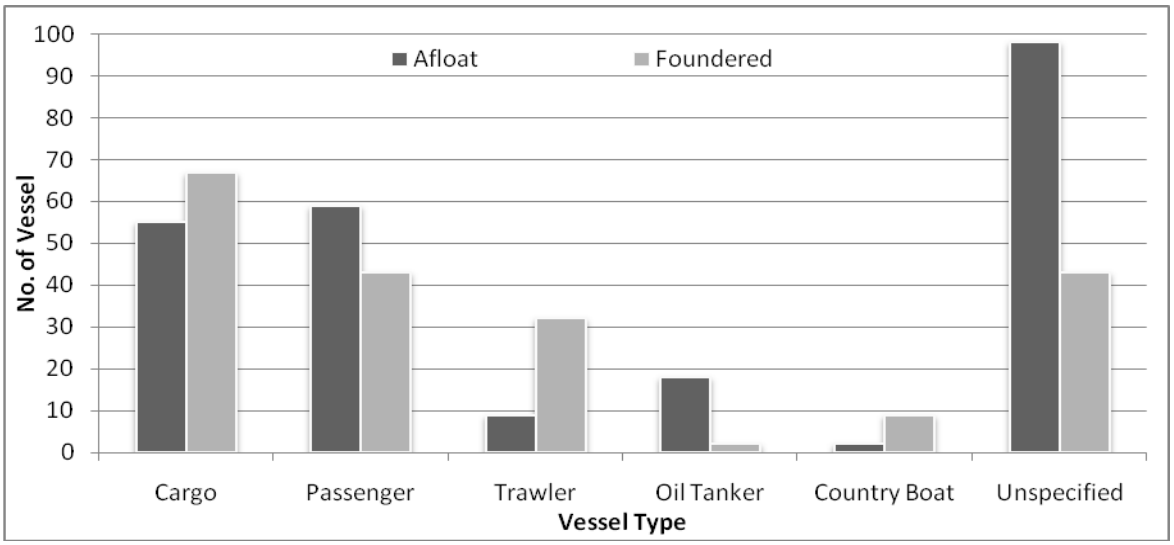

Figure 6: Distribution of the eventual condition of the vessels after the accident

4.6 Eventual Condition of Vessels after Accident

The distribution of the eventual condition of the vessels after the accident is illustrated in figure 6. It is observed that most of the cargo vessels are foundered after the accidents. Ultimately a huge loss of

cargo & valuable properties takes place due to these accidents. However, the number of passenger vessels that are foundered is higher in comparison to the afloat ones. In spite of this fact, it has been found during the analysis that foundering of the passenger vessels has caused the most significant loss of human lives. Besides, most of the trawlers & country boats are foundered after the accidents. The main reasons behind this fact are that as these types of boats are usually small in structure, have no proper lighting system and usually move in the overloaded condition. Moreover, in the case of collision, these boats are usually hit by the larger vessels. The oil tankers usually remain in afloat condition than being foundered after the accident. However, when these tankers remain in floated condition even after being collided with other vessels, spillage of oil takes place that causes severe impact on the environment.

5. CONCLUDING REMARKS

5.1 Research Findings

The research findings of the study can be summarized in the following way:

- Collision (57.8%) is the major cause of accidents in the inland waterways of Bangladesh.
- Most of the fatalities are involved in the collision accidents.
- Fatality constitutes the greater portion of overall casualties in the inland water transport accidents.
- The average fatality per accident ratio is higher for the accidents related to stormy weather and overload & stability failure.
- The waterway route of Dhaka to Barishal is the most vulnerable for the occurrence of accidents.
- The cargo vessel is the dominant type of vessels for maritime accidents.
- Most of the cargo vessels are foundered after the accidents.

5.2 Recommendations

On the basis of the above study the following recommendations can be made for ensuring the safety of inland water transportation system of Bangladesh:

- The availability of sufficient life-saving appliances should be ensured in all vessels to save the lives of the distressed people during any emergency situation. An important fact to be mentioned here is that there is still no law for keeping life jackets in the ships which is a matter of great concern. Therefore, immediate steps must be taken by the government authorities to issue new rules on this matter.
- Hazard analysis techniques should be applied to identify the underlying causal factors that are responsible for the occurrence of inland water transport accidents.
- The accident investigation & documentation process should be improved and relevant human resources should be trained up regularly. The recommendations of the accident investigation committees should be implemented within a very short period.
- The development of a standard maritime accident database is needed for analysis of accidents and to provide effective recommendations on the basis of the analysis.
- To check the fitness of the vessels, periodic & effective vessel survey should be conducted.
- The oil tankers should be constructed following the method of double-hull construction process to avoid spillage of oil after any accident. All existing single-hull oil tankers should be modified to the double-hull oil tankers.
- Maritime safety audits of all waterway routes, with special emphasis on the Dhaka to Barishal route should be conducted to ensure the safety of this popular route.
- The present search & rescue response mainly includes recovering the dead bodies and capsized or damaged vessels. Therefore, it should be improved so that human lives can be saved just after the occurrence of accidents.
- Adequate navigational aids should be fixed on the waterway routes to avoid accidents related to the collision.

- All unregistered vessels should be included in the registration process so that overall safety in the waterway can be ensured.
- Regular training programs should be conducted to enhance the skill of the masters, helmsmen, inland marine engineers, greasers, drivers & crews of the vessels.

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PERFORMANCE ANALYSIS OF OFF-STREET PARKING AND ON-STREET PARKING AROUND THE KHULNA CITY CORPORATION (KCC) KHULNA, BANGLADESH

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ABSTRACT

Khulna City Corporation (KCC) has a dense traffic which results in parking problems that are causing accidents and other uneven occurrences. 16 points were selected for detailed study in Khulna City Corporation (KCC), Khulna Bangladesh. Parking surveys were conducted to evaluate their parking index (efficiency) using both close and open-ended questionnaires. Parking index (efficiency) for ONP1, ONP2, ONP3, ONP4, ONP5, ONP6, ONP7, ONP8, ONP9, ONP10, ONP11, ONP12, were obtained as 95.42%, 68.61%, 65.28%, 73.615, 66.67%, 23.46%, 7.04%, 24.67%, 45.83%, 64.33%, 27.67%, 35.50%, OFP1, OFP2, OFP3 and OFP4 were obtained as 3.10%, 70.67%, 17.08% and 42.50%, respectively. Here ONP and OFP refer to On-Street Parking and Off-Street Parking respectively. The study shows that ONP6, ONP7, ONP8, ONP9, ONP11, ONP12, OFP1, OFP3 and OFP4 operated below the maximum capacity at parking index lower than 50%, while ONP1, ONP2, ONP3, ONP4, ONP5, ONP10 and OFP2 operated above the maximum capacity when compared with Policy 7 of the Parking Space Requirements in Parking Code Guidance 2012 of San Francisco Department of Transportation. Furthermore, 50%, 36% and 14% of the respondents affirmed that the existing facilities are not adequate, adequate and very adequate respectively. Inadequacy in parking signage and deficiency in enforcement by Management was observed. However, effective communication, parking enforcement, operational efficiency and provision of parking signage should be adopted in the study area.

Keywords: *Traffic, Parking index, Enforcement, Operational efficiency.*

1. INTRODUCTION

Parking, a fundamental component of the transport system, is a serious problem that antagonizes the urban planner and traffic engineer, as it plays a decisive role in the management of traffic and congestion extenuation (Joseph, 2016). The growing use of the automobile as a personal feeder service to transit systems "park-and-ride" has also increased the demand for parking spaces at transit stations. In areas of high density, where space is very expensive, the space provided for automobiles usually has to be divided between that allocated for their movement and that allocated for parking them. Providing adequate parking space to meet the demand for parking in the KCC may necessitate the provision of parking bays along curbs which reduces the capacity of the streets and may affect the level of service (LOS). Before any measure for the betterment of the conditions can be formulated, basic data pertaining to the availability of parking space, extent of its usage and parking demand are essential. It is the responsibility of the planner to provide proper parking space in the KCC area within possible shortest distance from the individual business or commercial shops. Because flexibility of parking space is desirable in any city center or central business district as because this place is the mostly traffic gathered area. Parking of vehicles is an integral part of the KCC area. Parking demand is particularly high in KCC area because of intense commercial activities. On-street parking and illegal occupants are mainly responsible for traffic congestion in Khulna city (Ahmed, 2012). Improper parking facilities decrease the effective width of roads or reduce the traffic flow capacity of roads and cause congestion. In the KCC area of Khulna city, it is a common feature that many motorized and non-motorized vehicles are parked in the main point or intersection of Dakbanglow that creates heavy traffic congestion. It also creates delay of the passengers and the pedestrian and causes a great loss in the economy and hampers the normal life cycle. So management of parking is an important issue for the urban area, especially, in KCC.

2. OBJECTIVES

The Specific objectives of the study are given below:

a. To find out the places around KCC, Khulna area with their capacity, location and cross sectional area.
b. To categorize the selected places in two parts commercial & Residential.
c. To recommend initiative to make those Commercial & Residential places to a suitable and working parking Space.

3. STUDY AREA

Khulna the south-western divisional city in Bangladesh is situated between 21.38' and 23.1' north latitude and 88.58 east longitude and is 12 ft above mean sea level. According to the census of 2011, Khulna city area of 4394.45 sq km, and 24,07,678 respectively. List of the parking location are given below:

1	Save & Safe New Market, Khulna (Commercial).
2	New Market, Gate #1, Khulna (Commercial).
3	New Market, Gate #2, Khulna (Commercial).
4	New Market, Gate #3, Khulna (Commercial).
5	Gollamari Bus Stand Out Side of (Auto Stand), Khulna (Commercial).
6	Save and Safe Daulatpur (East), Khulna (Commercial).
7	Save and Safe Daulatpur (West), Khulna (Commercial).
8	Hotel Castle Salam, Khulna (Commercial).
9	City Medical Collage Hospital, Moylaputa, Khulna (Commercial).
10	Hadis Park Khulna Lake (South Gate), Khulna (Commercial).

11	Hadis Park Khulna Lake (North Gate), Khulna (Commercial).
12	Dak Bangla Mor, Khulna (Commercial).
13	Rail Way Station, Khulna (Commercial).
14	Sib-Bari Mor (Toymur Center), Khulna (Commercial).
15	Sonadanga Residential Area, Khulna (Residential).
16	Western Inn International Ltd, Khulna (Commercial).

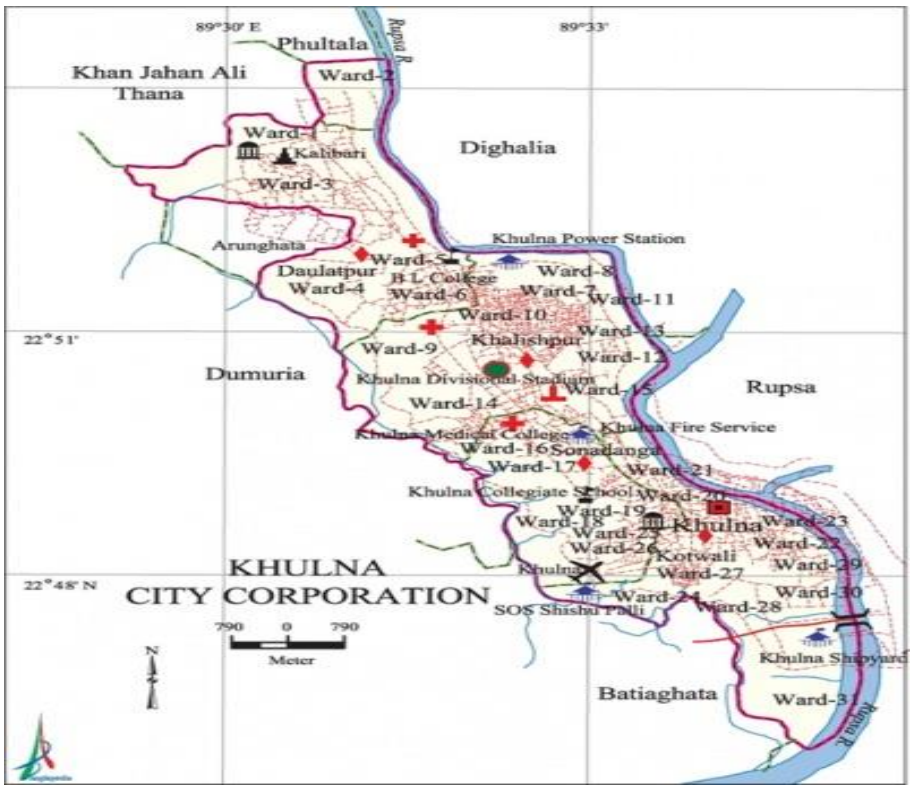

Figure 1: Khulna City Cooperation Area Map.

4. METHODOLOGY

This part is subdivided into 3 (Three) major parts.

(a) Population and Sample
(b) Constructs and Measurements
(c) Analytical Approach.

4.1 Population and Sample

The Study areas are Save & Safe New Market, New Market, Gollamari Bus Stand Out Side of (Auto Stand), Save and Safe Daulatpur, Hotel Castle Salam, Western Inn International Ltd, City Medical Collage Hospital Moylaputa, Hadis Park, Dak Bangla Mor, Rail Way Station, Sib-Bari Mor, Sonadanga Residential Area Khulna. Khulna city area of 45.65 sq km, and 1500000 people respectively. It's situated between 21.38' and 23.1' north latitude and 88.58 east longitude and is 12 ft above mean sea level. The sample size has been determined by using Solven's formula-

Number of sample: $\frac{N}{(1+N.e^2)}$ (Altares, 2003)

Where, e = Accuracy parentage, N= Number of users

4.2 Constructs and Measurements

Following the reconnaissance survey of the study area, four parks around the KCC shown in Figure 1 were selected for detailed study. The parks were as coded and shown while license plates 1 to 16 shows typical scene at the point. The primary data were obtained from well-structured questionnaires and personal interview while the parking surveys were conducted between 8a.m and 5p.m. License plate method of survey was adopted, so in this case of survey, every parking stall was monitored at a continuous interval of 15 minutes or so and the license plate number was noted. This gave the data regarding the duration for which a particular vehicle was using the parking.

4.3 Analytical Approach

To analysis of off-street & on-street parking for residential area, off-street & on-street parking for Commercial area Parking Accumulation, Accumulation, Occupancy, Average Parking Index % to implement this Formula and use Microsoft Office Excel,

a. Parking Index (Efficiency) = (Accumulation / parking capacity) * 100……...…… (1)
b. Accumulation=Initial count+ no. of entering vehicles−minus the no. of exit vehicles……. (2)
c. Average Parking Index % = (Total Parking Index/Number of Time Interval…… (3)
d. Average Accumulation = (Total Accumulation / Number of Time Interval)……..……. (4)

5. RESULTS AND DISCUSSION

Different type of data such as Parking Capacity, cross sectional area, use characteristics of place, Number of Vehicles Parked inside the Parking Lot, accumulation, occupancy, etc. was collected from the selected 16 station and then the calculation was done through process which is shown in methodology. Different type of result is given below which is obtained from field survey.

Table 1: Table shows the on street and off-street parking place there parking capacity, cross sectional area and location and use characteristics of place.

No	Point Name	Capacity	Area (m^2)	Location	Park Use Characteristics
1	Save & Safe New Market, Khulna.	40	18.55	New Market, Khulna.	Commercial, Truck Parks
2	New Market, Gate #1, Khulna.	60	92.76	New Market, Khulna.	Commercial, Truck Parks.
3	New Market, Gate #2, Khulna.	60	92.76	New Market, Khulna.	Commercial, Truck Parks,
4	New Market, Gate #3, Khulna.	60	185.52	New Market, Khulna.	Commercial, Truck Parks,
5	Gollamari Bus Stand Out Side of (Auto Stand)	20	92.76	Gollamari Bus Stand.	Commercial, Truck Parks,
6	Save and Safe Daulatpur (East), Khulna.	200	83.48	Save and Safe Doulutpur.	Commercial, Truck Parks,
7	Save and Safe Daulatpur (West)	200	83.48	Save and Safe Doulutpur	Commercial, Truck Parks,
8	Hotel Castle Salam, Khulna.	50	148.42	Royal Mor, Khulna	Commercial, Truck Parks,

No	Point Name	Capacity	Area (m^2)	Location	Park Use Characteristics
9	City Medical Collage Hospital, Moylaputa.	50	139.14	Moylaputa, Khulna.	Truck Parks, and Residential.
10	Hadis Park Khulna Lake (South Gate)	50	102.04	Hadis Park Khulna	Commercial, Truck Parks,
11	Hadis Park Khulna Lake (North Gate)	50	111.31	Hadis Park Khulna	Commercial, Truck Parks,
12	Dak Bangla Mor, Khulna.	50	278.29	Dak Bangla Mor	Commercial, Truck Parks,
13	Rail Way Station, Khulna.	1000	6261.5	Rail Way Station, Khulna	Commercial, Truck Parks,
14	Sib-Bari Mor (Toymur Center), Khulna.	50	148.43	Sib-Bari Mor	Commercial, Truck Parks,
15	Sonadanga Residential Area, Khulna.	20	143.78	Sonadanga, Khulna.	Residential.
16	Western Inn International Ltd, Khulna.	30	27.82	Bangladesh Bank Mor,	Commercial, Truck Parks,

5.1 The graph of Parking Accumulation & Parking Index

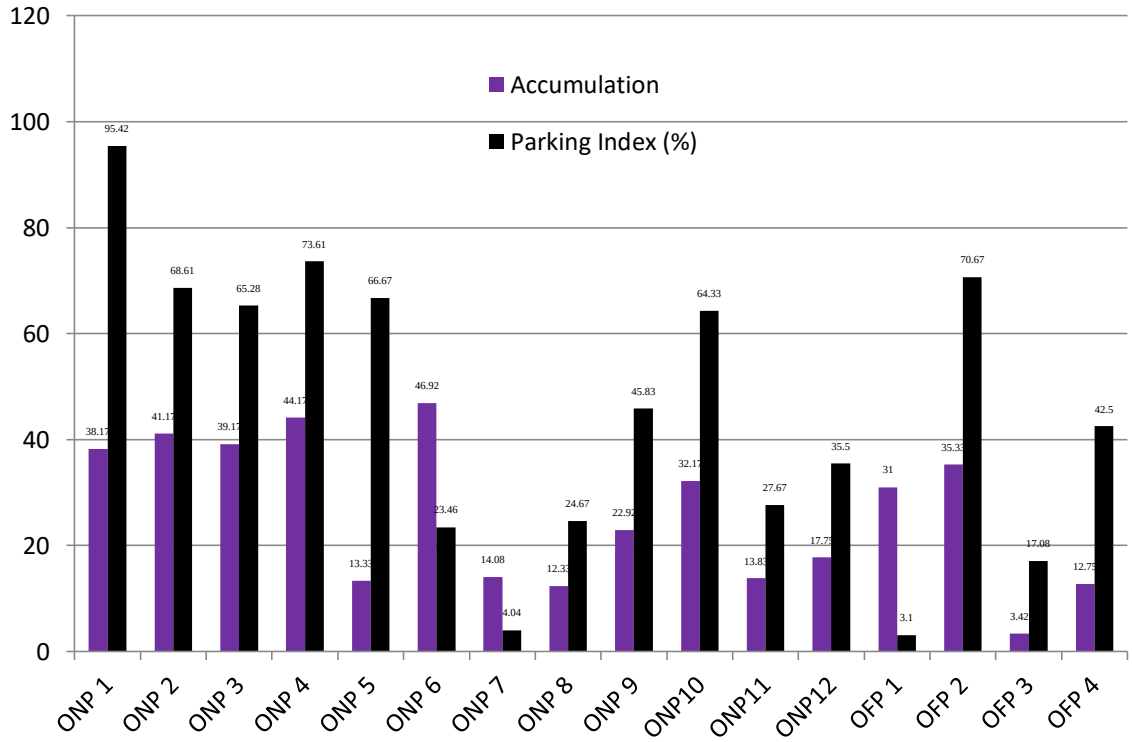

Figure 2: The graph of accumulation & parking index.

The Blue color in Figure 2 indicates average parking accumulation for on street parking (ONP) & off street parking (OFP). The average parking accumulation of On-Street Parking (ONP) is ONP1, ONP2, ONP3, ONP4, ONP5, ONP6, ONP7, ONP8, ONP9, ONP10, ONP11, ONP12 obtained as 38.17%, 41.17%, 39.17%, 44.17%, 13.33%, 46.92%, 14.08%, 12.33%, 22.92%, 32.17%, 13.83%, 17.75%, & off street parking (OFP) is OFP1, OFP2, OFP3, OFP4 obtained as 31.00%, 35.33%, 3.42%, 12.75%. The color Green in Figure 2 indicates average parking index for on street parking (ONP) & off street parking (OFP). The green color indicates average parking accumulation for on street parking (ONP) & off street parking (OFP). The Average Parking Index of On-Street Parking (ONP) is ONP1, ONP2, ONP3, ONP4, ONP5, ONP6, ONP7, ONP8, ONP9, ONP10, ONP11, ONP12 obtained as 95.42%, 68.61%, 65.28%, 73.615, 66.67%, 23.46%, 7.04%, 24.67%, 45.83%, 64.33%, 27.67%, 35.50%, & off street parking (OFP) is OFP1, OFP2, OFP3, OFP4 obtained as 3.1%, 70.67%, 17.08%, 42.5%.

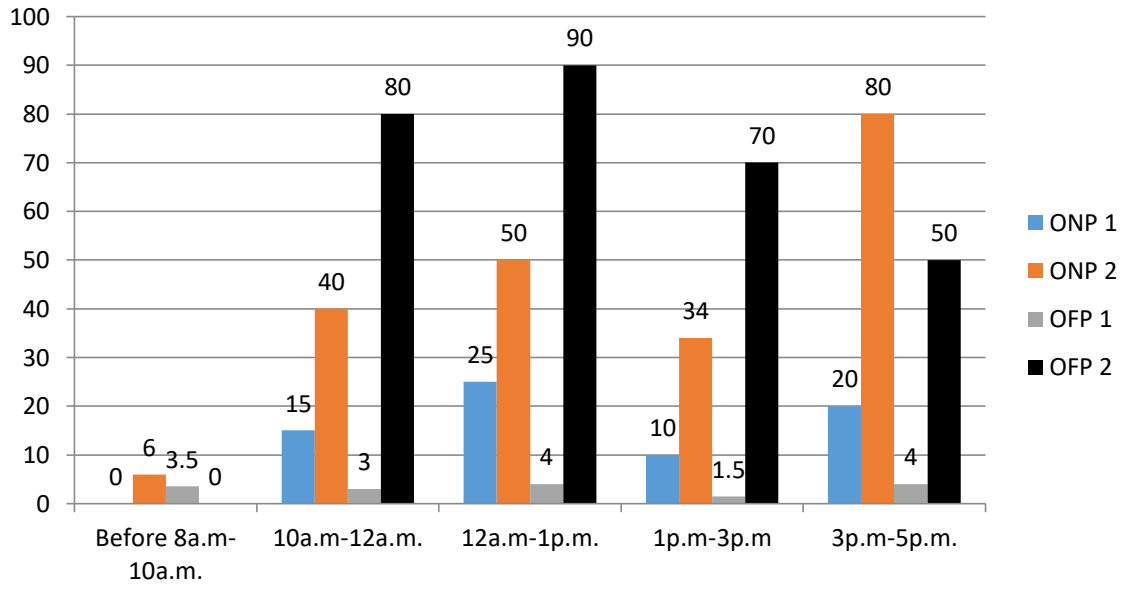

Figure 3: Parking Accumulation of ONP & OFP

Summary of Parking Accumulation in Figure 3 for ONP1, ONP2 & OFP1, OFP2 time duration before 8a.m to 10.00a.m obtained as 0, 6, 3.5, 0; 10a.m to 12a.m obtained as 15, 40, 3, 80; 12a.m to 1p.m obtained as 25, 50, 4, 90; 1p.m to 3p.m obtained as 10, 34, 1.5, 70; and 3p.m to 5p.m obtained as 20, 80, 4, 50.

5.2 Graph for On Street Parking

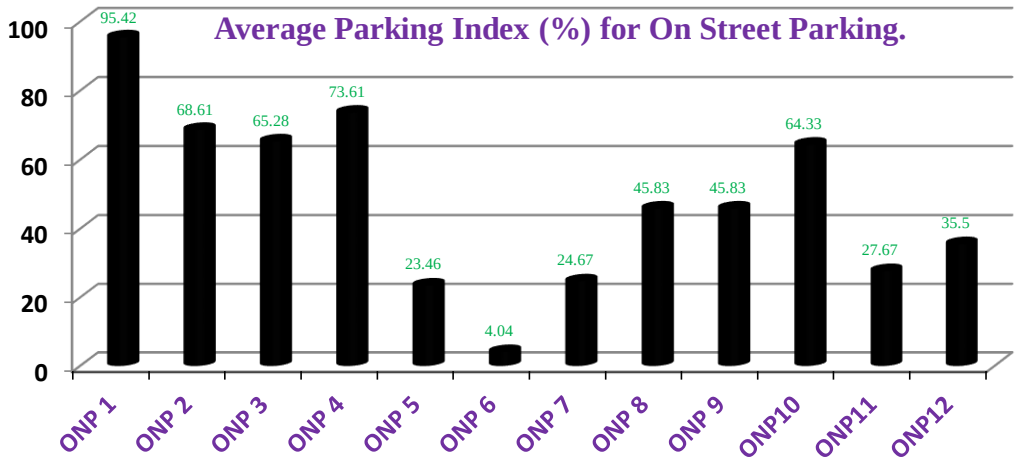

Figure 4: Average Parking Index (%) Graph for On Street Parking.

Figure 4 shows On Street Parking Average Parking Index the maximum parking Index is Save & Safe New Market (ONP1) 95.42% and the minimum parking Index Save & Safe Daulatpur (East) (ONP6) 4.04%

5.3 Graph for Off Street Parking

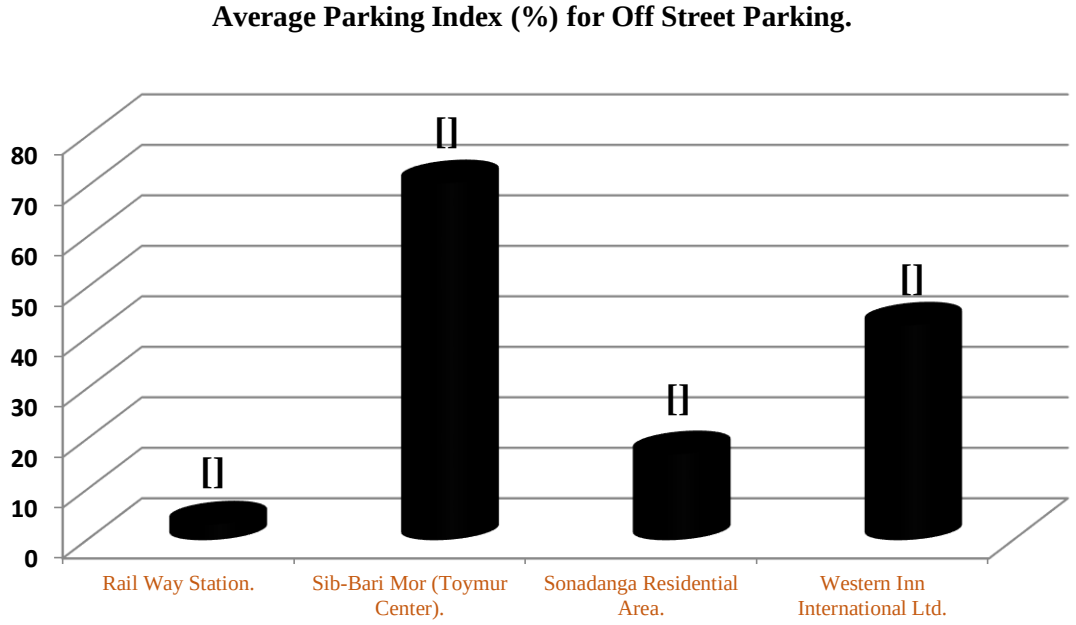

Figure 5: Average Parking Index (%) Graph for Off Street Parking.

Figure 5 shows Off Street Parking Average Parking Index the maximum parking Index is Sib-Bari Mor (Toymur Center), Khulna 70.67% and the minimum parking Index Rail Way Station Khulna is 3.1%

5.4 Graph of Parking Capacity in the Study Area

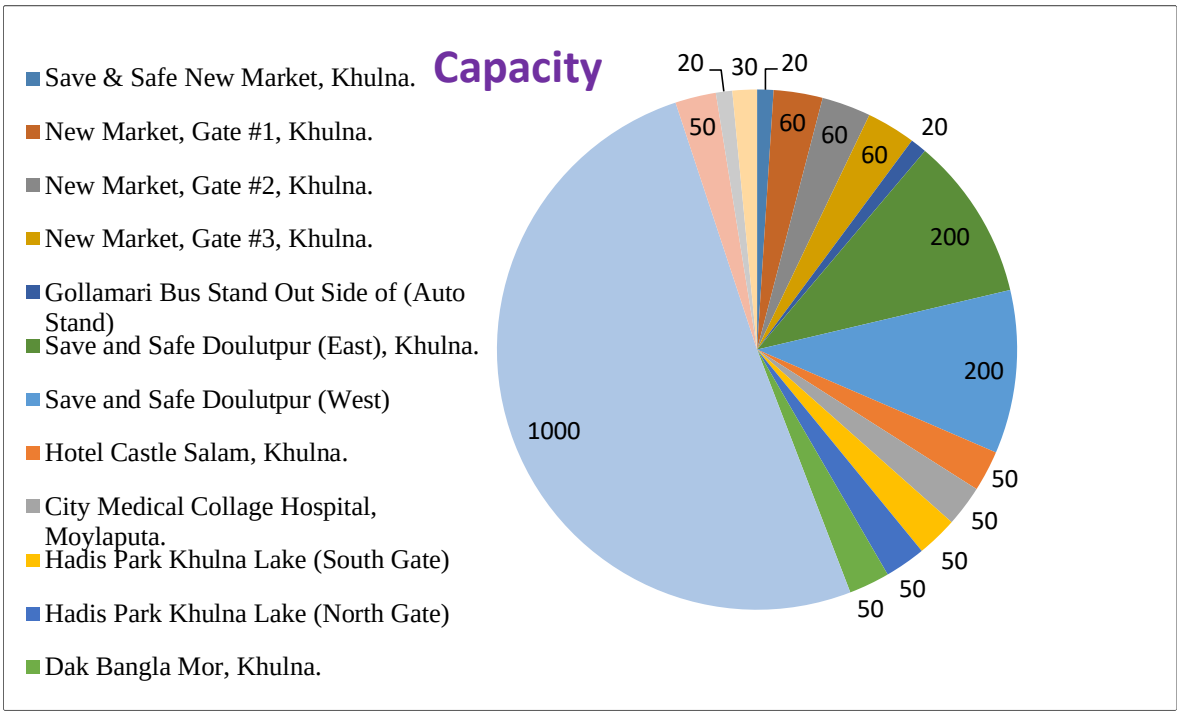

Figure 6: Parking capacity for the study area in KCC.

5.5 Analysis from Users' Perspectives

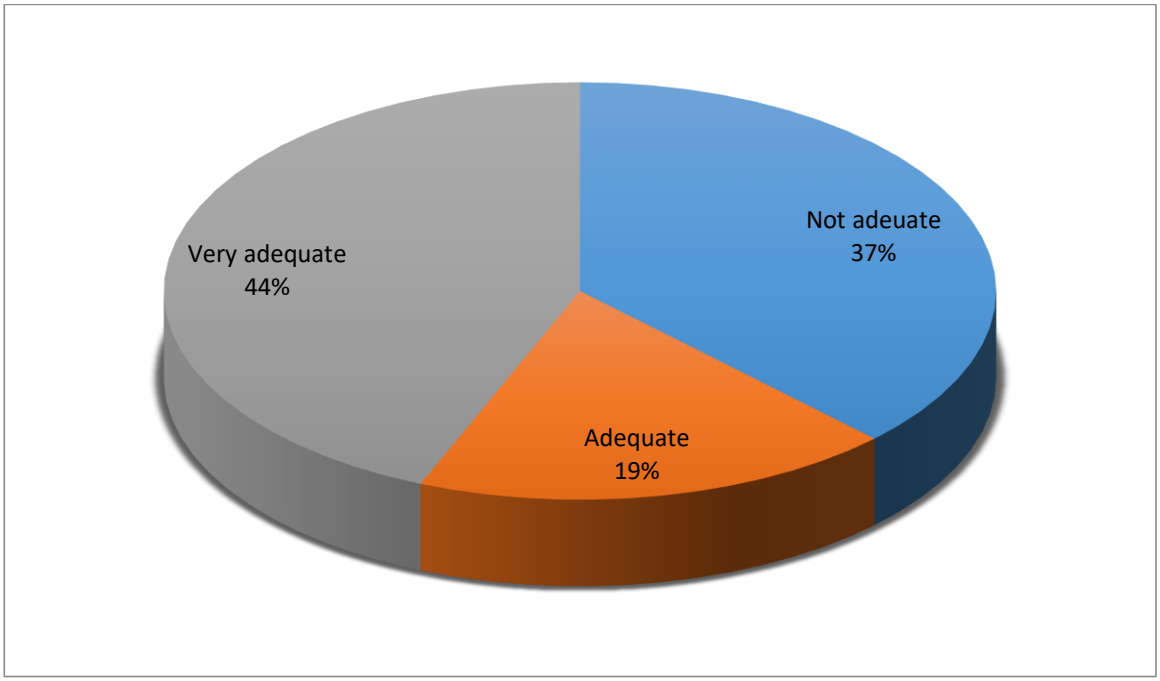

Figure 7: Adequacy of the Parking Spaces.

Figure 6 shows the parking capacity of various points of study area and Figure 7 is the representation of the user perspective of the parking. Figure 4.6 shows that 44% of the respondents affirmed that the facilities are not adequate, while 19% are of the opinion that it is adequate, and 44% believed it is very adequate.

6. CONCLUSIONS & RECOMMENDATION

6.1 Conclusions

a. The average parking accumulation of Sonadanga Residential Area, Khulna (Residential) parking accumulation is 3.42; New Market, Gate #2, Khulna (Commercial) parking accumulation 39.17 and City Medical Collage Hospital, Moylaputa, Khulna (Commercial) 22.92.
b. The average parking index of Sonadanga Residential Area, Khulna (Residential) parking accumulation 17% ; Gollamari Bus Stand Out Side of (Auto Stand), Khulna (Commercial) 23.46% ;Sib-Bari Mor (Toymur Center), Khulna (Commercial) parking accumulation 70.67%.
c. The average parking occupancy of Sonadanga Residential Area, Khulna (Residential) parking accumulation 17.3% ; Rail Way Station, Khulna (Commercial) 3.1% .

6.2 Recommendation

a. Residential Parking's have not Sufficient Parking Space & Security. So the owner may take specific measure regarding that.
b. The Garages are very small for the Residential Parking system that is hampering the regular work. So the space can be enlarged.
c. Now a day the Residential Area are associated with rent of the school & office that causes huge amount of problem in parking vehicles. So the owner of Building should avoid the rent the school & office.
d. There is not Sufficient Parking Space to the Commercial Building. So they should increase the more parking spaces. Or they can use the Multiple Vertical Space Parking System. Because this system can park many vehicles.
e. KCC should take initiative to illegal parking and increase awareness among people in the city.
f. The illegal parking in many intersection and roundabout in places like Shibabri and Royal mor, Moyla pota mor should be taken under the regulation with the help of law enforcing agencies.

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SOCIO-ECONOMIC IMPACT OF TRAFFIC CONGESTION –A CASE STUDY OF CHITTAGONG CITY

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ABSTRACT

In modern period, traffic problem is one of the most challenging and complex issues in major cities. Chittagong city, commercial capital of Bangladesh is not escaped from this problem. Due to the rapid growth of population and industrialization, the city has been extended exponentially without proper planning. As a result, there has been a disproportion between traffic supply and demand, which leads to intolerable traffic flow problems. Traffic congestion is one of the impediments for the efficient of a road network. It results in massive delays, a decrease in productivity and a bad impact on overall economic growth. Hence, the present study is to find out the pivotal causes of traffic congestion at Chittagong city. It also includes the ill-effects due to traffic congestion and possible remedial measures of traffic jam. Physical observations have been done at different intersections in Chittagong city and identified the causes regarding traffic congestion such as illegal parking on street, unplanned stoppage on road, excessive vehicles of different speed on the same road, road development activities & traffic mismanagement etc. It has also been continued through field investigation for space occupied by illegal parking, social survey and satisfaction report. Due to traffic congestion, ill impacts on the environment, health, social life, economy, and communication systems have been determined. Finally, from the result of the study, some remedial measures have been proposed to achieve effective traffic movement.

Keywords: *Traffic congestion, Chittagong city, Index of satisfaction, Bad impacts, Measures.*

1. INTRODUCTION

Urbanization, a global phenomenon, is taking place rapidly in the developing countries like Bangladesh. Rapid growth of urbanization and industrialization have brought about extreme levels of traffic congestion within the country. Bangladesh is the 10th most densely populated country in the world having 1152 people per square kilometer (World Population Review 2018). As a result, to cope with the growing public demand, number of traffic is increasing exponentially day by day. Now a days, the traffic problem has become a talk of the town and sensitive issue to the living people of Bangladesh (K.D.A, 2008). According to the Osman (2010), traffic congestion eats up around 5 million working hours every day and causes an annual loss of USD 03 billion. A developing nation like Bangladesh cannot bear up the huge losses stemmed from this severe traffic problem (Naznin at. el., 2010).

Chittagong city is not only the principal city of Chittagong division but also the second largest city of Bangladesh. The total population of Chittagong city is near about 6 million. As a result, large number of various vehicles are increasing rapidly due to expansion of urbanization, commercial activities and industrial development in the city (BBS 1981, 1991). Day by day vehicles are increasing very fast in this city but the transport network of this city is not expanding as per the population growing and demand. This expiation of population converts the dwellers life to stagnant situation during the rush hours of morning and evening owing to traffic gridlock. Some problems have been identified in the congested areas.

When buses and trams are stuck in traffic jams they fall behind schedule and this means that more people will be waiting at the next stops, they fall even further behind schedule leading to bunching and compounding delays (Jain & Vazirani, 2010). A common scene of huge traffic jam in Kaptai Rastar Matha in Chittagong has been shown in Figure 1a.

Wasted fuel increases air pollution by emitting Carbon-di-oxide and other poisonous gases (Levi et al., 2010). The noise pollution causes stress in most people and lead to many life-threatening medical conditions such as cardiovascular diseases and blood pressure related ailments. Emission from a private microbus has been shown in Figure 1b.

Disruption of traffic movement arises due to traditional water logging problem caused by tidal flow or heavy rainfall. Normal traffic movement is hampered creating traffic jam in Hat-Bazar area and people lose their valuable time that can be easily understood by Figure 1c.

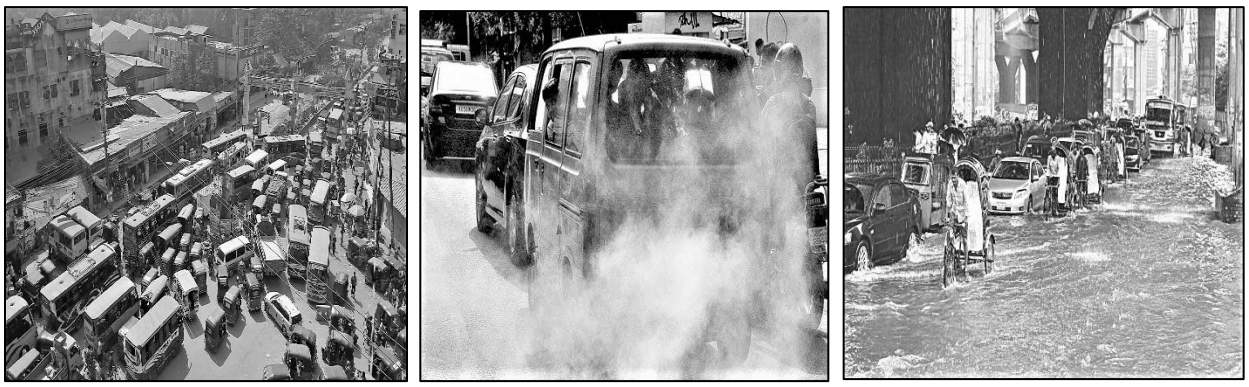


Figure 1a, 1b, 1c: Different sorts of problems faced by road users during traffic congestion

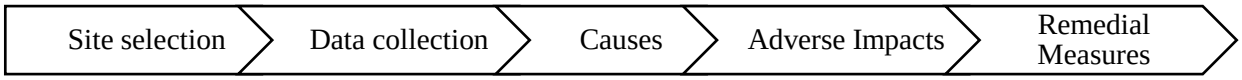
Therefore, this study tries to find out the causes and effects of traffic jam in major intersection points of Chittagong city and how it can be managed from the road user's perspective. The following research question guided this study (Agyapong & Ojo, 2018):

1. What are the main causes of traffic jam in Chittagong city?
2. What do you think about the degree of congestion in the city?
3. What are the bad impacts of traffic congestion in Chittagong city? and
4. Which period traffic congestion is mostly occurred in the city?

Studies will help improve on controlling traffic congestion in the big cities in Bangladesh and play a major impact on policy making. The findings of this studies might help to drivers, pedestrians, shoppers, and traders in the city. It will help explain the major causes of traffic jam and provide some remedial measures for managing this problem.

2. METHODOLOGY

The whole methodology of the study can be divided into a number of steps which can be summarized as cited in the following flow chart:



2.1 Site Selection

Chittagong is the principal seaport of the country. It is estimated population about 6 million, male 50.4%and female 49.6%. At present traffic jam is a common scenario in Chittagong city. The city people are suffering much due to traffic jam. Local people have regularly experienced traffic jam on most of the city roads, including New Market, Bahhadarhat, Chawk Bazar, Andarkilla, Agrabad, Terri Bazar, Dewanhat, Muradpur, 2 no gate and Jamal Khan mainly between 9:00am and 11:00am and between 4:00pm and 6:00pm. So, our physical investigation such as social survey, loss of time calculation etc have been done in these important intersection point.

2.2 Data Collection Procedures

The research consists of both primary and secondary data. Primary data were collected from reconnaissance survey and field survey. On the other side, secondary data were gleaned from various sources on overall status of traffic condition. For the primary source of the information, 200 questionnaires were surveyed in the study area with a questionnaire prepared on the basis of different aspects of traffic congestion after through study of relevant literature. Tabulation and data processing were done both by the hand and computer by using MS Excel. Finally, collected data were analyzed and presented tabular format.

2.3 Selection of the Individual Respondents

In the present study respondent are three types such as passengers 44.67 %, pedestrian 34 % and driver 21.33 %. Age structure of the respondents, young and middle aged (15-49 age structure) group are 77.33 % on the other hand 22.67 % respondents are old aged (46-60 age structure) group.

2.4 Index of Satisfaction

To determine the limit of satisfaction and dissatisfaction of the causes of traffic congestion variables by the respondents, the following satisfaction index developed by Hall, Yen and Tan (1975) is selected

$$Is = (fs-fd)/N \quad (1)$$

Where, Is = satisfaction Index, fs = Number of Satisfied Respondents, fd = Number of dissatisfied Respondents, N = Total number of Respondents

For this satisfaction index, *Is* = +1, meaning highest level of satisfaction and *Is*= -1, meaning highest level of dissatisfaction. In these cases, the negative index of satisfaction was taken to select causes of traffic congestion.

The above satisfaction index has been previously used by Hossain, 1995, Hasan, 1999, Rahman and Islam, 2001 to determine the satisfaction index of respondents of various income groups.

2.5 Loss of Time

During the calculation of loss of time, average journey time and average journey speed are required. For calculating average journey speed (V) we used the following formula:

$$V=d/\bar{t} \quad (2)$$

Where, d =total distance, $\bar{t}$ =average journey time

3. 3 PHYSICAL INVESTIGATION

3.1 Causes of Traffic Congestion

Most of the people believe that traffic congestion is mainly happened due to the increasing rate of population growth. In reality there are several other reasons behind this problem. These are following-

- ✓ Unplanned stoppage and Parking shown in Fig 2a
- ✓ Traffic rules violation by the road users.
- ✓ Carelessly placing construction materials on road shown in Fig 2b
- ✓ Water logging and dumping of waste materials on streets
- ✓ Inadequate traffic management and inefficient traffic police
- ✓ Lack of knowledge of driving and proper training
- ✓ Closure of one way road without any notice which is shown in Fig 3a
- ✓ Motorized and non-motorized vehicles on the same road shown in Fig 3b
- ✓ Queuing of CNGs and cars on the roads
- ✓ Lack of foot over bridges and under passes and unused of foot over bridges

Figure 2a, 2b: Traffic mismanagement due to illegal parking and construction materials on road


Figure 3a, 3b: Traffic jam owing to road closing and vehicles variation on same road respectively

3.2 Adverse Impacts of Traffic Congestion

The bad impact of traffic congestion on Chittagong City can be discussed in three ways. They are –
a. Impact on Economy
b. Impact on Health
c. Impact on Environment

3.2.1 Impact on Economy

Traffic congestion causes an adverse impact on economy in Chittagong city. For this traffic congestion, a huge amount of money is being daily compensated in many ways-

- Losing working-hours
- Extra transportation cost
- Vehicle operating and maintenance cost
- Extra fuel cost
- Miscellaneous cost

Two investigations have been done at between Bahaddarhat and Barik building, Bahaddarhat and New market to find out the percentage of loss of time as well as working hour that causing impact on our economy.

Table 1: Determination of Journey speed and Running speed between Bahaddarhat and Barik Building

Origin	Destination	Distance (km)	Travel time(sec)	Delay time(sec)	Journey speed(kmph)	Running speed(kmph)
Bahaddarhat	Muradpur	1.1	238	18	16.68	18.0
Muradpur	2 no gate	1.1	1100	730	3.6	10.70
2 no gate	GEC	0.9	202	11	16.04	16.96
GEC	WASA	1.0	171	21	21.05	24.0
WASA	Tigerpss	1.1	180	46	22.0	29.6
Tigerpass	Agrabad	1.7	370	79	16.54	21.03
Agrabad	Barik building	0.85	116	8	27.40	28.33

Table 2: Determination of Journey speed and Running speed between Bahaddarhat and New market

Origin	Destination	Distance (km)	Travel time(sec)	Delay time(sec)	Journey speed(kmph)	Running speed(kmph)
Bahaddarhat	Chawk bazar	1.6	401	105	14.40	19.5
Chawk bazar	Andarkilla	1.8	393	92	16.50	21.53
Andarkilla	Katwali circle	1.0	298	1089	12.1	18.95
Katwali circle	New market	.55	114	32	17.40	24.12

The local transport speed in city is not more than 40 kmph whereas we have mostly found the speed of the vehicles between 15-25 kmph. So, the percent loss of time in city is given below.

Table 3: Percent of loss of time

Junction	Distance (km)	Local vehicle speed (kmph)	Local vehicle journey time(min)	Average journey speed (kmph)	Average journey time(min)	Loss of time (min)	Percent loss of time (%)
Bahaddarhat-Barik building	7.75	40	11.63	17.75	26.2	14.57	55.6
Bahaddarhat-New market	4.95	40	7.43	15.1	19.2	11.77	61.3

So, it is seen that 50-60% of time loss due to traffic congestion of a person. It causes a great impact in our economy.

3.2.2 Impact on Health

Traffic congestion has a negative health impact on the city dwellers. General people suffer from many problems such as headache, mental stress, breathing problem, tiredness, eye-sight problem, heart disease, dehydration, hearing complexity, dust allergy, suffocation, and respiratory complication. Besides, vehicles operators are also getting into trouble of some other problems such as- back-pain, excessive breathing and sweating etc.

3.2.3 Impact on Environment

Traffic jam is also accountable for environmental contamination. Due to traffic congestion, environment is polluted in different ways such as noise pollution, air pollution, water pollution etc. Air pollution is mainly triggered by traffic jam. The vehicles get struck in the congestion and at that time vehicles emit gases like COx, SOx, NOx etc. These gases are liable for air contamination. Noise pollution is considered as one of the major threatening issues in urban areas. It is seen that the large number of vehicles is being struck on the roads for a long period of time. As a result, they use horn more and more to get of this problem.

3.3 Social Survey Report

Social survey is based on through questionnaires among the road users including passengers, pedestrians and drivers. These survey works are categorized in five different ways such as major causes of traffic jam, degree of congestion, time variation of congestion, different problems created by traffic jam, satisfaction levels on traffic jam which are shown in the following tables.

Table 4: Major causes of traffic congestion in the study area

Type of Causes	Frequency	Percentage	Rank
Illegal parking and Stopage	63	31.5	1
Absence of traffic law enforcement	42	21.0	2
Road construction around the year	34	17.0	3
Absence of signaling system	19	9.50	4
Lack of driver's training and over taking tendency	16	8.0	5
Different speed vehicles in the same road	14	7.0	6
Absence of footpaths and planned road network	12	6.0	7
Total	200	100	

Table 5: Degree of congestion in Chittagong city

Degree of congestion	Frequency	Percentage(%)
Heavy	105	52.5
Moderate	74	37.0
Light	21	10.5
Negligible	0	0.0
Total	200	100.0

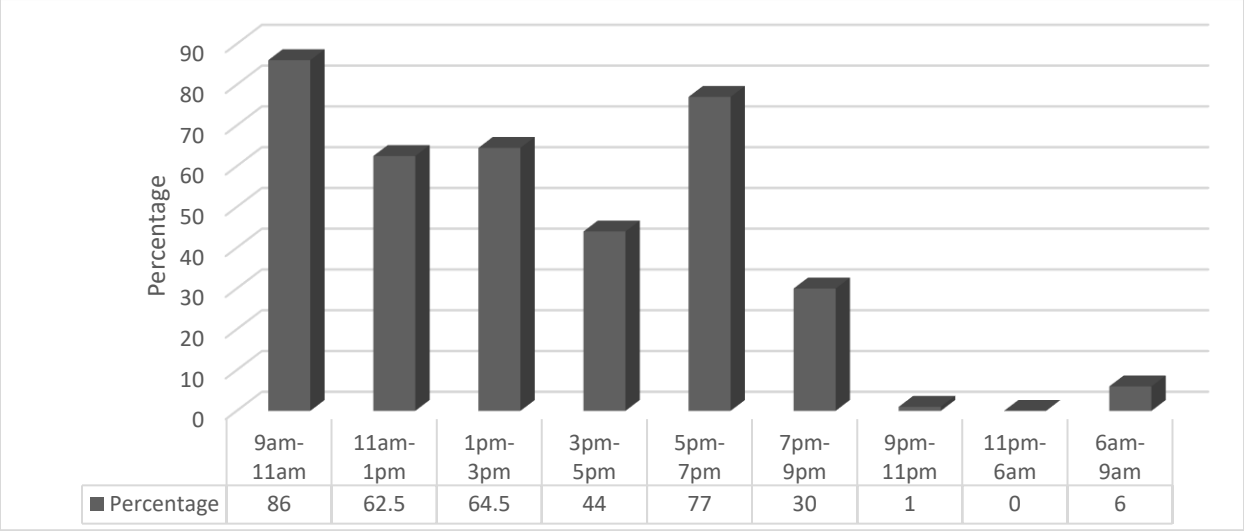


Figure 4: Time variation of traffic congestion in Chittagong

From the above figure, 86 % of participator of the survey thinks that traffic congestion is mostly occurred during the office hour between 9am -11am. It also happens severely returning from office between 5pm-7pm. Besides, Chittagong city is the port capital city of our country. Various vehicles like truck, container and heavy lorry are incoming 7 outgoing in 5pm to 7pm time schedule. At this time, traffic volume on roads is maximum.

Table 6: Different problems created due to traffic congestion in Chittagong city

Nature of problem	Frequency	Percentage
Air pollution	183	91.5
Noise pollution	162	81.0
Waste of time	158	79.0
Waste of Money	129	64.5
Water pollution	117	58.5
Accident	95	47.5

Table 7: Satisfaction level and ranking on traffic congestion in Chittagong city

Usable system	Satisfactory (%)	Averag (%)e	Unsatisfactory (%)	Index of Satisfaction	Ranking
Road surface	19.5	48.5	32.0	-0.125	1
Traffic signals	8.5	57.5	34.0	-0.255	2
Traffic signals and marking	26.0	52.5	52.5	-0.365	3
Adequate traffic police	20.5	28.5	51.0	-0.305	4
Trained drivers	14.5	40.0	45.5	-0.31	5
Adequate footpath	15.5	33.5	51.0	-0.36	6
Road width	15.5	32.5	52.0	-0.365	7
Pedestrians facilities	15.5	32.0	52.5	-0.37	8
Enforcement of traffic rules	16.0	30.0	54.0	-0.38	9
Parking facilities	10.5	33.5	56.0	-0.46	10

All of the criteria involving transportation system and management of the study area are unsatisfactory. Among them, the worst condition was for parking facilities (-0.46) followed by enforcement of traffic rules (-0.38) and pedestrians facilities (-0.37). On the other hand, relatively better condition was for road surface (-0.125). So, it can be expressed that the overall quality of transportation system in the study area is not satisfactory.

4. CONCLUSIONS AND RECOMMENDATION

From the study, it can be concluded that the ranked causes of traffic jam are mainly illegal parking and stoppage, absence of traffic law enforcement, lacking of coordination between road construction authorities, absence of signaling system etc. The effects of traffic jam are mainly indispensable loss in productivity, huge contamination in environment, time-consuming and adverse consequences on human health etc. Now time has come to take integrated planning, implementation and management of traffic system. Some specific recommendations for reducing traffic congestion from the Chittagong city are given bellow.

- ✓ Since the satisfaction index for parking facilities is maximum shown in Table-, it's the foremost duty to stop the parking of vehicles here and there and to provide sufficient specific parking area surrounding the city.
- ✓ The above study indicates that there is deficiency of proper footpath for pedestrian's movement. So adequate number of footpath has to be constructed along with the major roads in the city.
- ✓ Most of the traffic jam occur between 9-11 am during office hour shown in Fig 4. So different organization might follow different time schedule to disperse the traffic volume on roads in different time interval.

- ✓ Since there is not sufficient number of traffic police at the most intersection point on the roads, movement of traffic cannot be controlled strictly. So presence of adequate number of police has to be ensured at major intersection points.
- ✓ Moreover, some measures such as creation of public awareness, inception of public transport service, execution of traffic rules and regulation strictly, decentralization, banning of unauthorized parking etc. can reduce the problem to a great extent.

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A REVIEW OF MOTORCYCLE SAFETY SITUATION IN BANGLADESH

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ABSTRACT

Like the other Asian countries, the increase in motorcycle crashes and consequent fatalities in Bangladesh is a growing problem resulting from the massive increase of motorcycles. Of over 2.9 million of registered motor vehicles, motorcycles represent almost 65% in the country. This high percentage is the direct result of cheap and availability of the motorcycle and local road characteristics in the country. Crash and fatality data of this huge percentage of motorcycles showed a significant increase over the last decades. This study focuses on the safety situation of this mode in Bangladesh. The study used police reported crash database preserved at the Accident Research Institute (ARI) of Bangladesh University of Engineering and Technology (BUET). The analyses revealed that the highest number of motorcycle fatalities occurred in rural locations (74%). Among the road classes national highways contributed to the highest (45%) fatality rate. The majority of the victims were 26 to 30 years old (22%). Of those involved in fatal crashes, 88% of the motorcyclists did not wear helmets. The highest number of fatalities by type of collision was head on (49%) followed by rear end (29%) and sideswipe (12%). The study compared crash data of five national dailies to quantify the underreporting of police reported data. This comparison exposed significant underreporting in the country. In addition, structured self-administered questionnaire survey was conducted at five hospitals in Dhaka city in order to identify motorcyclists' driving behavior along with the predominant injury patterns due to the crashes. The survey results demonstrated that predominant injury patterns were fracture in the right leg (22%) and fracture in the left leg (15%). The survey results also exposed root causes of crashes, daily riding time and operating speed during crashes. Finally, the study recommends few effective strategies and countermeasures in this situation.

Keywords: *Traffic crashes, Mtorcycle, Fatalities, Injury patterns, Underreporting.*

1. INTRODUCTION

Road crashes and fatalities are a growing concern in Bangladesh, with more than 2,700 fatalities over 3,100 recorded crashes yearly for the past 19 years. Although the average yearly reported numbers for the last 5 years are around 1,900 and 2,000 respectively, WHO (2013) estimated more than 20,000 deaths occur annually from road crashes in the country. Of these fatalities, around 70% are attributed to Vulnerable Road Users (VRUs)-pedestrians, bicyclists, motorcyclists and users of non-motorized para-transit vehicles. Among the crashes involving VRUs, motorcycle crashes are increasing alarmingly. The share of motorcycle fatalities was 3% in 1998 which have increased up to 22% in 2017. However, the actual number of fatalities should be much higher at least four times the number officially reported (Hoque, Hossain, Rahman & Islam, 2014). The most alarming fact is that Bangladesh is the Asian country with the greatest motorcycle deaths rate, 28.4 per 10,000 motorcycles (Nguyen, 2013). Moreover, there hardly found studies addressing this issue in the country. Therefore, this study intends to provide an insight of motorcycle crashes and fatalities along with injury patterns of the motorcyclists in Bangladesh. It also addresses the underreporting of the crash data throughout the country. The study findings can be used for the evidence-based interventions for policy-making decisions to reverse the adverse motorcycle crash trend and to mitigate motorcycle injuries in Bangladesh.

2. GLOBAL MOTORCYCLE GROWTH AND SAFETY

Being one of the cheapest modes of transport, motorcycle has dominated recently in the registered vehicles across the world. The increase rate of motorcycle surpassed the rate of car growth during 2002-2010 and the total registered number reached up to 30% of the world's vehicles in 2010. However, this growth created headaches among safety researchers. It is found from the safety point of view that, the motorcyclist's risk of a fatal crash is 26 times greater than a passenger car per vehicle-mile travel (NHTSA, 2013). The situation is more concerning for Asian countries which accommodated most of the world's motorcycles, approximately 79% (Nguyen, 2013). Research identified that suitable tropical and sub-tropical climate, favorable economic and institutional infrastructure and inadequate urban road space for cars were the prime reasons for this higher ownership (Senbil, Zhang & Fujiwara, 2007). This tremendous ownership of motorcycles in the region was responsible for most of the motorcyclist deaths, accounting up to 78% (WHO, 2013). Five Asian countries (Thailand, Lao, Vietnam, Malaysia, and Cambodia) are among the top ten of countries with the greatest motorcyclist deaths per 100,000 populations. Six Asian countries (Bangladesh, Cambodia, Lao, Thailand, India, and Myanmar) have death rates higher than the average rate of Asia, in which the death rate in Bangladesh has found to be about 4 times greater than that in Asia and the world (WHO, 2013). Figure 1 shows the Asian countries with the greatest motorcyclist deaths per 10,000 motorcycles.

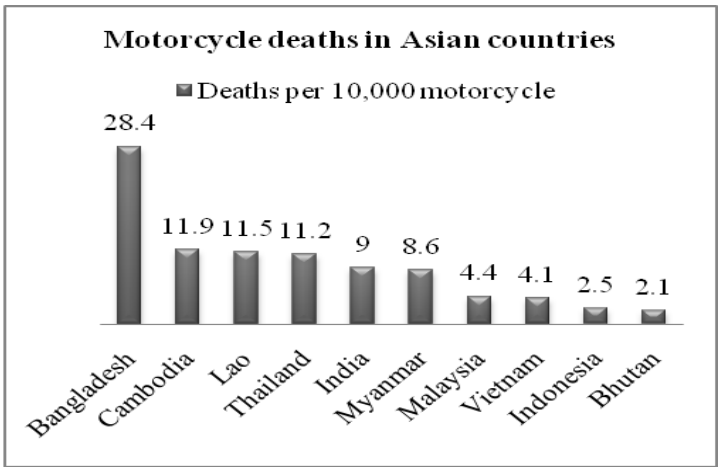

Figure 1: Asian countries with the greatest motorcyclist deaths rate (Nguyen, 2013; WHO, 2013)

Last decade showed a tremendous increase in the usage of motorcycles in Bangladesh. Currently, it occupies a large share (around 65%) in total registered vehicles in the country. The registered motorcycles grew from around 215,670 to 2,050,919 during 1999-2017 (Figure 2). The economic growth of the country, increase in per-capita income, cheaper cost and availability of national and international brands played an important role behind this growth. A growing number of city-dwellers are also going now for motorcycles to get around the heavy traffic jams. Moreover, it is the most convenient mode of transport in rural areas, particularly in the narrow village roads.

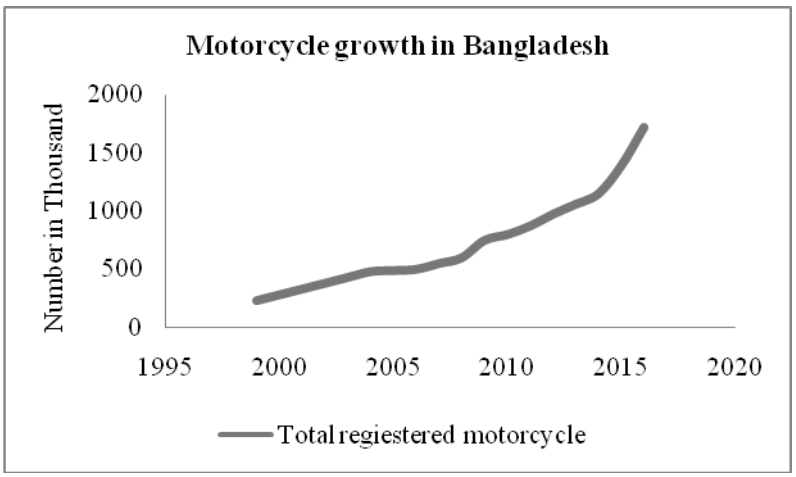

Figure 2: Trend of motorcycle growth in Bangladesh (BRTA, 2018)

3. METHODOLOGY

This study analyzed motorcycle crash and fatality data in terms of frequency and pattern by location type, road class, road geometry, age, time, lighting condition, collision type, uses of the helmet and contributing factors. These data were collected from the Accident Research Institute (ARI) of Bangladesh University of Engineering and Technology (BUET) that maintains police reported crash database. Microcomputer Accident Analysis Package 5 (MAAP5) software was used to analyze these data. The study assessed the injury patterns by a structured self-administered questionnaire survey of hospitalized motorcyclists. The survey was conducted among 100 patients at five specialized hospitals which were Dhaka Medical College Hospital, Sir Salimullah Medical College Mitford Hospital, Shahid Suhrawardi Medical College Hospital, National Institute of Traumatology and Orthopedic Rehabilitation Hospital (NITOR) and Trauma Centre. These are the leading hospitals in the country where patients from all areas of the country are taken for better treatment. Thus, these patients can be considered as a representative sample for the survey. The survey included questions regarding injury patterns (e.g. head injury, bone fracture, spinal cord, etc.), driving attitude and behavior of hospitalized motorcyclists. Furthermore, underreporting of crash data were quantified by comparing the police reported and the newspaper reported data.

4. TRENDS OF MOTORCYCLE CRASHES AND FATALITIES IN BANGLADESH

Analysis by MAAP5 showed that the motorcycle crashes and fatalities increased from 4% to 20% and 2% to 22% respectively from 1998 to 2017 (Figure 3). Both the crash and fatality rates (per 10,000 motorcycles) have shown alarmingly upward trend very recently (Figure 3). Further analysis of crash and fatality data by different road attributes is discussed in the following sections.

4.1 Motorcycle Fatalities by Location, Road Class and Road Geometry

Analysis revealed that motorcycle crashes are predominant in rural areas of Bangladesh. The major portion of the national and regional roads is situated in these areas where 69% of motorcycle crashes occurred, whereas 31% occurred in urban areas, resulted 74% and 26% fatalities respectively. Among

the road classes, national highways were responsible for 45% of the motorcycle fatalities and were followed by regional (19%) and feeder roads (17%), Figure 4. Research emphasized that greater speeds made possible by lower traffic volumes and less traffic control might be responsible for this higher rate (Silva, 1978). Further analysis revealed that fatalities per crash were higher on national (1.33) and regional roads (1.08) compared to that on city roads (0.60).

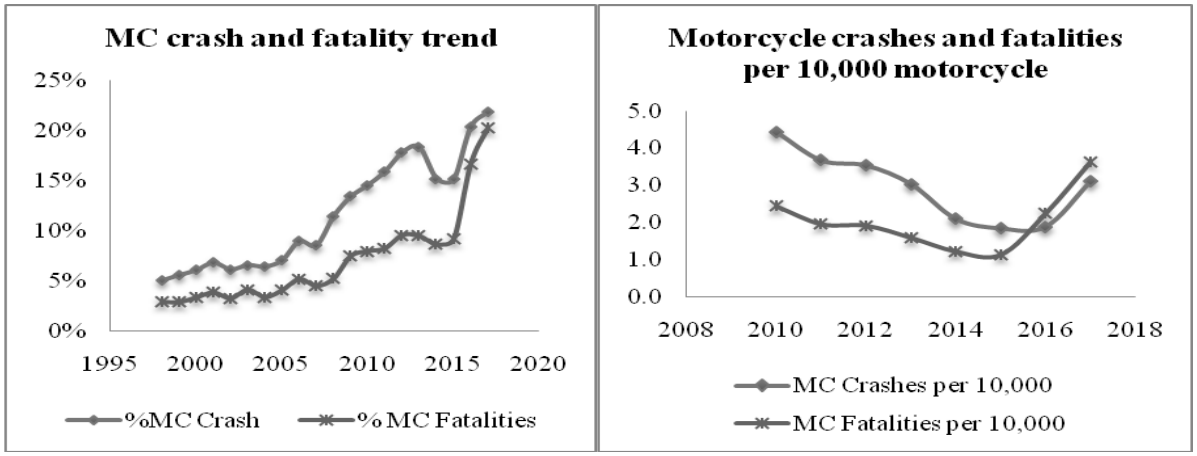

Figure 3: Motorcycle crash and fatality trends in Bangladesh (1998-2017)

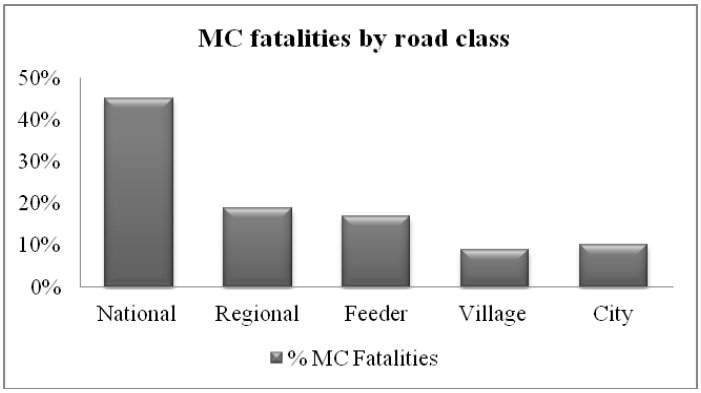

Figure 4: Motorcycle fatalities by road class (1998-2017)

Distribution of motorcycle fatality data by road geometry showed that most of the fatalities occurred at straight segments of roads (87%). The curve sections also contributed to a significant portion of motorcycle fatalities (11%). Other sections experienced only 2% of motorcycle fatalities.

4.2 Motorcycle Fatalities by Gender and Age

The reported data showed that the age group of 26 to 30 years was mostly involved in motorcycle fatalities during 1998-2017 (Figure 5). More alarmingly, the majority of the victims were working class people of age 21 to 35 (56% fatalities). It was also found that male shared 96% of motorcycle fatalities in the country.

4.3 Motorcycle Fatalities by Time, Day, Month and Weather Condition

The distribution of fatalities for motorcyclists was highest (78%) from 8.00 am to 7.00 pm. The fatalities peaked during the period of 10.00 am to 1.00 pm and later 4.00 pm to 5.00 pm in the day time coinciding with the higher level of motorcycle flow. Motorcycle fatalities by time of the day are shown in Figure 6.

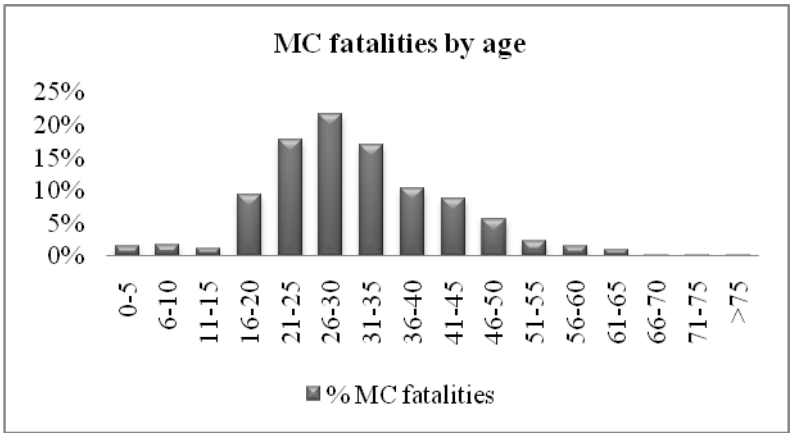

Figure 5: Motorcycle fatalities by age (1998- 2017)

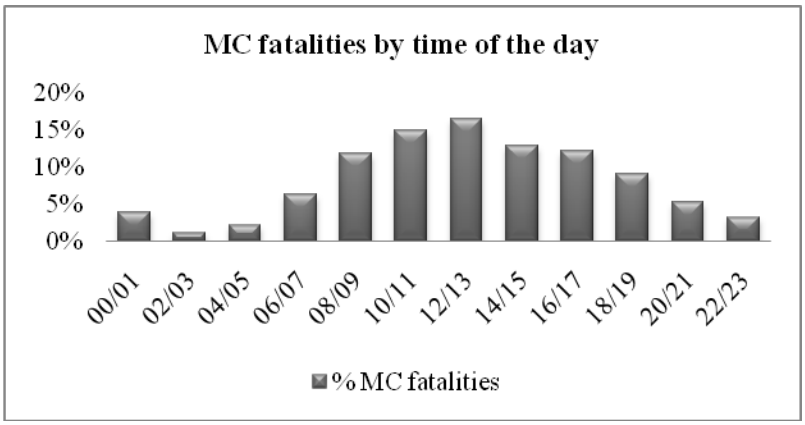

Figure 6: Motorcycle fatalities by time of the day (1998-2017)

Table 1: MC fatalities by day of the week (1998-2017)

Day of Week	% MC fatalities
Monday	14%
Tuesday	14%
Wednesday	13%
Thursday	15%
Friday	15%
Saturday	16%
Sunday	12%

From 1998 to 2017, motorcycle fatality data were almost evenly distributed over the days of the week with slight higher records from Thursday to Saturday (Table 1). Distribution of fatality data by months showed fluctuations throughout the year. The records were highest from December to May of the year, as seen in Figure 7. The fatalities occurred more during fair weather condition (92%) followed by rainy condition (5%). Records also showed that fatalities occurred more during the day time (76%) followed by dawn/dusk time (12%) and night (12%).

4.4 Motorcycle Fatalities by Collision Type

The most frequent fatalities by collision type were head on (49%) and rear end (29%). Sideswipe (12%) collisions with motorcycles were also significant (Table 2). Motorcycle crashes were splitted as 35% single-vehicle and 65% multi-vehicle crashes. The share of fatal motorcycle crashes was 5.6% and 11% for single-vehicle and multi-vehicle crashes respectively.

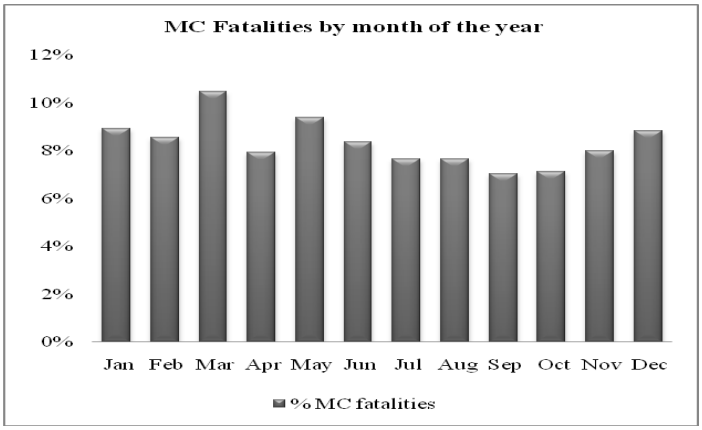

Figure 7: MC fatalities by month of the year (1998-2017)

Table 2: Motorcycle fatalities by collision type

Collision Type	% MC Fatalities
Head on	49%
Rear end	29%
Right angle	2%
Sideswipe	12%
Over turn	2%
Hit object	2%
Hit parked vehicle	2%
Hit pedestrian	0%
Other	3%

4.5 Motorcycle Fatalities by Helmet Use

According to the database, 88% of those involved in motorcycle fatalities did not wear helmet and 12% worn helmet during the ride. The reasons behind not wearing helmet came out from the questionnaire survey. The result showed that 43% of respondents did not wear helmet due to feeling hot inside helmets, 25% used to feel uncomfortable using helmet, 11% did not use while in the short distance trip and 5% did not have any helmet.

4.6 Motorcycle Fatalities by Contributing Factor

Analyzing police reported data it was found that driver factors were contributing to almost 92% of motorcycle fatalities. Among the driver factors, over speeding was the primary cause of 51% fatalities which was immediately followed by careless driving (40% fatalities). Motorcycle fatalities by contributory factors are shown in Table 3.

Table 3: Motorcycle fatalities by contributory factors

Contributory factor	% MC Fatalities
Over speed	51%
Careless driving	40%
Close Driving and wrong Signal	2%
Overtaking	2%
Overturning	1%
Road features	1%
Other	3%

4.7 Injury Patterns

Which parts of the body were injured due to motorcycle crashes were initially identified through physical observation of hospitalized motorcyclists and later confirmed by asking them regarding their injury. The fracture in the right leg had the largest share comprising 22% of total injury patterns. It was followed by fracture in the left leg (15%). Of the others, injury in the right lower leg and fracture in the right hand were 10% and 9% respectively. Head injury, fracture in the left hand and fracture in the right knee equally shared (7% each) in the injuries (Table 4).

Table 4: Injury patterns of hospitalized motorcyclists

Injury Pattern	% of Motorcyclists
Head injury	7%
Fracture in left hand	7%
Fracture in right hand	9%
Fracture in left elbow	2%
Fracture in left wrist	3%
Chest	1%
Backbone	2%
Fracture in waist	1%
Fracture in left leg	15%
Fracture in right leg	22%
Fracture in left knee	5%
Fracture in right knee	7%
Fracture in left ankle	2%
Fracture in right ankle	4%
Injury in right lower leg	10%
Right knee cut-off	3%

It is clear that about half of total injury was in the right leg and more than one-fifth was in the left leg. This finding implies that the lower part of the body is mostly prone to injury for motorcycle crashes.

4.8 Riding Time and Operating Speed

The questionnaire survey revealed that around 50% of the motorcyclists used to ride between 1 and 2 hours daily and 32% of the motorcyclists used to ride daily less than 1 hour. Almost 12% of respondents told that they daily travel on motorcycle between 2 and 4 hours. Only 6% used to ride more than 4 hours daily (Figure 8). Thus, the survey found a notable percentage of the motorcyclists with higher daily riding time.

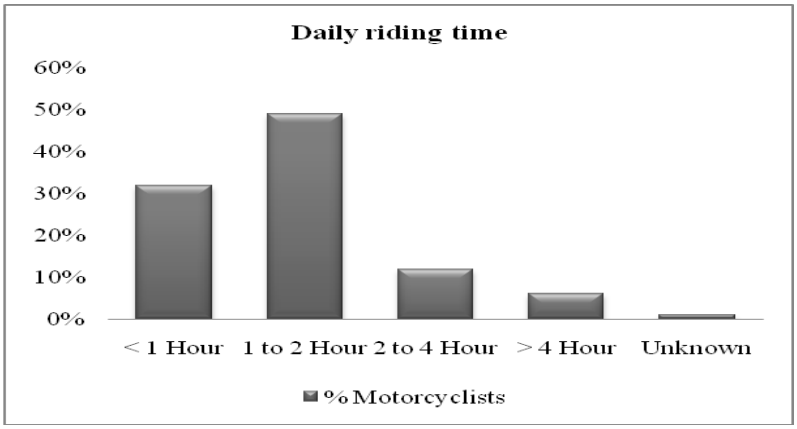

Figure 8: Daily riding time of motorcyclists

The majority of the respondents were riding with a little higher speed during crashes. It is very clear from Figure 9 that about 67% were riding with speed greater than 50 km/h that is higher than the posted speed limit (30-40 km/h) in the survey area. About 51% were with speed ranges from 60 km/h to 80 km/h. Only 8% motorcyclists rode with speed (<40 km/h.) lower than the posted speed limit.

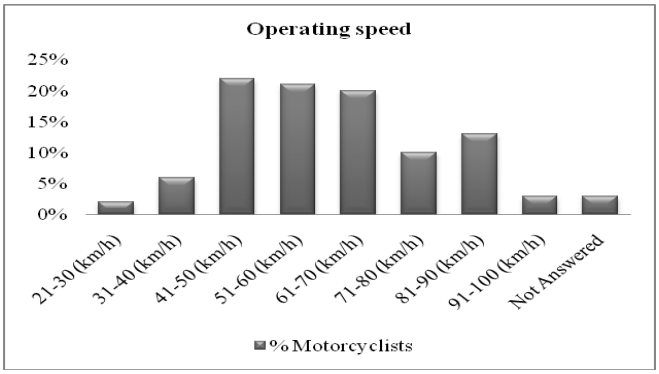

Figure 9: Operating speed of motorcyclists

4.9 Underreporting of Crash Data

To quantify the underreporting in the crash data recording system, crash and fatality data were recorded from 5 National Daily Newspapers for the period of one year. It was found that the number of crashes and fatalities recorded by the police (191 crashes and 158 fatalities) vary from the newspaper recorded data (325 crashes and 388 fatalities) in the same year (Table 5 & Table 6).

Table 5: Police Vs Newspaper reported motorcycle crashes and fatalities by day of the week

Day of Week	Newspaper Reported		Police Reported	
	MC Crashes	MC Fatalities	MC Crashes	MC Fatalities
Monday	40	42	31	24
Tuesday	40	46	23	17
Wednesday	43	55	25	23
Thursday	41	48	22	21
Friday	39	48	34	28
Saturday	56	67	26	23
Sunday	66	82	30	22
Total	325	388	191	158

Table 6: Police Vs Newspaper reported motorcycle crashes and fatalities by month of the year

Month	Newspaper Reported		Police Reported	
	MC Crashes	MC Fatalities	MC Crashes	MC Fatalities
January	33	41	12	12
February	58	64	19	12
March	11	12	22	20
April	28	35	10	8
May	8	11	24	19
June	18	21	13	16
July	14	20	14	14
August	15	17	15	10
September	37	44	9	6
October	30	36	16	15
November	31	35	22	16
December	42	51	15	10
Total	325	387	191	158

Recorded data showed almost 3 times under reporting of motorcycle fatality data. This quantity could be more if more number of newspapers would have been considered. The police reported data showed very little fluctuations in daily motorcycle crash and fatality rates, whereas newspaper recorded data showed daily variation in both crashes and fatalities. The fluctuations are shown in Table 5. Again, police reported data also showed less fluctuation in monthly motorcycle crashes and fatalities whereas newspaper reported data showed a variation in the distribution (Table 6).

5. DISCUSSIONS

This study demonstrates the increasing trend of motorcycle crashes and fatalities along with the increasing share of the motorcycle in total vehicles of Bangladesh. This upward trend of the motorcycle crash and fatality rates (per 10, 000 motorcycle) is alarming, particularly in the rural areas of the country. The greater fatality of motorcyclists in rural areas might be caused by lower volume and hence the higher speed of the vehicles in this area. In urban areas, the flow is congested with lower speed and stop-go situation. This could be one of the reasons behind the lower share in fatalities. Again, the mixing of short tripped motorcycle with high speed vehicles and frequent access from the connecting road might be responsible for higher motorcycle crashes in national highways. The higher edge drop of pavement, lack of adequate shoulder, loose materials after repairing works and damage pavement surface also aggravate the safety of the motorcyclists in the highways. These situations should be addressed by road designers and maintenance authorities. Research emphasizes to take into account the interaction between motorcycles and other heavy vehicles in road planning, design, and operation (Nguyen, 2013). Study suggests exclusive or inclusive lane for motorcycle to prevent interaction among motorcycle, Non Motorized Vehicle (NMT), passenger private car and other heavy vehicles, especially in city areas (Hoque, Chowdhury & Rashedi, 2015). It is also emphasized that motorcyclists should maintain lane while driving. It is found that higher speed and careless driving are the primary contributing factors to these fatalities. This is also substantiated by the survey result regarding operating speed during crashes. Besides, it is seen that the fatality rate is highest among the young motorcyclists. Several factors such as drugs, alcohol and suicidal tendencies are prominent for these young motorists' behavior and risky rides which eventually contribute to this rate (Harrison & Christie, 2005; Steg & Brussel, 2009). However, no adequate study is found in Bangladesh regarding the young motorcyclists' behavior on risky rides. Setting speed limit for motorcyclists and enforcement of laws is necessary in this circumstance. Again, the use of helmets is essential for motorcyclists. Research indicates that the use of helmets could decrease the likelihood of these deaths. Compared with helmeted motorcyclists, non-helmeted motorcyclists are more than four times as likely to have head injuries and ten times as likely to have brain injuries (Yu, Chen, Chiu & Lin, 2011). Public awareness regarding the importance of helmet uses is highly needed since the death rate of non-helmeted motorcyclists is found higher in this study.

This study shows that the lower part of the body is mostly prone to injury in motorcycle crashes. However, studies in developed countries found different injury patterns, especially higher injury rates of lower extremity, chest and abdomen. Studies in California and Britain reported that multiple intra-thoracic and intra-abdominal injuries, as well as pelvic ring fractures associated with long bone injuries and the rib fractures were common serious injuries in motorcycle crashes (Kraus, Peek-Asa & Cryer, 2002; Ankarath, et al., 2002). It is also seen that injury risk appears to be related to crash types (Patricia, Gabriel, Shiu & Braver, 2006). In Bangladesh, higher sideswipe collisions along with side sway during head on and rear end collisions could be responsible for different injury patterns. Along with collision types, daily riding time also plays an important role in crashes and injuries. Though the survey results demonstrate the lower daily riding time, it could be higher if the survey were conducted in rural areas where long distance trips are generated. This long riding time induces fatigue and decreases riding quality of the motorcyclists (Ma, Williamson & Friswell, 2003).

This study has also quantified the underreporting of the crash data which affects understanding the crash magnitude and total loss, setting target and evaluating the countermeasures. Bangladesh police

has to be more concern regarding crash reporting issues. Besides, training on reporting and recording of road traffic crash data will play a significant role in reducing the underreporting.

6. CONCLUSIONS

Being a convenient mode of transport, motorcycle is continuing to play a great role in the transport sector of Bangladesh. Hence, motorcycle crashes and fatalities are going to be an alarming issue unless the safe mobility of motorcyclists can be ensured. This study has put some insights into facts, causes and behavioral aspects of motorcyclists. The safe road infrastructures, speed management strategies, safety awareness and behavior of motorcyclists should be considered by road planners, designers, engineers and respective agencies. Moreover, mitigating underreporting problems will definitely play a greater role in motorcyclists' safety research, plan, design and implementation of the above strategies.

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URBAN ROAD SAFETY SITUATION IN BANGLADESH: A SYNOPSIS

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ABSTRACT

Rapid urbanization and migration of rural population to urban areas have challenged the existing urban transportation system of Bangladesh. This ever-growing demand posed a tremendous pressure on the cities road network to cater the need which eventually allowed heterogeneous unfit vehicles, over-loaded and over-crowded buses, minibuses and human haulers. Thus, the urban transport system has become imbalanced and unsustainable with increasing road safety hazards. This study presents a synopsis of the nature and extent of the urban road safety scenario in Bangladesh. Microcomputer Accident Analysis Package five (MAAP5) software of Accident Research Institute (ARI) at Bangladesh University of Engineering and Technology (BUET) was used to analyze the police reported crash data. The analyses revealed that urban road fatalities increased from 20% of total road fatalities to 37% of the total road fatalities during 2005-2015. The major collision type for fatalities was hit pedestrian (57%). The analyses also demonstrated that the fatalities were comparatively higher (63%) during daytime (6 am to 6 pm) than night. Mid-blocks of the road network contributed to the major percentage (65%) of the urban fatalities. The study also compares the safety situation of the major metropolitan areas of Bangladesh. The comparative analyses elicited that almost half of the urban road fatalities occurred in the Dhaka metropolitan area. Dhaka, the capital, contributed up to 55% of urban hit pedestrian fatalities, 48% of urban fatalities due to right angle and 45% of urban fatalities due to rear end collisions. The findings from this study will help authorities to assess the urban road safety scenario, and thus assist decision-making processes for improving the safety situation of Bangladesh.

Keywords: *Road safety, Urban, Metropolitan city, MAAP5.*

1. BACKGROUND

Every year more than 1.35 million lives are lost, and 20 to 50 million people suffer non-fatal injuries which incurre disabilities due to road traffic crashes. 90% of these fatalities occur on the roads of low and middle-income countries which have 60% of the world's registered vehicles (World Health Organisation [WHO], 2015). Road traffic crashes have emerged as a serious socio-economic issue and are affecting the communities enormously in the developing countries like Bangladesh. Although the official statistics (police reported crash data) reveal 2,500 crashes and 3,000 deaths eache year in Bangladesh, the actual scenario is quite contrasting (ARI, 2015); the actual numbers could well be at least four times higher than the reported figures (Hoque, Hossain, Rahman & Islam**,** 2014). WHO (2015) estimates the annual road traffic fatalities in Bangladesh could be around 20,000.

The road crash problem is disproportionately greater in urban areas compared to rural areas (Lundebye, 1995). Rapid urbanization, migration of rural people and economic development have played a pivotal role behind such disproportionity, particularly in developing countries (WHO, 2013). In Bangladesh, around 36% of total population is urban dwellers (Worldometers, 2018). However, there was only 9% property living in urban areas of Bangladesh in 1994 (Hayes et al., 2015). Employment opportunities in the urban areas is the primary reason for people migrating from rural areas in the country. This migration have immensely enhanced transportation demand that outstripped roadway capacity. To meet up this demand, a wide range of vehicles sharing the same road networks are providing urban public transportation facilities. But, the preference for a particular mode is often influenced by cost of the service rather than its quality. Therefore, low-income commuters often prefer unfit and overcrowded bus, minibus and human haulers due to cheaper fare (Gallagher, 2016). These unfit and substandard vehicles often create both on-road and off-road troubles, such as, congestions, higher emissions, adverse health effects and higher traffic crashes. Thus, road safety and sustainability has become a major concern for the urban dwellers.

2. LITERATURE REVIEW

2.1 Global Context of Urban Road Safety

The life in urban areas is facing tremendous threat due to continuous increase of urban population. In 2014 the urban populations were accounted up to 54% of the total global population (Economic and Social Commission for Asia and the Pacific [ESCAP], 2014). In Asia, ESCAP (2014) estimated 1.6 billion people (40 % of total population) lives in urban areas in 2011 which is predicted to be 2.7 billion in 2030. This continuous growth of urban residents has resulted in rapid increases of transport activities and private vehicle ownership. Study of Europian Transport Society Council [ETSC] (2017) revealed that cities and towns are home to 72% of the population of the European Union (EU). Their statistics also show that 9500 people were killed on urban roads in the EU in 2017, accounting for 38% of all road deaths. Additionally, 70% of those killed on urban roads are vulnerable road users: 39% are pedestrians, 12% cyclists and 19% powered-two-wheeler riders. Besides, car occupants account for 25% of all roads deaths on urban roads in EU. The study also highlighted that on average 26 people are killed on urban roads per million urban inhabitants in EU, 5 people in Norway, 9 in Sweden, 11 in the UK, 13 in the Netherlands and 14 in Ireland and Spain. The same study demonstrated that countries with a good overall road safety record tend to have lower mortality on urban roads too. In the USA, over the past decade, road fatalities have increased in urban areas and decreased in rural areas. Study of Safe Road USA (2017) underscored that there has been a general downward trend in the proportion of road deaths in rural areas, with the proportion declining from 61% in 2000 to 47% in 2017 while in urban areas the deaths proportions have increased from 36% in 2000 to 53% in 2017. According to the study pedestrian fatalities have surged by 46% in urban areas since 2008. In Australia, Bureau of Infrastructure, Transport and Regional Economics [BITRE] (2017) showed that urban areas accounted for 86% of the population and 49% of all fatal crashes. They also published that the proportion of urban fatal crashes was 48% in 2010 which increase to 49% in 2015.

2.2 Context of Urban Road Safety of Bangladesh

As urban population is increasing in Bangladesh, the pressure on transport networks and facilities is also increasing simultaneously. However, the existing networks and facilities are often failed to meet up this pressure. While the standard road space for an urban city is 25% of its area, there is only 9% of area is occupied by road space in Dhaka city (Mahmud & Hoque, 2008). This limited road space cannot provide enough space for increasing traffic. Therefore, occupied walkways, congestions, outdated public transportations and substandard in-vehicle conditions are the daily life occurrence of city dwellers. Several studies quantified the safety and adverse health effects of these occurrences. Hoque, Mahmud & Qazi (2008) demonstrated that around, 25% of the total fatalities occurred in urban areas of Bangladesh during 1998-2006. The study also showed that urban crashes are concentrated in metropolitan areas. Of the total urban accidents of Bangladesh, 82% are metropolitan related accidents which contributed to nearly 75% of urban fatalities during 1998-2006. More alarmingly, pedestrians were the worst sufferers of these road fatalities in the metropolitan areas with an average of 65%. Further analysis revealed that most of the pedestrians' fatalities occurred while crossing the road (41%) and was closely followed by walking on the road (39%) from 1998 to 2006. Another study suggested that large proportions of road crashes in cities are concentrated on the main street network (Hoque, Rabbi, Mahmud**,** Siddiqui & Anowar, 2007). They suggested to install exposure control, injury control and behavior control measures to address these concentrated crashes. Apart from road fatalities, emission of hazardous pollutants into the air and additional noise is common from unfit vehicles in urban areas. It was estimated that around 1000 tons of pollutants are pumped into the environment every day in Dhaka, of which 70% comes from vehicles (Mahmud, Rahman & Rabbi, 2007). Adequate studies and research are needed in this arena for further understanding the facts and taking necessary measures.

3. RESEARCH GAPS AND OBJECTIVES OF THE STUDY

Urban crash characteristics might have changed in recent years in Bangladesh. The safety situations considering recent data are yet to be analyzed. Pedestrian locations during crashes have been scarcely considered in available studies. Considering the recent transportation growth in Dhaka city, its contributions to urban safety need to be assessed. To develop effective road safety strategies, introduce modern and smart technologies, and prioritize these strategies, up-to-date urban road safety research is of utmost importance. Therefore, this study intends to provide a synopsis of the prevailing urban road safety scenario considering the latest data in Bangladesh. The findings of the study will help to provide an insight into the recent safety situation and guide the stakeholders to take appropriate urban road safety improvement strategies for the country.

4. DATA COLLECTION AND METHODOLOGY

In Bangladesh, police is the primary source of road crash data. They collect information of each crash after site investigation and fill up the First Information Report (FIR). Later, the information from FIR is transferred into Accident Report Form (ARF) which is the prescribed form of road crash data. The data is sent to Accident Research Institute (ARI) of Bangladesh University of Engineering and Technology (BUET). After necessary corrections and editing with Road User Movement (RUM) code the data is stored in Microcomputer Accident Analysis Package 5 *(MAAP5)* software. This study collected latest available data from *MAAP5* of ARI, BUET from 2005 to 2015. The software was also used to analyze the collected data.

5. ANALYSIS AND DATA INTERPRETATION

Detailed analysis of road crash and fatality data was done in terms of frequency and pattern by time, day of the week, month, junction type, collision type, age, pedestrian action, road sections, metropolitan area and contributing factor to fatalities. The results of the analysis are discussed in the following sections.

5.1 Trend of Urban Crashes and Fatalities in Bangladesh

Analysis of road fatality data showed that the proportion of urban road fatalities gradually decreased from 1998 to 2005 (Figure 1). But, afterward, it increased steeply. From the year 2007 to till now the ratio has not decreased below 30%. The probable cause of this high percentage of fatalities in urban areas in recent times may be due to rapid urbanization, outdated transport facilities, lack of road safety knowledge of the road users and uncontrolled flow of people from rural areas to urban areas.

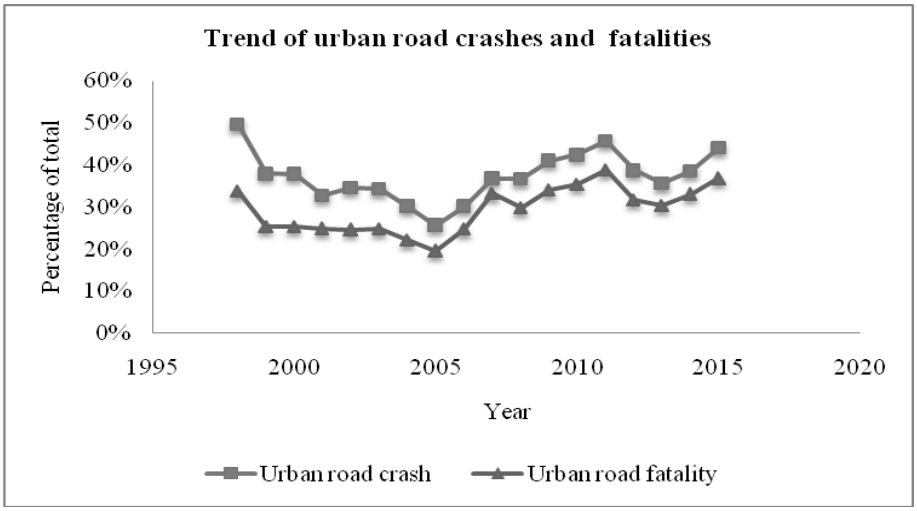

Figure 1: Trend of urban road crashes and fatalities in Bangladesh

5.2 Urban Fatalities by Time of the Day

The time distribution of the road fatalities in the urban areas of Bangladesh shows that the highest percentage of fatalities occurred during the interval of 10 am to 12 pm (12%), Figure 2. Though the percentage of fatalities was comparatively high during the day (60%), a significant percentage of fatalities at night (40%) time implies that human error plays a significant role in traffic crashes in urban areas. It is evident from several studied that drivers' ability to avoid collisions is hindered under low lighting (Owens & Sivak, 1993; Elvik, 1995; Rice, Peek-Asa & Kraus, 2003). Other studies highlighted that pedestrians are three to seven times more vulnerable in the dark than in the daylight (Owens & Sivak, 1993; Elvik, 1995; Rice, Peek-Asa & Kraus, 2003). Moreover, it was seen that the installation of overhead lighting reduces the number of night-time crashes (Elvik, 1995).

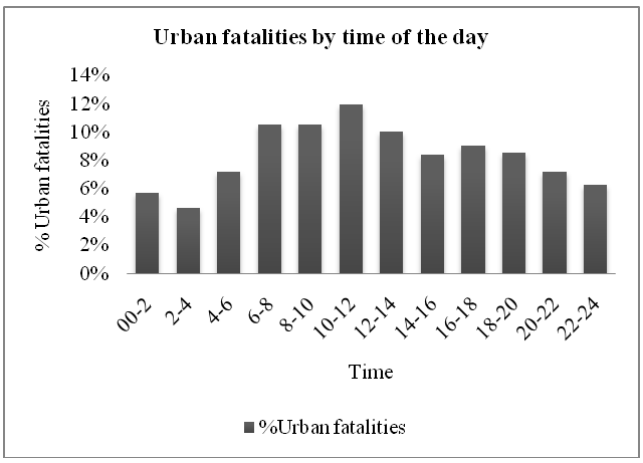

Figure 2: Urban fatalities by time of the day

5.3 Urban Fatalities by Days of the Week

Figure 3 shows the distribution of urban fatalities by day of the week. The data revealed that the fatality constituted a lower percentage during government holidays in Bangladesh i.e. Friday (14%) and Saturday (13%). During the other days of the week, the percentage was higher except for Monday. This might be the result of unholy competitions among drivers and higher traffic flow at working days in urban areas. Most of the fatalities occurred on Sunday (15%) as seen from Figure 3.

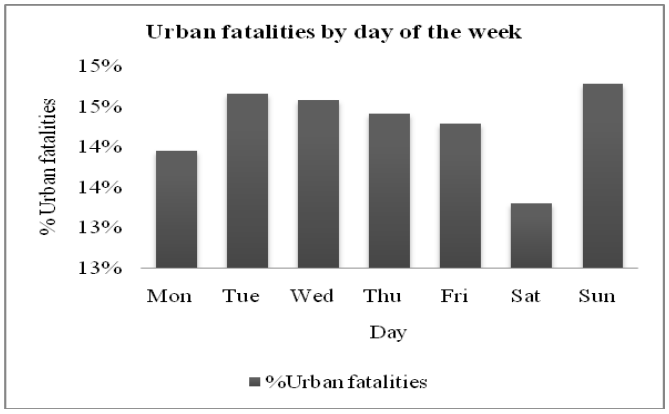

Figure 3: Urban fatalities by day of the week

5.4 Monthly Variation of the Urban Fatalities

The month-wise distribution of fatalities in the urban areas of Bangladesh showed that urban fatalities were higher during the month of January (10%) and April (10%). Besides, February, March, May and June also showed higher percentages (9% in each month). The month from October to December showed lower percentages (7% in each month) (Figure 4). These higher fatalities, particularly between January to May may have been due to the increased travel for major government vacations, picnics and other recreational activities.

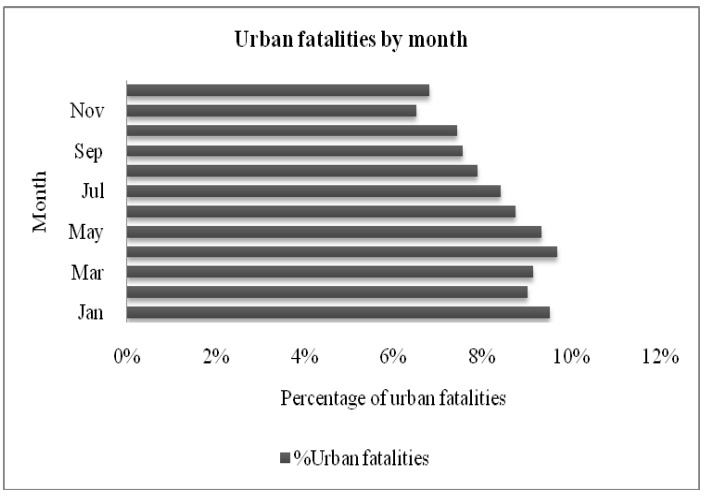

Figure 4: Urban fatalities by month of the year

5.5 Urban Fatalities by Junction Type

The distribution of fatalities according to junction type in urban areas showed that the major fatalities occurred in the not-junction areas (61%), shown in Table 1. It is a matter of great concern in the context of Bangladesh. Because it is claimed that most of the crashes in Bangladesh occur due to over speed and careless driving. Besides, tee junctions (11%) and cross junctions (9%) also shared a significant percentage of fatalities. Fewer fatalities were involved in the crashes at the staggered junctions (2%) and roundabouts (2%), shown in Table 1.

Table 1: Urban fatalities by junction type

Junction type	Urban fatalities
Not junction	61.2%
Cross	9.3%
Tee	10.6%
Staggered	1.7%
Roundabout	1.6%
Railway crossing	0.4%
Other	15.2%

5.6 Urban Fatalities by Collision Type

Data analysis depicted that, the major collision type for fatalities was hit pedestrian (55%) (as shown in Figure 5). This implies that they are the most vulnerable road users of the area. This high percentage also represent poor facility for pedestrians in the urban roads of Bangladesh. Moreover, pedestrians also do not know the proper rules while using the roads. Besides, head on (15%) and rear end (14%) types of collision also shared a significant percentage of fatalities in the urban roads. These head on collisions occur mostly at local urban roads and few in primary roads due to wrong side driving. The other collision types responsible for fatalities were side swipe (4%), vehicle overturn (4%), hit parked vehicle (2%), right angle (1%), hit object off road (1%), hit object on road (1%), and others (3%) (Figure 5).

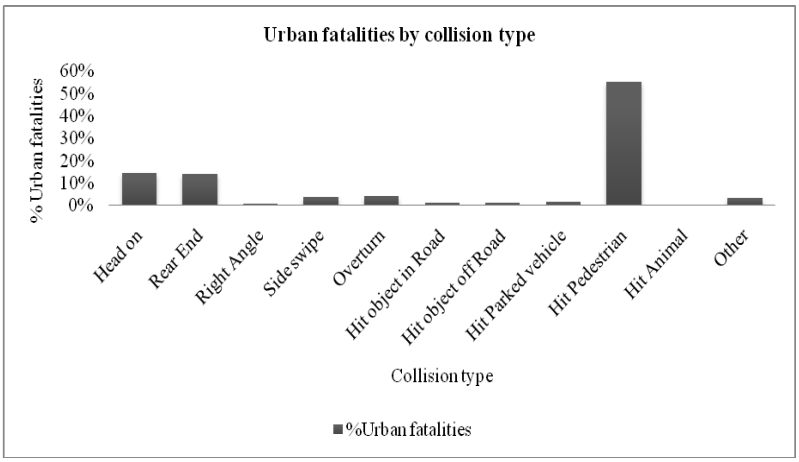

Figure 5: Urban fatalities by collision type

5.7 Urban Fatalities by Sex and Age Group

The percentage of fatalities in urban areas based on age group is shown in Figure 6. It is observed that the young and working group (age 21-40) of the society was mostly killed due to crashes in the urban area (49%). This is a critical issue as it affects the national GDP more severely. The most vulnerable age group was 26-30 years (15%). Again, from the analysis it was seen that 83% of victims of urban fatalities were male.

5.8 Urban Pedestrian Fatalities by Pedestrian Actions

Table 2 shows the comparison of pedestrian fatalities based on the pedestrian actions in the urban and rural areas of Bangladesh. It is observed that most of the fatalities of pedestrian occurred while crossing the road (53%) in urban areas, whereas in rural areas the percentage was 25%. The major causes behind this high percentage of fatalities of pedestrians in urban areas may be due to the absence of proper road crossing facilities and poor knowledge of pedestrians on road safety issues. Moreover, the density of traffic as well as traffic congestion is higher in urban areas is higher than in rural areas.

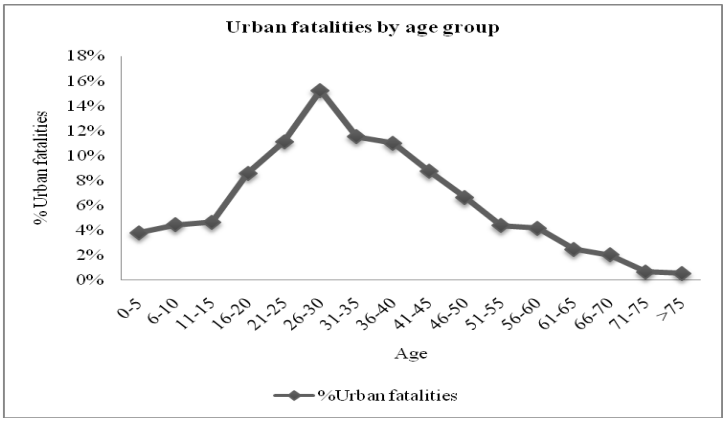

Figure 6: Urban fatalities by age group

Walking through the edge of the road contributed up to 28% and 48% of urban and rural fatalities of pedestrians respectively. In this case, the percentage of rural fatalities was higher than urban fatalities. Because in rural roads are narrower and has a very limited facility for walking for the pedestrians. In many segments of the road, it is also absent due to the presence of small plants, bushes and stagnant water due to poor drainage facility. Moreover, the presence of permanent wall, shops etc. Just on the edge of the road also compels pedestrians of rural areas to walk on the edge of the road. Walking on the road contributed to 6% and 9% of urban and rural fatalities of pedestrians respectively. Besides, working/playing on the road contributed to 1% and 2% of urban and rural fatalities of pedestrians respectively.

Table 2: Urban urban and rural fatalities by pedestrian actions

Pedestrian actions	Urban fatalities	Rural fatalities
None	12%	16%
Crossing	53%	25%
Walking on the road	6%	9%
Walking through edge of the road	28%	48%
Working/playing on the road	1%	2%

5.9 Urban Pedestrian Fatalities by Road Sections

It is observed that most of the fatalities of pedestrians occurred at the center of the road (48%) in urban areas, whereas in rural areas the percentage was 20%, as shown in Table 3. This result demonstrates that significant percentage of pedestrians cross the roads at any section other than using designated pedestrian crossing The percentage of fatalities of pedestrians in the walkways was the same (2%) in both urban and rural roads. It emphasizes that pedestrians are still unsafe while using walkways.

Table 3: Urban and rural fatalities by road sections

Road sections	Urban fatalities	Rural fatalities
Pedestrian crossings	16%	26%
Within 50m of pedestrian crossings	2%	3%
Divider	0%	0%
Centre of the road	48%	20%
Walkway	2%	2%
Roadside	30%	48%
Bus stop	1%	1%

Higher pedestrian fatalities at side of road (31% in urban and 48% in rural roads) underscore that the lacks of adequate sidewalk or occupied sidewalks force pedestrians to walk along side of the road. Besides, the pedestrian fatalities in pedestrian crossing (16% in urban and 26% in rural roads) imply that pedestrians are not getting priority in the roads. The data also showed few pedestrians died within 50m of pedestrian crossing (2% in urban and 3% in rural roads).

5.10 Urban Fatalities by Metro Cities

The DMP shared nearly half (48%) of total fatalities that occurred in the urban areas of Bangladesh (Table 4). The fact shows the vulnerable situation of road safety in the Dhaka metropolitan area. Besides, each of Chittagong Metropolitan (CMP) and Rajshahi Metropolitan (RMP) shared 10% fatalities of urban areas. Moreover, Sylhet Metropolitan (SMP), Khulna Metropolitan (KMP) and Barishal Metropolitan (BMP) shared 5%, 3% and 1% of total urban fatalities respectively.

Table 4: Urban fatalities by major metro cities

Metro cities	% Of urban crashes	% Of urban fatalities
DMP	52%	48%
CMP	10%	10%
RMP	3%	10%
SMP	3%	5%
KMP	3%	3%
BMP	1%	1%

5.11 DMP Fatalities by Urban Fatalities by Collision Types

Fatality data of DMP shows that the percentage of hit pedestrian fatalities was about 63% of urban hit pedestrian fatalities. The rest of 37% fatality due to hit pedestrian crashes was shared by all other major metro cities except DMP. This shows the vulnerable conditions of pedestrians in DMP. Moreover, fatalities due to the right angle, hit parked vehicles and rear end crashes shared 56%, 54% and 50% respectively (Table 5).

Table 5: DMP fatalities by collision type

Collision type	%DMP crashes by urban	%DMP fatalities by urban
Head on	22%	17%
Rear end	50%	40%
Right angle	56%	18%
Side swipe	47%	43%
Overturn	36%	31%
Hit object in Road	38%	12%
Hit object off Road	49%	60%
Hit Parked vehicle	54%	43%
Hit pedestrian	63%	64%
Other	32%	23%
Total	52%	48%

5.12 Principle Contributing Factor to Urban Fatalities

Analysis of police reported crash data indicated that 90% of total urban crashes occurred due to overspeeding and careless driving of the driver (Table 6).

Table 6: Urban fatalities by contributing factor

Contributing factors	Fatalities
Over speeding and careless driving	90%
Pedestrian actions	5%
Adverse road conditions or environment	2%

Contributing factors	Fatalities
Vehicle defects	1%
Overtaking, overturning and others	2%

Only 5% and 2 % of crashes occurred due to pedestrian actions and adverse road conditions respectively.

6. DISCUSSION ON KEY FINDINGS

This study reveals that the urban fatalities have shared 32% of total fatalities in Bangladesh during 2005-2015 whereas it was only 25% of the total fatalities during 1998-2006 (Hoque, Mahmud & Qazi, 2008). It emphasizes that road safety problems in urban areas should be taken as an emerging issue and thus need to be addressed urgently. The reduction of urban hit pedestrian fatalities from 59% to 55% during this period indicates few interventions have been taken to address the pedestrian safety in these areas. More inventions could further reduce this type of fatality. Our study also demonstrates that during 1998-2006, the pedestrian fatalities while crossing the road were 41% which has been increased to 53% during 2005-2015. Again, it is found that only 16% of pedestrian fatalities occur at designated crossings while 48% of pedestrian fatalities occur at the center of the road other than designated crossings. It warrants adequate crossing facilities in the urban areas. Additionally, random and erratic pedestrian movements could be also a reason behind this high percentage. In this case, awareness and road safety knowledge among pedestrians should be disseminated effectively. Again, recent increasing of the fatalities due to head on collisions from 11% to 15% draws new attention to the road safety practitioners. Prohibition of wrong side driving and strict law enforcement is essential in these circumstances. Furthermore, the meeting points of feeder roads and primary roads in urban areas should be focused more to reduce this type of fatality. Channelization, traffic islands and necessary traffic control devices along with adequate street lighting could be taken as standard treatments for these points. This study also shows that the share of DMP crashes in total urban crashes has been decreased from 60% to 52% while there have not been found any significant changes in other major metropolitan cities. However, the share of the fatalities of other metropolitan cities has been increased significantly. The road environmental and engineering improvements by incorporating new approaches and methods are needed to be addressed to solve this emerging problem in these areas.

7. CONCLUSIONS

The major aspects considered in this paper are the traffic safety issues of Bangladesh's urban areas. The upward trend of urban road fatalities elicited from the study has emerged as a priority issue. Furthermore, higher pedestrian fatalities highlighted in this study demonstrate the urgency of safe pedestrian facilities in urban areas. The study found higher fatality rates at mid-blocks of the road network which substantiated the prevalent higher speed and careless user behavior in the causation of urban fatalities. These factors should be addressed while designing and setting safety measures. The study also compared the safety situation of the major metropolitan cities of Bangladesh. The comparative analysis revealed that the road fatalities in Dhaka metropolitan area should be taken as an emergency problem. The integrated and comprehensive approach of stakeholders is essential to solve this problem. Furthermore, policy for effective public transportation management, safe vehicles, safe pedestrian management and adequate research should be adopted for safe and sustainable urban transport for Bangladesh.

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ACHIEVING OPERATIONAL EFFICIENCY THROUGH INTEGRATION OF NON-MOTORIZED VEHICLE WITH IMPROVED BUS SYSTEM IN HERETOGENEOUS TRAFFIC CONDITION OF DHAKA

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ABSTRACT

Currently over 19 million people live in Dhaka, the capital city of Bangladesh, with annual growth rate of 4.2% and density of 47,000 people per square kilometer. The rapid rise of population along with mixed land use, growing motor vehical ownership rate and huge number of non motorized vehical on street resulted in huge travel demand, traffic congestion and air pollution..

Bus is still the main mode of public transportation in Dhaka, when metro rail (MRT-6) implementation is on-going. Like most other developing cities, public transport system at Dhaka lacks the much needed integration of an organized feeder service. The capital has an abundance of rickshaw in city roads since they are the most preferred mode of transportation especially for making short trips. Keeping in mind the escalation of multiple MRT and BRT projects, it would be ideal to use rickshaw as a feeder service of the public transport system. But over the last few years, the government of Bangladesh has implemented policies to phase out rickshaws from the major traffic spines of Dhaka City. The acceptability, rationality and implication of such 'solutions' are widely argued in Bangladesh. The argument is severe in Dhaka. The case study of this research considered social acceptability, economic response, fuel free ecofriendly characteristics and magnitude of role of rickshaw in sustaining the traffic and mobility needs of citizens.

With the backdrop and given the immense significance of the problem, this paper delineates an engineering design of non-motorized vehicle (NMV : rickshaw) integration to improved bus service system to increase its efficiency and focuses on challenges to be faced to implement it. A framework outlining improved physical design, infrastructure development and seamless flow of non-motorized transport is presented. The case studies for this research were conducted in Azimpur-Mirpur-Savar route considering it as an arterial road. A system has been designed whereby the rickshaws serve as feeder services to improved bus system for seamless flow passenger from any origin to bus station. Rickshaw will be restricted from major arterial and can only serve in collector and local road. Separate rickshaw lane near bus station (collector road), rickshaw parking space and pedestrian walkways facilities have been designed.

Keywords: *NMV integration, Feeder service, Sustainable, Heterogeneous traffic, Public transport.*

1. INTRODUCTION

Rickshaw is one of the principal means of transport in the urban areas of Bangladesh. But the capital city Dhaka is turning into chaotic, unsafe and immobile day by day due to chaotic management of rickshaws.

According to the Dhaka city corporations, there are 79,554 licensed rickshaws in the capital. However, the actual number is estimated to be around 1.1 million (Shafiq, 2017). According to the international standard, maximum 2.16 lakh vehicles can run in the city. But now, around 1.1 million rickshaws ply in the city daily along with the engine-driven vehicles. Sources of both city corporations said giving new licenses has remained stopped since 1980s. But there is a provision to renew the licenses after a scheduled period (Jibon, 2017).

Non-Motorized Vehicle (NMV) integration is one of the major issues regarding an efficient mass transit system. Some non-motorized profit can be monetize using methods commonly used by transportation agencies to evaluate policies and investments. These include congestion reductions, road and parking facility cost savings, consumer cost savings, energy conservation and emission reductions, and reduced accident risk to other road users. Thorough study is must for ascertain the number and pattern of vehicle for a city or town. But there is a crisis of study to ascertain the number and pattern of NMV in the city. Adaptive system of managing rickshaws are searched for many years and some measures have been taken by authority, albeit not very successfully. Restriction on rickshaw plying was imposed in some routes in the city in 2002. But the directive is debated among researchers, users, rickshaw pullers and even policy makers (Md. K. Rezaul, A.S Khandoker, 2019). To eliminate NMV from urban feeder roads or corridor cannot be a practical solution rather than to integrate it with mass transit system. Every location can be reached by walking, bicycles or rickshaws and is a fast and efficient means of transport particularly at the short distances. It is necessary for Dhaka to devise a functional and indigenous integration mechanism that is contextual to the traffic characteristics and travel demand while meditating the majority of the transport users. Public transport and NMV can be complementary. Integration of NMV with public transport can cancel out the negatives of both systems and provide efficient and sustainable door-to-door service to the bus or rail based commuters.
Conventional planning and evaluation practices tend to overlook or undervalue many non-motorized transportation benefits. Comprehensive evaluation methods are needed to identify the full benefits of policies and investments that improve non-motorized travel and encourage shifts from motorized to non-motorized modes. In this paper an attempt has been made to develop an effective NMV integration plan based on literature review and present scenario of transportation system of Dhaka city.

2. INTEGRATION OF NON MOTORIZED TRANSPORT WITH PUBLIC TRANSIT SYSTEM: RICKSHAW

The role of rickshaw in transportation sector of Dhaka city, the potential of rickshaw and improved bus transit system as a combined mode and the policy & benefits of modal integration has been recognised in literature.
Rickshaw, bicycle and walking are common forms of non-motorized transportation observed in the traffic composition of Dhaka, where Rickshaw is the most common and immensely used NMV mode for people of all ages. Factors contributing to rickshaw popularity include its socio-economic contribution as middle class and lower middle class people primarily depend on rickshaw for short trips; extensive physical network structure and access equity as almost all local and collector roads are accessible by rickshaw and fuel free nature yielding environmental sustainability. Most of the factors also correspond to transport sustainability for which the role of NMV in achieving such transport sustainability is tenable, especially in developing cities of Asia. Like many developing countries of Asia, the mixed land use distribution and lack of effective public transit mode of Dhaka resulted in short trip lengths, around 2 to 2.5 km (DUTP 1998 & Bari,M & Efroymson, D, 2007)) and where NMV already has a dominant share in the overall traffic composition. For balanced system

development public transport along with increasing motorized vehicle cannot be viable alternative to non-motorized transport in Asian cities (H. Kubota, T. Kidokoro, 1996). For achieving sustainable transportation and reduced climate change effects in developing countries a modal shift to zero emission vehicle like NMV is highly recommended by World Bank (World Bank-GEF, 2003).

2.1 Social Significance

Rickshaws plays a major socio-economic role at transportation sector in Dhaka. They are the preferred travel mode by vulnerable social groups - women, children and the elderly – due to their safety, security and comfort perspective. In addition, they provide an alternative to more costly motorized para-transit like taxis and auto rickshaws. Figure 1 shows the relation between trip distribution and household income. For low income group walking, rickshaw and bus are major mode of travel where rickshaw trips slightly decline with increase of income but still it is the highest modal share.

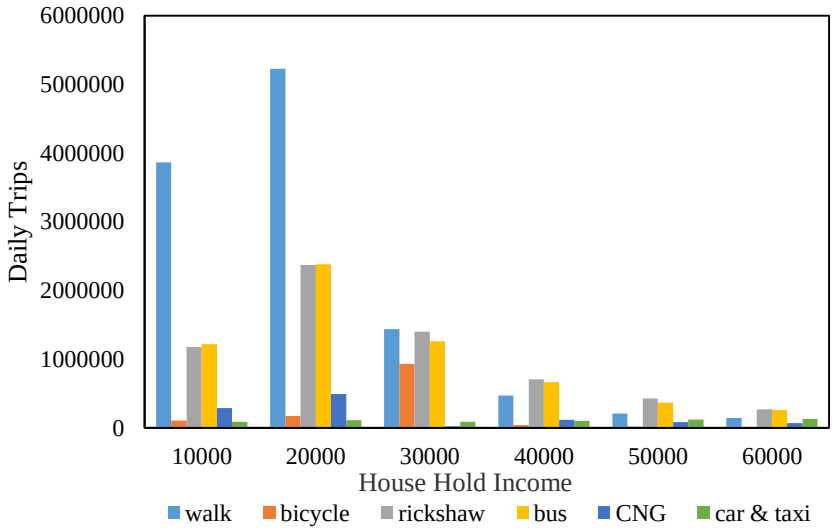

Figure 1: Trip distribution of different household income group
(Source: Derived from RSTP 2015 and critical analysis)

2.2 Sustainability Issue

Rapid increase of travel demand accelerates the demand for fuel in the transport sector which resulted in huge environmental pollution in developing countries (Singh, 2006). Cheaper fuel and fuel efficient technologies are not readily available in developing countries. The percentage of total consumption of petroleum products in India is about 50% (Singh, 2006) and in Bangladesh is about 54% (Rahman, 2009). The energy consumption per passenger-km is 0.91 mega joules (MJ) for light rail, 0.92 MJ for the average bus, 1.7 MJ for motorcycle, and 2.1 MJ for the average car (Banister et al., 1997). The estimated carbon footprint of the non-motorized transport is very low compared with all modes of motorized transport (ADB, 2010). Hence, future urban transportation policy should be oriented towards the promotion of mass public transport along with NMVs.

2.3 Modal Dominance

The latest BRT study (Advance Logistics Group Study, 2011) estimated that on an average day 21 million trips are taking place in Dhaka metropolitan area (Hoque et al., 2012). Despite the rapid growth of motorized traffic in Dhaka, non-motorized transport (walking and rickshaw in particular) still remains the dominant mode for the city dwellers who are mostly middle and low income groups. Rickshaw accounts for 34% of all person trips in Dhaka, which was 19% in 1998 and 61% of all rickshaw trips are made by people of middle income levels. Again, 40% of rickshaw trips are made by

women, children or people with goods, while other 20% of users are students (Louis Berger Group and BCL, 2005). With due attention, it can be the most demanding mode of transport in future Dhaka, particularly to the poor segment of the travellers.

2.4 Demand Responsive and other Operating Utility

The demand responsiveness nature, route choice flexibility and ease accessibility & widespread coverage of rickshaw compared to other para-transit like taxi or CNG, Car or Public Transit makes it more desirable as primary mode of travel for daily short trips (trip length ranges 3-4 Km or less) and supporting mode for long distance trips (trip to and from bus and metro station). In Dhaka, the majority of trips are short and local which accounts for three-quarters of total trips, with average trip lengths around 3.8 km (Hoque M. M. et al, 2014). For short distance trips, rickshaw is competitive in terms of overall travel time (when walking, waiting and transit time is taken into account) and is cheaper than traveling by auto-rickshaw, taxi or car. It can provide door to door services and high service frequency which promises the opportunity to integrate rickshaw as a feeder service to public transit system.

2.5 Increased coverage and efficiency of public transit system

The quality of public transport is determined not only by the quality of the main transport mode, but also by the before (access) and after (egress) modes. Access and egress are the weakest links in a public transport chain. The comprehensive interconnectivity of public transit and NMV is important to realize a trip and also to determine the availability and convenience of public transport (Krygsman, 2004). Initiatives aimed at improving access and egress hold potential to significantly reduce public transport trip time and are inexpensive options compared to the expensive infrastructure and vehicle enhancement alternatives frequently considered. Systematic modal integration has several benefits with regard to public transport which are crucially important for Dhaka. In Dhaka, non-motorized transport (walking, rickshaw, and bicycle) is currently a major component of the transport system. Murray et al (1998) estimates a 400m walk to public transit stops as the distance most people can walk comfortably under normal condition. Use of NMV as a feeder mode has seen to increase coverage of public transport as well as decrease the journey time.

2.6 Road Space Efficiency

The rise of automobiles i.e. car, CNG are significant in Dhaka city. Private cars take over 60-65% space of roads in the capital, while public transports use 7% only ((Rimon, 2017). But still the total number of automobiles are less than half (17%) that of NMV. However, the total road space occupied by car and CNG is almost equals to that of rickshaw (34% road space for automobiles compared to rickshaw's 38%), which means that the NMV uses half the road space than that of a car while transporting more people per vehicle than cars across all urban areas in Bangladesh (Rahman M. M. et al, 2008). The space efficiency of NMV gives operational flexibility and ease access to narrow roads. These features give the opportunity to connect public transit stations at major arterial road with single NMV lane serving as feeder.

2.7 Initiative towards Integration between Public Transit with NMV and Walk Mode

As a sustainable and environment friendly mode of transportation, cities in developed countries as well as developing countries are recently promoting non-motorized transportation as a successful urban development model. Cities with old concept of urban sprawl and car dependency exhibits paradigm shift towards transit oriented mixed land use development, where public transit mode (bus or metro) serve as main transit mode and NMV serves as feeder to the public transits. In Western Europe and Japan, the bicycle is the fastest growing and predominant access mode to suburban railways (Replogle 1992). In India, bicycles play a major role in access to commuter railways (Tiwari 2002). The Bogotá sustainable urban development models in recent years promoting NMV and public transport while restricting cars transport, which is considered by many researchers like Hidalgo (2002), Bari (2003) and Joewono & Kubota (2005) as highly successful. This model is under active consideration for implementation in a number of African developing cities like Cape Town Dakar and

Accra. Bogotá approach demonstrated how NMVs, pedestrian mobility and public transport facilities could be integrated for the development of sustainable transport system and is worthy of exploring to cities like Dhaka (Bari, 2003). The integration lessons from Delft, Netherlands, Tama New Town in Tokyo, which provides for pedestrian and bicycle access to town centres and railway stations completely segregated from vehicular road traffic, also gives literature background to develop efficient physical NMV integration plan with public transit system in heterogeneous traffic condition like Dhaka (World Bank 2002).

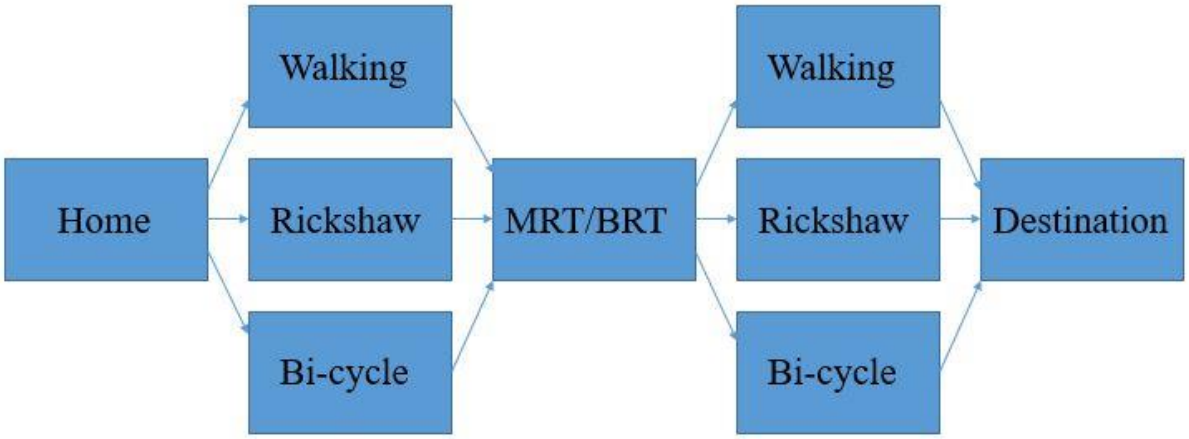

Figure 2: NMV integration with Public Transit System (BRT/MRT) Representation

2.8 Rickshaw Ban Policy and End Resul

Rickshaw restriction have been implemented by many cities i.e. Jakarta, Manila, Delhi, Dhaka etc. for either reducing congestion (smooth flow of motorized traffic) or enhancing the city image by eliminating traditional modes from the entire city or from certain roads. But evidence shows that, the purpose of smooth flow of motorized traffic or to get rid of congestion, is not served by simply restricting rickshaws (Gallagher, 1992; Barakat, 2004).

According to the recommendation of Dhaka Urban Transport Project (DUTP) (1998) and the National Land Transport Policy (2004), Dhaka City Corporation (the city government), in 2002 adopted plan to eliminate rickshaws from eight major roads of Dhaka, comprising a total of 120 km. The objective was to improve traffic flow, more space for motorized transport and creating some separate lanes for rickshaws. As a result, average monthly travel expenditure increased by 10%, travel hardship exaggerated for women and children, frequency reduced for social/recreational trips and inefficiency occurred in making a short trip. A comparative scenario between pre-rickshaw ban (2000) and post-rickshaw ban (2005) shows that, in automobile movement marginal improvement of speed (3.6%) and reduced travel time (5.7%) has been found but average travel times for buses have declined by 26.1% (Bari, M & Efroymson, D., 2007). Observing socio economic implication of such policy World Bank in 2005 revised its patronage to rickshaw restriction in Dhaka (DUTP, 2007).

NMV bans, which has been made over the years in different cities of Asia, experienced failure and decision reversal in most of the cases. Long after the ban, about 70% of residents in the low income neighbourhoods of New Delhi and Jakarta favour reintroduction of NMV (GTZ, 2009). In contrary, some cities have started favouring policies towards NMV movement- Bogota, Colombia from 2004;Yogyakarta, Indonesia from 2005 and few cities in India (Delhi, Agra, Chandigarh and Vrindavan) since 2002 (Gadepalli. S, 2006; Hidalgo. D, 2004; Zudianto, H. & Parikesit. D, 2009).

Rickshaw ban policy is a failure because it focuses on private motorized vehicles but not on broader mobility needs. But it is also true that the allowance to grow rickshaw without incorporating them in the overall transport system in a planned manner creates a chaotic traffic situation. Therefore rather

than simply pursuing policies to eliminate NMV, a better approach should be to integrate motorized and non-motorized vehicles as complementary rather than competitive forces in meeting the comprehensive transport demand. Rickshaws could play an important role of transport in Dhaka if they are modernized, planned properly, and the required facilities are provided (Rahman, et al. 2008; Gallagher, 1992; Rahman, 2011).

2.9 Principles of modal integration:

To implement integrated transportation system, the following aspects should be achieved in a project or in an area, preferably as many as possible:
• An integrated network,
• Integrated schedules,
• Physical transfer facilities,
• A common ticketing or fare integration system

3. OBJECTIVE:

The main purpose is to develop a plan for the integration of rickshaws with a pre developed improved bus system and thus promoting energy efficient and sustainable travel. The scope of the paper are:
(a) Explore the ability of rickshaws to serve as a feeder service of improved bus systems which is justified by literature review;
(b) Proposing a design for improved bus station that could assist for NMV integration by ensuring easy transfer between rickshaws and bus through their close/weather protected physical location;
(c) Integrated pedestrian walking facilities plan and
(d) Investigation on fare integration opportunity

4. METHODOLOGY

In this research, literature review has been done to understand standard NMV integration with public transit provision, previous studies and experiences of NMV integration. For traffic study data and distribution of traffic in future, Dhaka Strategic Transport plan (RSTP) by DTCA and Survey Report of Dhaka Metro Rail by DTCB has been considered as secondary data sources. According to literature rickshaw integration plan with improved bus system has been developed and presented with AUTOCAD drawing. In this paper, it has been assumed that rickshaw movement is not allowed in the study area Azimpur–Mirpur-Savar corridor, which is considered as an arterial road. Separate NMV lane is considered in collector road (collector road: which ends in arterial road), where NMV is used as feeder service to improved bus system and no lane restriction is imposed on local roads. 100% modal shifting is assumed from conventional bus and other para-transit to improved bus system on the study corridor.

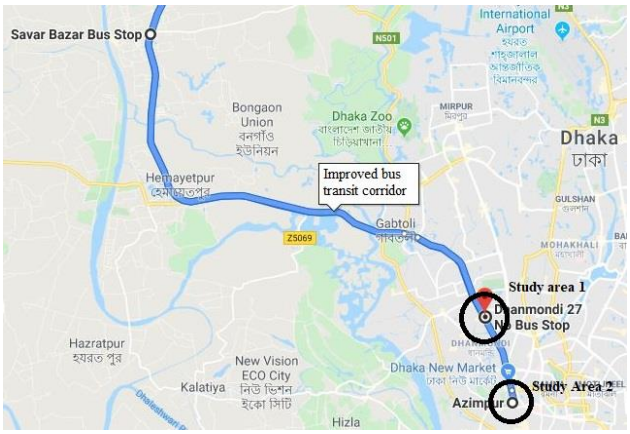

Figure 3: Azimpur–Mirpur-Savar route (major arterial) and study area (Azimpur and Dhanmondi 27)

5. STUDY AREA: AZIMPUR-MIRPUR-SAVAR CORRIDOR

Due to time and resource constraints, two potential integration area for NMV and improved bus system have been studied and one integration plan is presented in this paper. While selecting the locations, the socio-economic condition, demography, urban structure, and traffic situation have been considered as selection criteria. One location is in an unplanned and low-income residential area, developed along the major corridor of mixed traffic (azimpur); and the other location is a planned and high-income residential area with higher car ownership rate (Dhanmondi 27).

5.1 Location A: Azimpur

Azimpur is the starting point of Azimpur-Mirpur-Savar corridor. The right-of-way (ROW) of this corridor at Azimpur station is about 88 feet and provides three lanes in each direction. There exists a very busy and congested traditional bus station, a shopping centre called Dhaka new market nearby and also lots of busy hawker markets at Nilkhet end. This area basically deals with students and mid income people daily. The existing average vehicle composition at azimpur-new market circle is determined by field survey which shows the dominance of NMV mode on that area in figure-3.

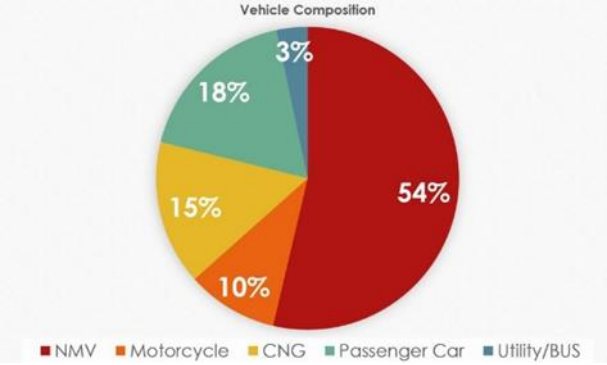

Figure-3: Classified vehicle count of sample data field at Azimpur station area

5.2 Location B: Dhanmondi 27

Dhanmondi 27 is located between dhanmondi 32 and Asad Gate on the azimpur- mirpur- savar corridor. This is a T section. The ROW of the corridor at dhanmondi 27 involves a road width of about 80 feet (29-30.5 m) and provides three lanes in both directions. This place is used as bus stoppage. Road users are mostly employees of mid income. The existing vehicular composition at Dhanmondi-27 circle is derived from Strategic Transportation Plan (RSTP) 2015, which shows the dominance of bus mode on mirpur route and less modal share of NMV in arterial route in Figure-4.

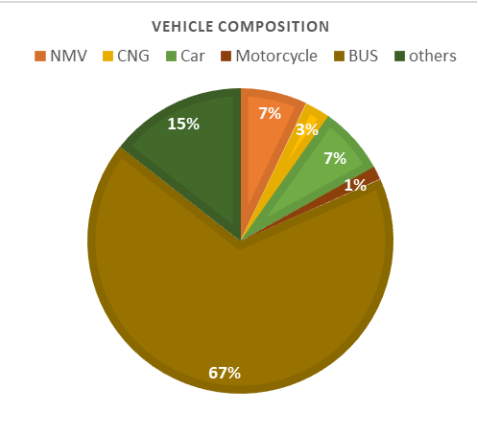

Figure-4: Vehicular composition at Dhanmondi 27
(Source: Derived from RSTP 2015 and critical analysis)

5.3 Traffic Demand:

The traffic demand for dedicated bus lane along 25 km Azimpur-Mirpur-Savar route is estimated by using conventional four step demand forecasting model, which has been commonly utilized and found to be effective in many cities around the world. For demand forecasting process circular area of 2 km radius around improved bus corridor was considered and demand was found 4.4 million daily household trips in 2018, with an increment of 5% rate considered (Rahman, 2018). Estimation of demand along study corridor is beyond the scope of this paper.

6. PROPOSED NMV INTEGRATION PLAN AT IMPROVED BUS STATION:

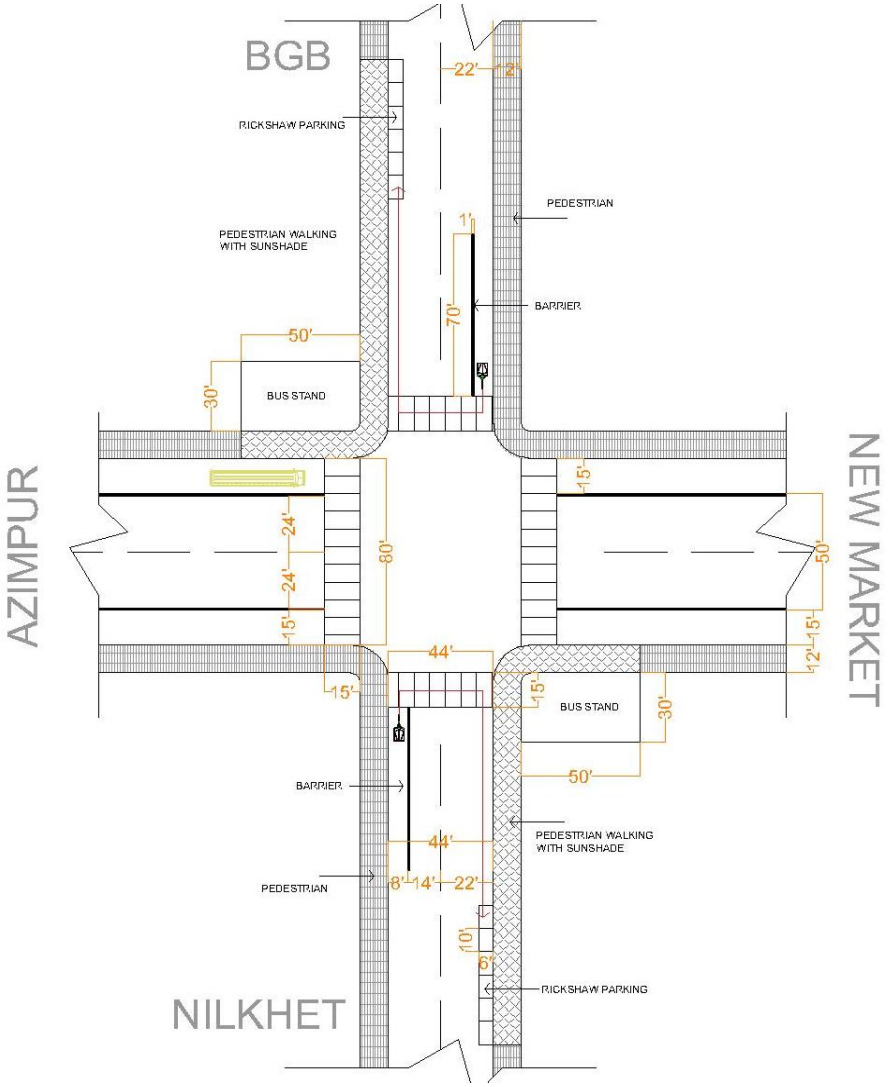

Figure 6: NMV integration plan with Improved Bus Station (Azimpur station)

6.1 Rickshaw Parking

To ensure least distance in modal interchange between bus and rickshaw, rickshaw parking is given in each approach road beside the arterial road. A parallel parking of 6-10 rickshaws on the left side of the road, at least 40 feet away from intersection has been designed (Figure-6 & 7). Two or more parking may create congestion so only one parking area is suggested. Parking is designed only for minor collector roads connected with major arterial, no rickshaw parking is allowed inside major arterial.

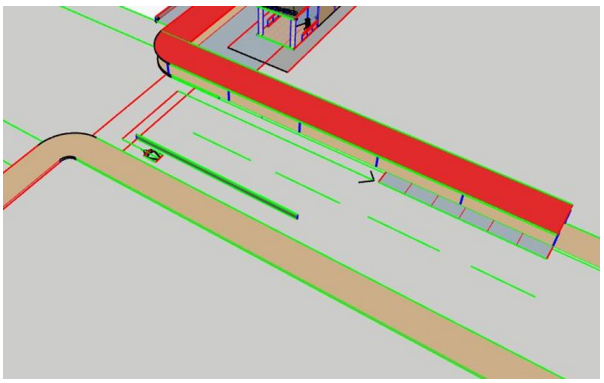

Figure-7: rickshaw barrier and rickshaw parking

6.2 Rickshaw Barrier Near Station

Physical barrier should be constructed for rickshaws approaching station to separate rickshaw flow from the other vehicle, as they will not cross the intersection to enter into major arterial. They will only drop passengers near the station and will go to the rickshaw parking if it has empty space to take return passenger or have to leave without any. An offset of 15 feet from the bus lane should be kept at the end of rickshaw barrier (figure 6 & 7)

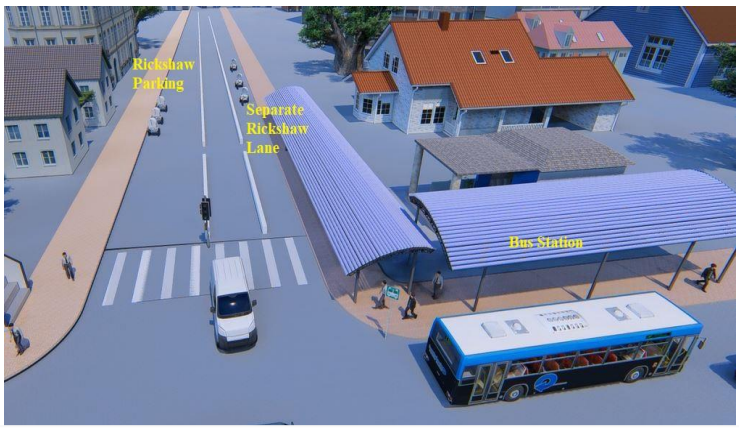

Figure-8: Demonstration of separate rickshaw lane, rickshaw parking, bus station and modal integration arrangement

6.3 PEDESTRIAN WALK-WAY AND SUN SHADE

• To ensure walking friendly environment for pedestrian foot-path of 10 feet width is considered near bus station and modal interchange area (Figure 7 & 8). No hawker, car parking and non-motor activities are not allowed near 20m of bus station.

• Footpath must be clean from garbage, brick/sand piles blocking the walkway

• A continuous sunshade from rickshaw dropping area to bus boarding/alighting area is provided.

As the dedicated bus lane is in curb side, foot over bridge is not needed. In collector road with NMV lane, Zebra crossing is used for pedestrian road crossing.

Figure 9: Pedestrian walkway facility near station

7. IMPLEMENTATION FRAMEWORK

Implementation of NMV integration in Dhaka is challenging because of the huge number of unregistered rickshaws, inadequate effective enforcement of law, absence of education and awareness among rickshaw pullers and unwillingness of pedestrians to follow rules. Engineering design can achieve limited success if these other conditions are not improved along with it.

Currently there are no designated rickshaw stand for picking up and dropping off passengers in Dhaka city. Rickshaws are found in 3 to 5 locations surrounding high ridership area like around shopping centres, bus stops and some are scattered in residential areas for potential passengers. If rickshaws are to act as feeder services for improved bus system, along with planning of bus stations to accommodate rickshaws, factors like discipline and organization of rickshaws in a tidy queue at station area and pre-determined fare structure to be addressed. Some shopping malls in Dhaka city have restricted zone for rickshaw queue but often they face a problem of ‘last-in first-out’ (when a rickshaw comes to drop passenger, came at last, but pick another passenger for another trip ahead of the waiting pullers); hence pullers will not follow the queuing.

Moreover, it should be noted that given the limited width of rights-of-way (ROW) of many roads in Dhaka city it might be very difficult to provide 40 or 50 spaces for rickshaws. Consequently, the rickshaws wait on streets occupying the carriage. Hence, the empty rickshaws are more problematic than a moving rickshaw because they occupy half of the carriage way. To stop extra rickshaws accumulating beyond the number of allowable limit should be executed through law enforcement as well as awareness generation among the pullers about the benefits they may get from following this. However, given the reality of more than three-quarter of existing rickshaws operating in Dhaka without a valid registration makes it difficult to enforce the law properly.

In Dhaka, almost 25 organizations are responsible for social and political activities rickshaw pullers including Dhaka Divisional Rickshaw and Van Owners Association, Bangladesh Rickshaw and Van Owner Federation, Metropolitan Rickshaw Owner League etc. These organizations must be afforded with responsibility to ensure awareness generation among rickshaw pullers. Again, rickshaw fare in a particular route or between major locations in Dhaka is already becoming determined at an acceptable rate through the market force itself, it would still create much bargaining between users and pullers and consequently end up creating delay in a queue. Pre-determined fare would be advantageous for smooth flow operation. Establishing large billboards with fare rates and periodic revision of fare rates is essential to keep this design functional.

8. CONCLUSION

Rapid urbanization, growth of vehicular population, unwarranted inflow of people in urban areas resulting in increase of urban poor are worsening the transport problem in Dhaka, like any other developing city in the world. But, it is a fact of life in Bangladesh that there are never, hardly ever, sufficient resources. So, to carry on progress in socio-economic field and prevent environmental pollution, a sustainable urban transportation system is required. The prerequisite for that is management and creating solutions for existing problems and implementation of them in infrastructure development and policy making.

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SENSITIVITY ANALYSIS OF HDM-4 IN BANGLADESH

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ABSTRACT

HDM-4 is a computer software for highway development and maintenance management practices developed by World Bank. It can be used in any locality of the world with the calibration of the parameters of HDM-4. And calculating the sensitivity of the parameters is a part of the calibration process.

The sensitivity of different road deterioration and maintenance input parameters are classified according to their impact elasticity in "Highway Development and Maintenance Management Model" (HDM-4 version-2). The more the impact elasticity, the more the sensitivity of the input parameters. And so the calibration factor of that parameter will differ more.

The aim of this paper is to quantify impact elasticity of some of the most important parameters of road deterioration and work effects model. In this paper, sensitivity analysed of the deterioration parameters which have been already classified in HDM-4 Volume 5 Sensitivity Class I, is provided. The way we are following here is the Traditional Ceteris Paribus (TCP) method in which by changing single input parameter and holding other parameters to be unchanged, the impact elasticity will be calculated. Impact elasticity is the ratio of the percentage change of specific result by the percentage change to individual input parameters of the pavement deterioration models. This study is executed by the project analysis of the HDM-4 application using TCP method and then the results are used to find the impact elasticity which is used for sensitivity ranking.

The parameters which are chosen from the sensitivity class-I for the deterioration sensitivity analysis are as follows: Adjusted Structural Number (SNP), Pavement Roughness and All Structural Cracking. Each parameter has been studied separately from real road sections of Dhaka zone. For the lack of sufficient data and time, only the data of Dhaka zone has been chosen which covers approximately 11% of National Highway.

The result of this paper shows that, for Dhaka zone, Adjusted Structural Number (SNP) has impact on Roughness. Roughness has impact on two common parameters: All Structural cracking and Mean Rut Depth. All Structural Cracking has impact on two common parameters: Wide Structural Cracking and Ravelled Area. All data has been taken from the RHD RMMS database tool.

Keywords: *Sensitivity analysis, HDM-4, Road deterioration, Impact elasticity, Traditional ceteris paribus method.*

1. INTRODUCTION

Bangladesh is a developing country of current world. Especially at the beginning of the 21st century, its economy is developing rapidly. With the improvement of its economic condition, the usage of transportation is increasing rapidly, so as the roads. As a result, most of the roads are now in very poor condition. Insufficient maintenance and rehabilitation of Bangladesh's road network has resulted in chronic congestion, with traffic growth outstripping capacity on strategic corridors. So it has now become very essential to take necessary steps for pavement maintenance and rehabilitation. This can only be done after the proper analysis of present condition and finding the major causes of the road deterioration. Evaluation of pavement is a requirement in the pavement management system (Haas, 1975).

Most of the highway and road projects are constructed with high budgets but it is a matter of regret that these roads deteriorate earlier than the expected time for the lack of attention to the maintenance at the right time. Prioritization of projects and their maintenance at the right time not only can improve the condition of the pavement, but also will economize the investment and optimize allocated budgets. For this purpose, Highway Design and Maintenance Management System (HDM-4) models are developed to manage analysis and make strategy for the road and highway projects. The software is designed to provide prediction of the performance and treatment programing of the roads, estimation of funds, budget allocation, project appraisal, also to study policy impacts and more applications for special cases (Bannour, 2015).

Effectiveness of these models is dependent on its ability and level of accuracy. Model predicts the performance of the pavement in which pavement performance is affected by the factors such as structural design, material properties, traffic situation, methods of the construction, operation cost of the vehicles, environment condition in which the project is located and maintenance policies (Giummarra, 2007).

HDM-4 is a prediction software which helps to predict the future road condition. But calibration of this software for local condition is a must. And the first step of calibration process is to do the sensitivity measurements of the input parameters. Sensitivity analysis of the individual input parameters of pavement deterioration models have a critical role in the prediction process, because proper concentration and emphasis can be given to the most sensitive and important parameters and less to less sensitive; by this way, loosing of time will be prevented (Zakaria, 2013).

To calculate the sensitivity of HDM-4 Deterioration models, the highest sensitive parameters which have been introduced by HDM-4 Manual (Volume 5 Section 4) are chosen (Bennett & Paterson, 2004). The following input pavement deterioration parameters were selected: Adjusted Structural Number (SNP), Roughness and All Structural Cracking. And The following parameters are the affected results of pavement deterioration models: Adjusted Structural Number (SNP), Pavement Roughness, All Structural Cracking, Wide Structural Cracking, Transvers Thermal Cracking, Raveled Area, No. of Pothole, Edge Break, Mean Rut Depth, Rut depth Standard Deviation, Texture Depth and Skid Resistance (Mushule, 2001).

2. METHODOLOGY

In HDM-4, the predictions sometimes or always differ from the field data or actual data. So it is very important to adjust the calibration factors for model prediction. HDM-4 is the new version of HDM-III and it has more calibration factors than HDM-III (Kerali & Odoki, 2000). So proper calibration factors should be determined for each local conditions and road networks for a better quality prediction. But first sensitivity analysis should be done for each parameters.

It is important for users to be aware of the general level of sensitivity of the model of each parameter so that appropriate emphasis is given to important parameters and less emphasis to second or third order

effects. The influences of individual parameters differ according to the particular parameter. And these variations occur under different circumstances.

Sensitivity analysis were conducted with the HDM-4 RUE (Road User Effects) and RDWE (Road Deterioration and Work Effects) sub-models so as to determine the levels of sensitivity and to rank them (Bennett & Paterson, 2004). It was determined by the **IMPACT ELASTICITY**, which is simply the ratio of percentage change in a specific result to the percentage change of the input parameter, holding all the other parameters constant at a mean value.

Different approaches can be used in sensitivity analysis. Among them, the traditional **CETERIS PARIBUS** method is used here. Here a single factor is changed while holding the other factors constant. On the basis of the analysis, four classes of model sensitivity have been establishes as a function of the impact elasticity. The higher the sensitivity, the more sensitive the model predictions (Jain, 2005). The Sensitivity classes of HDM are explained in the Table 1.

Table 1: HDM Sensitivity Classes (Bennett, 2004)

Impact	Sensitivity Class	Impact Elasticity
High	S-I	> 0.50
Moderate	S-II	0.20 - 0.50
Low	S-III	0.05 - .20
Negligible	S-IV	< 0.05

2.1 Data Collection

Because HDM-4 predicts future road performance from current and historical conditions, the reliability of its results depends upon how well input data represent actual conditions and how well HDM-4 predictions model actual behaviour.

Here the sources of data were Road Transportation and Highways Division and RMMS Database. And all the roads of Bangladesh are divided into three groups: National Highways, Regional Highways and Zilla Roads (Maintenance and Rehabilitation Needs Report of 2018-2019 for RHD Paved Roads 2018). Different Types of Road Coverage in Bangladesh are presented in Figure 1 below.

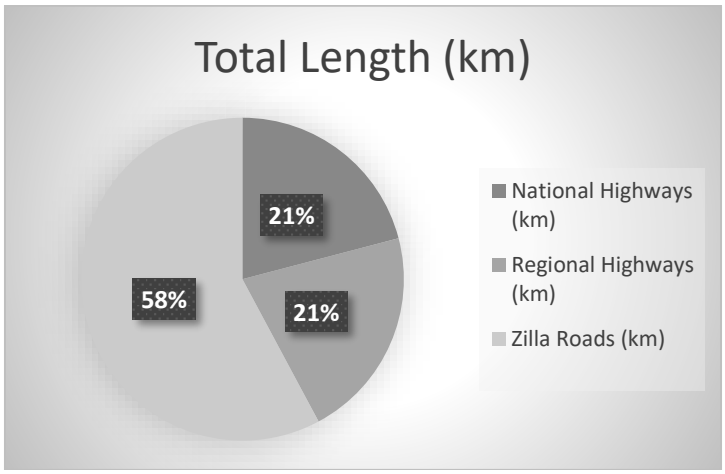

Figure 1: Different Types of Road Coverage in Bangladesh (Maintenance and Rehabilitation Needs Report of 2018 - 2019 for RHD Paved Roads 2018)

Again all the roads are divided into 10 zones by RHD department. The zones are: Barishal, Chittagong, Comilla, Dhaka, Gopalganj, Khulna, Mymensingh, Rajshahi, Rangpur and Sylhet (Road Maintenance & Management System [RMMS], 2018-2019). Different road zone lengths are presented in Table 2. The selected zone for this paper is Dhaka zone. Because appropriate amount of data for the analysis was found for this zone.

Table 2: Different Road Zone Lengths of Bangladesh (RMMS, 2018)

Road Zone	National Highways (km)	Regional Highways (km)	Zilla Roads (km)	Total (km)
Barishal	117.9	266.1	823.8	1207.8
Chitagong	422.9	442.4	1054.4	1919.7
Comilla	334.8	317.7	1419.4	2071.9
Dhaka	403.2	431.6	461.7	1296.5
Gopalganj	261	156.8	646.3	1064.1
Khulna	469.5	566.5	1426.6	2462.6
Mymensingh	302.5	385.9	1232.3	1919.7
Rajshahi	509	459.8	1149.9	2118.7
Rangpur	584.4	360.6	1739.6	2684.6
Sylhet	355.6	434.4	440.7	1230.7
Total	3760.8	3821.8	10393.7	17976.3

2.2 SENSITIVITY ANALYSIS

The purpose of sensitivity analysis is to find out the most important individual input parameters to pavement deterioration models. This will help the users to be aware of the most sensitive parameters, and then the emphasis can be put on collection of them.

Sensitivity of the individual parameters of pavement deterioration models in HDM-4 is determined by the impact elasticity. Impact elasticity is the ratio of the percentage change to a specific result by the percentage change to individual input parameters of the pavement deterioration models (Bennett & Paterson, 2004)

To find the sensitivity of the parameters, two methods are used in this sensitivity analysis: Traditional Ceteris Paribus (TCP) and Factorial Latin Hypercube (FLH) (Ognjenovic, 2015). In this paper, the 1st method is used for the analysis. Traditional Ceteris Paribus (TCP) is used in this paper and the purpose is to find the sensitivity of the following parameters to the pavement deterioration:

a) Sensitivity of *SNP* to pavement Deterioration;
b) Sensitivity of Roughness to Pavement Deterioration;
c) Sensitivity of All Structural Cracking to Pavement Deterioration;

To find out the exact sensitivity of individual inputs the case with no maintenance is the paper desired one, and any decision can only be taken according to those results. So here no maintenance case analysis is done in HDM-4 software.

2.2.1 Sensitivity Analysis of Dhaka Zone

In this paper, Sensitivity was done for Dhaka zone with respect to three input parameters separately. Sensitivity analysis was done using Traditional Ceteris Paribus method.

2.2.1.1 Sensitivity to Adjusted Structural Number (SNP)

Sensitivities of pavement deterioration parameters to the SNP are determined by using the Traditional Ceteris Paribus (TCP), in which two input values of SNP are iterated and then its impact elasticity to the deterioration parameters are calculated, and then ranked as the levels mentioned later in Table 3.

Table 3: Sensitivity to SNP for Dhaka Zone

Sensitivity to SNP after 10 years						
	1st Iteration		2nd Iteration			
Deterioration	Original Value	End Value	Original Value	End Value	% Change	Impact Elasticity
SNP	4.1	3.12	5.2	4.34	26.83	
Roughness	5.44	8.76	5.44	9.33	6.51	0.243
All Structural Cracking(sq. m)	4.6	6.21	4.6	6.21	0	0
Wide structural cracking (sq. m)	2.9	4.45	2.9	4.45	0	0
Transverse Thermal Cracking	0	0	0	0	0	0
Raveled AREA (sq. m)	3.48	6.44	3.48	6.44	0	0
No. of potholes	0.26	0.68	0.26	0.68	0	0
Edge break area (sq. m)	2.96	3.1	2.96	3.1	0	0
Mean Rut depth	2	2.09	2	2.1	0.48	0.074
Rut depth Standard Deviation	0.5	0.61	0.5	0.62	1.64	0.061
Texture depth	3	2.3	3	2.3	0	0
Skid Resistance	1	1	1	1	0	0

Level 1	Impact Elasticity greater than 0.5
Level 2	Impact Elasticity greater than 0.2 and less than 0.5
Level 3	Impact Elasticity greater than 0.05 and less than 0.2
Level 4	Impact Elasticity less than 0.05

So from the above table, the most sensitive parameters found are Roughness, Mean Rut Depth and Rut Depth Standard Deviation. The impact elasticity of the roughness is 0.243 with respect to SNP. It is in between 0.2 and 0.5. So it has a sensitivity of level 2. The impact elasticity of the other two parameters are in the range of 0.05 to 0.2. So these parameters have level 3 sensitivity.

2.2.1.2 Sensitivity to Roughness

Sensitivity of the Pavement Roughness to the pavement deterioration parameters are determined by using the Traditional Ceteris Paribus (TCP). In which two input values are iterated for Roughness and then their impact elasticity to the deterioration parameters are calculated. After that they are ranked as the levels mentioned later in Table 4.

Table 4: Sensitivity to Roughness for Dhaka Zone

Sensitivity to Roughness after 10 years						
	1st Iteration		**2nd Iteration**			
Deterioration	Original Value	End Value	Original Value	End Value	% Change	Impact Elasticity
Roughness	4.2	7.76	6.48	9.98	54.29	
SNP	4.8	3.45	4.8	3.45	0	0
All Structural Cracking(sq m)	4.6	5.92	4.6	7.94	34.12	0.629
Wide structural cracking (sq m)	2.9	4.45	2.9	4.45	0	0
Transverse Thermal Cracking	0	0	0	0	0	0
Raveled AREA (sq m)	3.48	6.44	3.48	6.44	0	0
No. of potholes	0.26	0.68	0.26	0.68	0	0
Edge break area (sq m)	2.96	3.1	2.96	3.1	0	0
Mean Rut depth	2	2.1	2	0.9	57.14	1.053
Rut depth Standard Deviation	0.5	0.63	0.5	0.65	3.17	0.0585
Texture depth	3	2.3	3	2.3	0	0
Skid Resistance	1	1.2	1	1.3	8.33	0.154

Level 1	Impact Elasticity greater than 0.5
Level 2	Impact Elasticity greater than 0.2 and less than 0.5
Level 3	Impact Elasticity greater than 0.05 and less than 0.2
Level 4	Impact Elasticity less than 0.05

So from the above table, the most sensitive parameters found are All Structural Cracking, Mean Rut Depth, Rut Depth Standard Deviation and Skid Resistance. The impact elasticity of the All Structural Cracking and Mean Rut Depth are greater than 0.5. So these parameters have level 1 sensitivity. The impact elasticity of Rut Depth Standard Deviation and Skid Resistance are in between 0.05 to 0.2. So they have a sensitivity of level 3.

2.2.1.3 Sensitivity to All Structural Cracking

Sensitivity of the Pavement Roughness to the pavement deterioration parameters are determined by using the Traditional Ceteris Paribus (TCP). In which two input values are iterated for All Structural Cracking and then their impact elasticity to the deterioration parameters are calculated. After that they are ranked as the levels mentioned later in Table 5.

Table 5: Sensitivity to All Structural Cracking for Dhaka Zone

Sensitivity to All Structural Cracking after 10 years						
	1st Iteration		**2nd Iteration**			
Deterioration	Original Value	End Value	Original Value	End Value	% Change	Impact Elasticity
All Structural Cracking	6	7.3	3.2	4.8	46.67	
SNP	4.8	3.66	4.8	3.79	3.55	0.076
Roughness	5.44	9.2	5.44	9.43	2.5	0.054
Wide structural cracking (sq m)	2.9	4.12	2.9	5.44	32.04	0.687
Transverse Thermal Cracking	0	0	0	0	0	0
Raveled AREA (sq m)	3.48	5.64	3.48	6.26	10.99	0.236
No. of potholes	0.26	0.68	0.26	0.68	0	0
Edge break area (sq m)	2.96	3.1	2.96	3.1	0	0
Mean Rut depth	2	2.1	2	2.1	0	0
Rut depth Standard Deviation	0.5	0.63	0.5	0.63	0	0
Texture depth	3	2.3	3	2.3	0	0
Skid Resistance	1	1	1	1	0	0

Level 1	Impact Elasticity greater than 0.5
Level 2	Impact Elasticity greater than 0.2 and less than 0.5
Level 3	Impact Elasticity greater than 0.05 and less than 0.2
Level 4	Impact Elasticity less than 0.05

So from the above table, the most sensitive parameters found are SNP, Roughness, Wide Structural Cracking and Raveled Area. The impact elasticity of Wide Structural Cracking is 0.687 with respect to All Structural Cracking. It is greater than 0.5. So it has a sensitivity of level 1. The impact elasticity of the Raveled Area is 0.236 which is in the range of 0.2 to 0.5. So it has a sensitivity of level 2. The impact elasticity of the SNP and Roughness are in the range of 0.05 to 0.2. So these parameters have level 3 sensitivity.

2.2.1.4.Changes of Road Conditions of Dhaka Zone over Time

A prediction of the road conditions has been made for Dhaka zone using HDM-4. The average roughness over time for Dhaka zone is shown in Figure 2 and the progression of damaged surface area over time is shown in Figure 3 below.

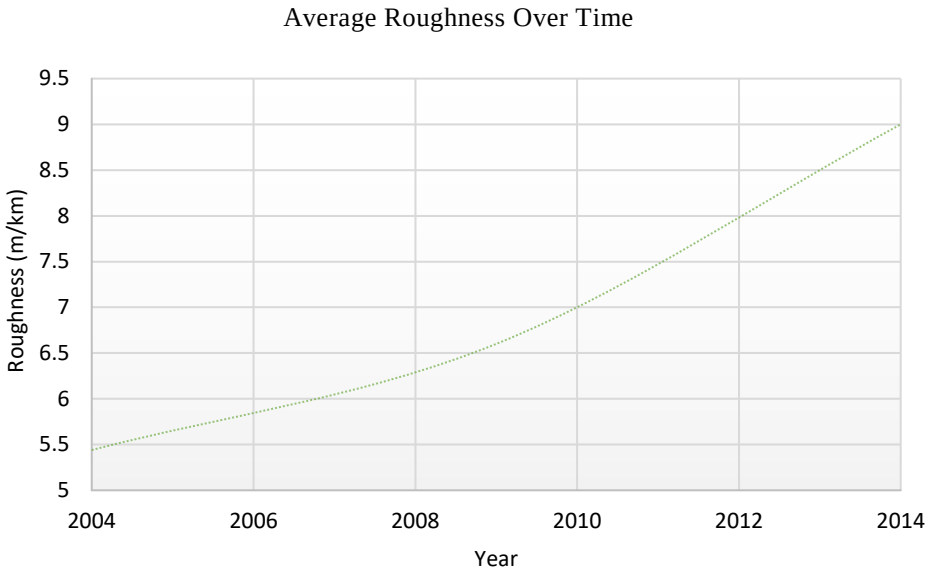

Figure 2: Average Roughness over Time

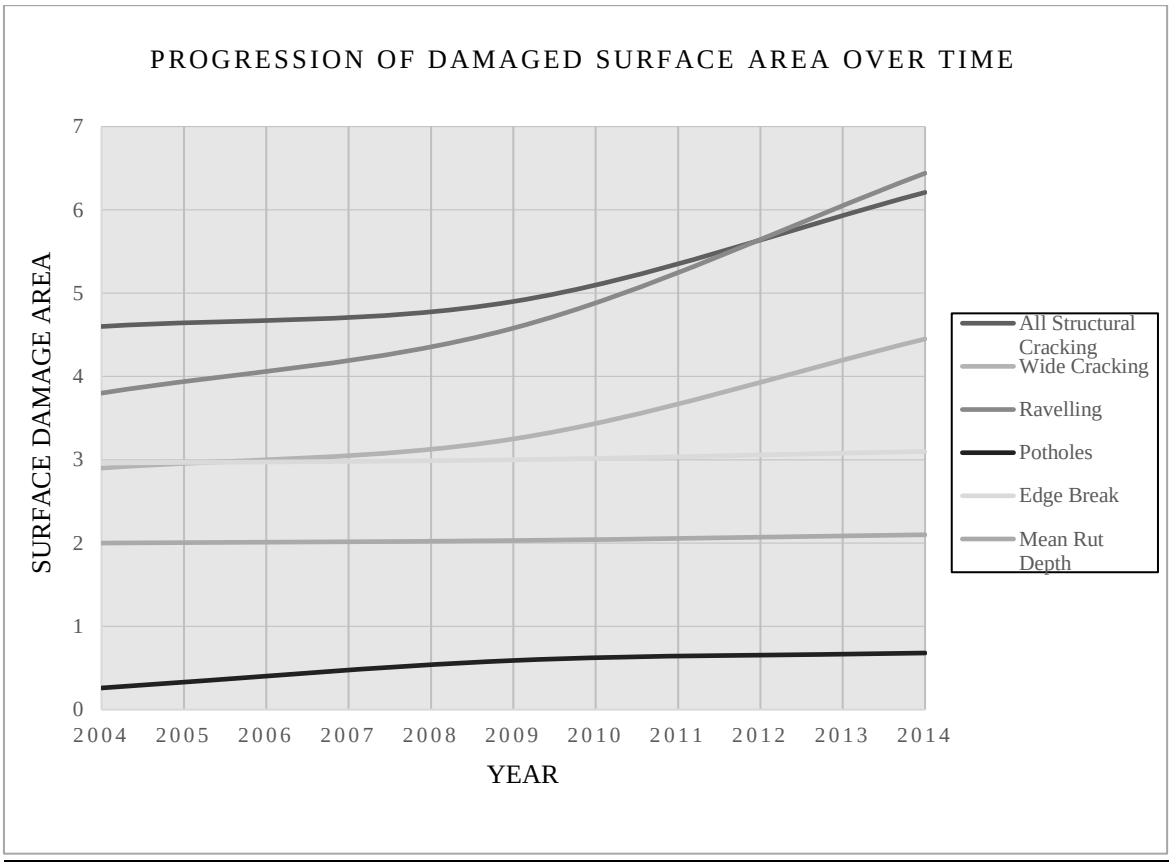

Figure 3: Progression of Damaged Surface Area over Time

3. ILLUSTRATIONS

3.1 Equations

$$\%\ Change = \frac{End\ Value_{1st\ iteation} - End\ Value_{2nd\ Iteration}}{End\ Value_{1st\ iteation}} * 100 \quad \text{(Kandary, 2016)} \quad (1)$$

$$Impact\ Elasticity = \frac{Percentage\ Change\ In\ specific\ result}{Percentage\ change\ in\ critical\ parameter} \quad \text{(Bennett \& Paterson, 2004)} \quad (2)$$

4. CONCLUSIONS

The whole paper, in a glance, is stated in the following:

1. Pavement deterioration models for sensitivity analysis are selected here from the hdm-4 manual (volume 5). The models selected here are introduced as the highest level of the sensitivity in the volume.
2. The results of the impact elasticity of deterioration model shows that adjusted structural number (snp) has impact on the following parameters for Dhaka zone: roughness (level 2 sensitivity), mean rut depth (level 3 sensitivity) and rut depth standard deviation (level 3 sensitivity).
3. The results of the impact elasticity of deterioration model shows that roughness has impact on the following parameters for Dhaka zone: all structural cracking (level 1 sensitivity), mean rut depth (level 1 sensitivity), rut depth standard deviation (level 3 sensitivity) and skid resistance (level 3 sensitivity).
4. The results of the impact elasticity of deterioration model shows that all structural cracking has impact on the following parameters for Dhaka zone: wide structural cracking (level 1 sensitivity), raveled area (level 2 sensitivity), roughness (level 3 sensitivity) and snp (level 3 sensitivity).
5. In this paper, we got the sensitive parameters of different sections. And these parameters need to be calibrated to get a better prediction for the future works. So, these sensitivity parameters would be helpful in finding the different calibration factors of the sub-model parameters.
6. All the other parameters do not need to be calibrated or 'do nothing' should be applied because the prediction of these parameters will not be affected by the critical parameters.

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PERFORMANCE EVALUATION OF ROUNDABOUT INTERSECTIONS IN DHAKA METROPOLITAN CITY, BANGLADESH

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ABSTRACT

Operational performance of intersections conduces remarkably towards the efficacy of the entire road network system of a city. The population in Dhaka Metropolitan City in Bangladesh is growing rapidly and as a result, the number of vehicles on the streets are increasing at an alarming rate. Due to this, traffic congestion and accident rates are also on the rise. In addition, poor and cursory planning of road networks leads toward an overall tedious and unsafe journey for a commuter. Traffic congestion has a direct impact on social, economic and environmental costs. It is imperative to acquire a thorough idea about the existing conditions of the intersections for adopting appropriate corrective measures. In this regard, this study concentrates on analyzing the operational performance of the roundabout intersections in Dhaka Metropolitan City in Bangladesh. This paper presents an evaluation of the capacity of three roundabouts located in Dhaka Metropolitan City; namely, Doyel Chattar, SAARC Fountain and Zero Point. The capacity and consquently, level of service were assessed using two methods: the empirical gap-acceptance technique that is adopted by SIDRA software and the analytical method by using Akçelik's Base Capacity Equation. The required geometric data (Island Diameter, Entry Width, Circulatory Lane Width, Entry Angle etc.) for the analysis and traffic volume data traffic volume data along with vehicle characteristics were collected during evening peak hour (4.30 pm to 5.30 pm) on a typical busy, working day from the aforementioned roundabouts. For conducting capacity analysis by the analytical method, critical gap and follow-up headway values were required to be estimated. The critical gap values for each lane in each leg of the roundabouts were evaluated based on the widely used Raff's Method. As estimation of follow-up headway is less intricate, it was measured directly from the field data. Afterwards, from the analysis using SIDRA software for the three roundabouts, the degree of saturation (v/c ratio) was found greater than 0.85 which indicated heavy traffic congestion. In developed countries such as, USA, UK, Germany, the roundabouts are designed as so that the v/c ratio does not exceed the saturation limit of 85%. The level of service (LOS) was found 'F' for all the roundabouts in this study. SIDRA also rendered a comprehensive lane-by-lane analysis for each roundabout. The equation based analytical method exhibited roughly similar results which further corroborated the analysis results. Finally, the results, on the whole, suggest that the main causes of over-saturation are the inadequate number of circulatory and entry lanes, lack of important geometric elements and high traffic volumes.

Keywords: *Roundabouts, SIDRA, Critical gap, Level of service.*

1. INTRODUCTION

A roundabout fall under the category of intersection that is distinguished by yield-on-entry approaches and circulation of traffic flow around a central island (clockwise in Bangladesh). Circulating vehicles are given priority but approaching vehicles at entries are compelled to wait for a gap in the circulating stream. Roundabouts are popular alternatives to signalized intersections owing to the fact that they are much more efficient in dealing with lower volumes of vehicles. Roundabouts are the best substitutions for intersections having two entry lanes that deal with heavy through and/or left traffic turning volumes (Sisiopiku and Oh, 2001). A roundabout, in various cases, is a more convenient option as vehicles are required to slow down while making their way around the central island but the vehicles entering the roundabouts, unlike stop and signalized intersections, are not required to stop. Evaluation of roundabout performance and gap acceptance behaviour is essential as it is directly linked to overall delay, accidents, level of service and operational cost. The FHWA, in the year 2008 have released the Guidance Memorandum on Consideration and Implementation of Proven Safety Countermeasures, distinguishing roundabouts as one of nine safety countermeasures (Lindely, 2008). In Dhaka Metropolitan City, Bangladesh, there are several roundabouts and have been in service for a few decades. However, hardly any of them have been assessed for their design and capacity or level of service. Therefore, it has become necessary to acquire an approximate idea about their current level of service and capacity so that proper solutions can be sought to minimize traffic congestions, accidents and delays. Extreme traffic congestion and delay is prevalent during the peak hours on the streets of Dhaka Metropolitan City. Hence, the traffic police are required to intervene to manage the road traffic, especially at roundabout intersections as they rely more upon driver behaviour. The situation is deteriorating with increased population growth rate and number of vehicles. Inappropriate road planning and defective geometric conditions of roundabout intersections impose a significant effect on capacity and efficiency of roundabout and traffic congestion.

2. LITERATURE REVIEW

Regarding capacity and delay analysis of modern roundabouts, quite a good number of comprehensive and novel research work have been conducted in the recent years. McDonald and Noon (1978) published a study on the impact of geometric factors to delay. A new equation was also theorized to estimate delays. In Akcelik's (1997) paper, SIDRA was employed for evaluating capacity of roundabout and conducting delay analysis in addition to traditional gap acceptance and queuing theory. Sisiopiku and Oh (2001) evaluated performance of different types of intersections and discussed in which cases roundabouts function better than controlled intersections. SIDRA was adopted for roundabout analysis in this study. Polus et al. (2003) asserted that throughout Europe and Australia, the use of roundabouts is prevalent, and are extensively being used in North America in lieu of the traditional intersections. Arroju et al. (2015) calibrated a simulation model using VISSIM and estimated the capacity of a roundabout. Dahl and Lee (2012) revealed that exiting traffic have considerable impact on the entry lane capacity. Ren et al. (2016) analyzed capacity of roundabouts with single lane using five different analytical models including SIDRA. The study introduced a new roundabout capacity (NRC) model based on the gap acceptance theory. The NRC model assesses single-lane roundabout capacity with inclusion of the effect of exiting traffic. In our study, we have used SIDRA, the most commonly used roundabout analysis software for analyzing the capacity of the roundabout junctions in the prevailing traffic condition. We have also employed the analytical method based on gap-acceptance theory, suggested by Akcelik et al. (1999) for the further assessment of capacity evaluation. Evaluation of critical gap is crucial for developing a capacity model based on gap-acceptance theory. As critical gap value is not determinable directly from the field, there exists more than 20 models around the globe for the estimation of critical gap. In practice, the most commonly used models are that of Raff et al. (1950) and Troutbeck (1992). Ashworth (2001) has also suggested alternative models for gap-acceptance analysis.We had to estimate critical gap and follow-up headway for implementing Akcelik Base Capacity Equation method. Hence, we had chosen Raff's Method to evaluate critical gap values for its wide acceptability and ease of applicability.

3. ANALYTICAL APPROACH & METHODOLOGY

The site survey was conducted in three roundabout locations in Dhaka Metropolitan City, namely, Doyel Chattar, SAARC Fountain & Zero Point Roundabout. These three roundabouts were chosen considering the most common attributes of the existing roundabouts in terms of size and traffic condition. As a matter of fact, a notable number of these roundabouts were built decades ago when traffic circle was a more popular option but at the present time, the drivers are obliged to operate conforming to modern roundabout traffic rules, even though some geometric elements of modern roundabouts are lacking. All the roundabouts in Dhaka Metropolitan City are more or less similar to each other, so, these roundabouts can provide a preliminary idea of the current state of all the other roundabouts.

3.1 Employment of SIDRA Software

The software tool that was used for capacity analysis is SIDRA, Version 8.0. PLUS. SIDRA is a comprehensive software that can be used for design and assessment of different categories of intersections, such as, roundabouts, signalized intersections, yield-sign control intersections (Akcelik, 1996). This is the most widely used software tool in the USA for roundabout performance analysis. The geometric data required by SIDRA include: island diameter, inscribed island diameter, circulatory roadway width, average lane width at entry, number of circulatory and entry lanes, entry angle and entry radius. These geometric parameters were measured by using a measuring tape and applying concept of geometry. The measurements were taken as accurately as possible since road geometric design is a major factor that impacts overall capacity and safety during operation. Along with geometric data, traffic volume data were collected from these intersections during the peak hour (4.30 pm to 5.30 pm) on a sunny, working day under prevailing traffic and road condition as well as the direction of movements of the vehicles.The geometric data obtained are summarized in Table 1 and Table 2.

Table 1: Summary of Roundabout Geometry

SL No	Name of Roundabout	No. of Legs	No. of Circulatory Lanes	Island Diameter (m)	Circulatory Roadway Width (m)	Inscribed Circle Diameter (m)
1	Doyel Chattar	4	2	30	15	45
2	SAARC Fountain	5	2	26	23	49
3	Zero Point Roundabout	4	2	6	21	27

According to Roundabout Information Guide, FHWA (2000), Doyel Chattar and SAARC Fountain fall under the category of Urban Double Lane Roundabout and Zero Point Roundabout is a typical Urban Compact roundabout. Entry lane width and number of entry lanes are two geometric elements that have a direct effect on the capacity of a roadway. Another important parameter is entry angle. It is the angle measured between the entering and circulating traffic streams for each entry at a roundabout. Larger entry angles may cause vehicles crashing into the center-island and are also uncomfortable for drivers to negotiate, reducing capacity in the long term.

Table 2: Summary of Legs of Roundabouts

SL No.	Name of Roundabout	Name of Legs	No. of Entry Lanes	Average Entry Lane Width (m)	Entry Angle (Degree)	Entry Radius (m)
1	**Doyel Chattar**	Secretariat Road	2	5.0	35	39
		High Court Road	2	5.0	21	26
		University Street (from DMC)	2	4.5	33	17
		University Street	2	4.5	32	51
2	**SAARC Fountain**	Airport Road	2	6.5	39	9
		Panthapath Road	2	5.7	26	17
		Link Road	2	5.5	48	30
		Sonargaon Road	1	4.8	22	49
		Kazi Nazrul Islam Ave	2	5.9	25	15
3	**Zero Point Roundabout**	North South Road	2	5.7	30	11
		North South Road (from Paltan)	2	6.0	28	25
		Abdul Gani Road	2	5.3	39	18
		Bangabandhu Ave	2	6.4	21	7

On the streets of Dhaka city, different categories of vehicles can be observed. Heavy vehicles, for example, bus, truck, pulled rickshaw and cycle van and light vehicles, such as, car, CNG three-wheelers, motorcycles, pickup etc. traverse the same segment of road at the same time. In most cases, separate lanes for buses and bicycles are absent. Hence, it disrupts the normal traffic flow and forces drivers to violate traffic rules. In SIDRA, the standard passenger car equivalent factor used for heavy vehicles and light vehicles were 2.00 and 1.00 respectively. Rickshaws and cycle vans are slow moving vehicles and in general, have PCU value of 2.00 in Bangladesh according to MoC (2001). Therefore, they had been considered as heavy vehicles in the analysis. In this study, SIDRA has been calibrated as so that the simulated traffic resembles the actual traffic in the field. The vehicles counted are compiled as depicted in Table 3. The data were collected for one-hour duration during 4.30 pm to 5.30 pm.

Table 3: Traffic Volume at Peak Hour at the Roundabouts

Name of Roundabout	Heavy Vehicles				Light Vehicles				
	Bus	Truck	Rickshaw & Cycle Van	Total	Car	CNG three-wheeler & Motorcycle	Pickup	Bicycle	Total
Doyel Chattar	13	-	2172	2185	1293	1539	58	97	5172
SAARC Fountain	208	21	-	214	1982	3275	50	107	5857
Zero Point Roundabout	281	19	1968	2268	886	2064	12	36	5266

Finally, both geometric and traffic data were entered as inputs into SIDRA software and analysis was run.

3.2 Application of Akcelik's Base Capacity Equation

Analytical approach is a more suitable means. One of the advantages of this approach is that the gap acceptance technique provides a logical premise for the evaluation of capacity. In addition, gap-acceptance theoretically correlates traffic interactions at roundabouts with the availability of gap in the circulating traffic streams as stated by Taekratok (1998). The capacity equation requires determination of the circulating flow to calculate the capacity of each entry lane. This equation is largely based on the follow-up headway and critical gap values, inclusive of bunching parameters. The drawback of this analytical procedure is that it is only calibrated for roundabouts having two circulatory lanes.

$$Q_e = \left(\frac{3600}{\beta}\right) * \left(\left(1-\Delta_c * q_c\right)+\left(0.5*\beta*\Phi_c*q_c\right)\right) * e^{-\lambda*(\alpha-\Delta_c)} \quad (1)$$

Where,
Q_e = Capacity of a single entry lane (pce/hour)
β = Follow-up Headway (seconds/vehicle)
α = Critical gap (seconds/vehicle)
Δ_c = Intrabunch headway (seconds/vehicle)
q_c = Circulating flow at entry (pce/hour)
Φ_c = Proportion of unbunched vehicles in the circulating stream
λ = Parameter in the exponential arrival headway

3.3 Determination of Critical Gap

In terms of a roundabout, the critical gap is the minimum gap a vehicle entering a roundabout accepts between two circulating vehicles. It cannot be directly measured in the field as any gap that is accepted by the driver is larger than the critical gap. Hence, one of the first and simplest technique for estimating critical gap - Raff's method (Raff et al., 1950) was used. After their definition, the value of critical gap can be estimated graphically by finding the point of intersection between percentage of rejected and accepted gap times. The example below demonstrates the method adopted for determining the critical for the left in the leg "University Street" of Doyel Chattar. Table 4 presents the percentage of vehicles that rejected or accepted each corresponding gap size. The graph plotted based on these data are shown in Figure 1. In the similar manner, critical gap was estimated for each lane for all three roundabouts. The data are tabulated in Table 5.

Table 4: Raff's Method Reduced Data for Left Lane (University Street)

Gap Size (sec)	Percent Rejected	Percent Accepted	Count Rejected	Count Accepted
≤ 2	85	15	103	18
3	55	45	43	35
4	47	55	42	47
5	36	64	32	58
6	22	78	8	30
7	14	86	2	12
≥ 8	8	92	2	15

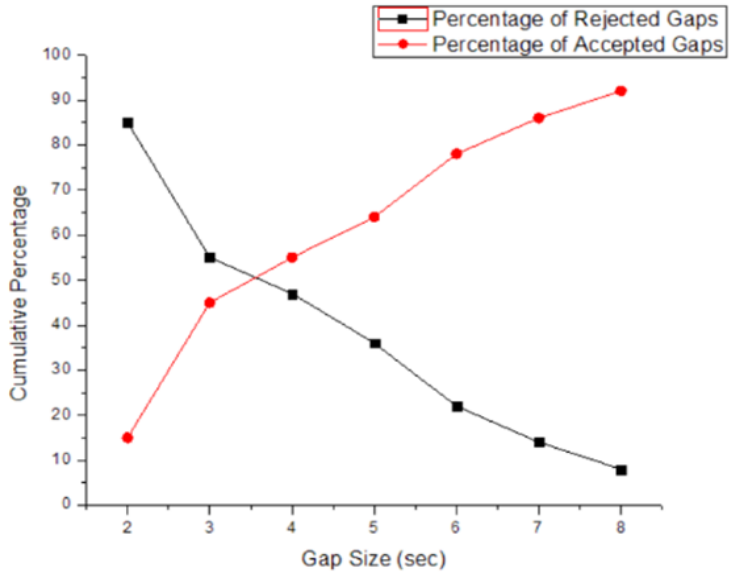

Figure 1: Determination of Critical Gap using Raff's Method for Left lane (University Street)

3.4 Determination of Follow-up Headway

Follow-up headway is another pivotal parameter that controls the entry capacity. In contrast to critical gap, it can be measured directly from the present traffic in the field (Ren et al., 2016). All follow-up headways were determined for each roundabout. The follow-up headway was calibrated by taking a mean value of all measured follow-up headway for each lane in a roundabout. A sample size of 20 vehicles for each lane in each leg of the roundabouts was chosen for this evaluation. The estimated values of critical gaps and follow-up headway are presented in Table 5.

Table 5: Critical Gap and Follow-up Headway values for each lane of the roundabouts

Name of Roundabout	Name of Leg		Critical Gap, α (sec)	Follow-up Headway, β (sec)
Doyel Chattar	Secretariat Road	Left lane	3.33	3.10
		Right lane	3.25	2.94
	University Street (from DMC)	Left lane	4.20	3.30
		Right lane	4.14	3.27
	University Street	Left lane	3.55	3.00
		Right lane	3.50	2.97
	High Court Road	Left lane	3.57	3.20
		Right lane	3.42	3.00
SAARC Fountain	Airport Road	Left lane	3.20	3.00
		Right lane	3.09	2.89
	Link Road	Left lane	3.00	2.80
		Right lane	2.82	2.53
	Panthapath Road	Left lane	3.46	3.20
		Right lane	3.00	2.64
	Kazi Nazrul Islam Ave	Left lane	2.85	2.60
		Right lane	2.71	2.51
	Sonargaon Road		2.48	2.87
Zero Point Roundabout	Abdul Gani Road	Left lane	3.64	3.35
		Right lane	3.60	3.29
	North South Road (from Paltan)	Left lane	3.92	3.60
		Right lane	3.85	3.50
	North South Road	Left lane	3.40	3.63
		Right lane	3.35	3.55
	Bangabandhu Avenue	Left lane	3.83	3.53
		Right lane	3.70	3.50

3.5 Step-by-Step Example of the Formulation

In order to find the capacity of each lanes of leg "University Street" (Northbound approach) of Doyel Chattar, first, it is required to determine the circulating flow at that approach.This traffic flow comprises the southbound lefts, and eastbound lefts and throughs, along with U-turns, with the exclusion of northbound. The equations fitted for the outside and inside lane are shown in the following example. Circulatory flow, VOL'_c = 989 pce/hour

For right lane, $q_{cr} = \sum_d VOL'_c * P_c * \Psi$ (2)

$q_{cr} = 989*0.8*1.075 = 851$ pce/hour

And for left lane, $q_{cl} = \sum_d VOL'_c * \Psi$ (3)

$q_{cl} = 989* 1.075 = 1063$ pce/hour

Now, the Equation (1) is used to obtain the capacity of each entry lane for the given approach.

$$Q_e = \left(\frac{3600}{\beta}\right) * \left(\left(1 - \frac{\Delta_c * q_c}{3600}\right) + \left(\frac{\beta * \Phi_c * q_c}{2*3600}\right)\right) * e^{-\frac{\lambda}{3600} * (\alpha - \Delta_c)}$$

$$Q_{er} = \left(\frac{3600}{2.97}\right) * \left(\left(1 - \frac{1.2*851}{3600}\right) + \left(\frac{2.97*0.55*851}{2*3600}\right)\right) * e^{-\frac{851}{3600} * (3.50 - 1.2)}$$

$$Q_{el} = \left(\frac{3600}{3.00}\right) * \left(\left(1 - \frac{1.2*1036}{3600}\right) + \left(\frac{3.00*0.55*1036}{2*3600}\right)\right) * e^{-\frac{1036}{3600} * (3.55 - 1.2)}$$

Thus, Q_{er} = 640 pce/hour and Q_{el} = 544 pce/hour

The values of the criteria varied for each entry lane. It is observed that follow-up headway and critical gap hold lower values for the right entry lane compared to the left since it takes a driver longer to get into the inside lane. The determined values for α and β are 3.50 and 2.97 for the right entry lane, and 3.55 and 3.00 for the left entry lane. These values are in seconds per vehicle. Φ_c is the proportion of unbunched vehicles in the circulating stream. It is a calculated variable in the above equation. In order to maintain simplicity for users, this was kept as a fixed parameter with the value of 0.55 for this formulation. Δ_c denotes intrabunch headway. Akcelik recommends a value of 1.2 seconds for circulatory roadways with two lanes assuming equal flows. Additional equations may be used for unequal flows. However, to keep it less intricate, value of 1.2 was used. λ is a parameter in the exponential arrival headway. According to Tanner (1962), its value can be considered as equal to the circulating flow. λ is to be converted to pce/sec, by dividing it by 3600.

4. RESULTS & DISCUSSIONS

4.1 SIDRA Analysis Results

A summary of the results from capacity analysis is shown in Table 6. The performance of the roundabouts was measured on the basis of Degree of Saturation (v/c ratio) and the level of service (LOS) had also been determined. From the analysis, it is noticed that all the roundabouts exhibit high degree of saturation. Higher traffic flow may have led to higher v/c ratio. All three roundabout intersections provide LOS "F". In reality, the capacity of the roundabouts depend on the performance of the approaches of legs. In Table 6, the maximum v/c ratio among the approaches has been represented.

Table 6: Summarized SIDRA Capacity Analysis Results

SL No.	Name of Roundabouts	Total Vehicle Flow (veh/h)	Effective Capacity (veh/h)	Degree of Saturation (v/c ratio)	Average Delay (sec)	LOS
1	**Doyel Chattar**	5172	3604	1.957	240.0	F
2	**SAARC Fountain**	5857	4503	2.482	256.3	F
3	**Zero Point**	5266	3296	3.039	401.1	F

In the following Table 7, summarized output results for each leg of the roundabouts have been shown.

Table 7: Summarized SIDRA Capacity Analysis Results on the Approaches or Legs

SL No.	Name of Roundabout	Name of Leg	No. of Entry Lanes	No. of Circulatory Lanes	Entry Traffic at Legs (veh/h)	Capacity at Legs (veh/h)	v/c
1	**Doyel Chattar**	High Court Road	2	2	1961	1002	1.957
		University Street	2		798	783	1.027
		University Street (from DMC)	2		1065	867	1.229
		Secretariat Road	2		1168	952	1.278
2	**SAARC Fountain**	Airport Road	2	2	1577	1073	1.469
		Link Road	2		1027	1122	0.916
		Panthapath Road	2		1778	899	2.482
		Kazi Nazrul Islam Ave	2		1401	1156	1.212
		Sonargaon Road	1		188	253	0.745
3	**Zero Point Roundabout**	Abdul Gani Road	2	2	1055	507	2.081
		Bangabandhu Ave	2		1340	526	3.039
		North South Road	2		1685	1115	1.511
		North South Road (from Paltan)	2		1668	1148	1.454

By examining the v/c ratio from the above Table 7, it is easy to identify which legs are in critical condition. From the table, it is conspicuous that the number of entry lanes at each leg are inadequate to carry such high amount of traffic during the peak hour. The value of 0.85 is recommended in many countries such as USA, Australia, United Kingdom and Germany where roundabouts are designed to operate at no more than 85 percent of their estimated capacity. When the demand exceeds the capacity (v/c ratio greater than 1.0), traffic flow becomes unstable and excessive delay and queuing is anticipated. Number of entry lanes and average entry lane width controls capacity at legs substantially.

4.2 Results from Analysis by Akcelik Base Capacity Formula

According to the analytical method of capacity analysis, gap-acceptance data were collected and as described earlier, capacity was analyzed for each lanes and legs. All the results from the calculation are shown in Table 8, Table 9 and Table 10.

Table 8: Capacity Evaluation of Doyel Chattar Roundabout

Name of Legs	Entry volume (pce/h)	Circulatory Volume (pce/h)	q_{cr}	q_{cl}	Capacity on right lane (pce/h)	Capacity on Left Lane (pce/h)	Capacity at leg (pce/h)	v/c ratio
High Court Road	2653	851	732	915	685	588	1273	2.084
University Street (from DMC)	1482	901	775	969	547	448	995	1.489
University Street	981	989	851	1063	640	544	1184	0.828
Secretariat Road	1424	1013	871	1089	675	546	1221	1.166

Table 9: Capacity Evaluation of Zero Point Roundabout

Name of Legs	Entry volume (pce/h)	Circulatory Volume, (pce/h)	q_{cr}	q_{cl}	Capacity on right lane (pce/h)	Capacity on Left Lane (pce/h)	Capacity at leg (pce/h)	v/c ratio
Abdul Gani Road	1364	1412	1214	1518	439	338	777	1.755
Bangabandhu Ave	1669	1390	1195	1495	442	310	752	2.219
North South Road	2158	655	563	704	678	620	1298	1.663
North South (from Paltan)	1861	702	604	755	658	540	1198	1.553

Table 10: Capacity Evaluation of SAARC Fountain Roundabout

Name of Legs	Entry volume (pce/h)	Circulatory Volume, (pce/h)	q_{cr}	q_{cl}	Capacity on right lane (pce/h)	Capacity on Left Lane (pce/h)	Capacity at leg (pce/h)	v/c ratio
Airport Road	1362	844	725	907	781	437	1218	1.118
Panthapath Road	1450	1290	1109	1387	669	413	1082	1.340
Link Road	1301	1005	864	1080	848	586	1434	0.907
Sonargaon Road	221	2229	-	-	-	-	423	0.522
Kazi Nazrul Islam Ave	1133	1167	1004	1255	808	647	1455	0.779

As the PCU values differ from the SIDRA standard PCU values and as the analytical method mainly depends on the gap-acceptance parameters, the results obtained from SIDRA and the equation based method vary to a certain extent. However, from the tables 8, 9 and 10, we can see that quite a few

numbers of legs at those roundabouts tackle high traffic volume and end up in over-saturated condition (v/c ratio > 1.00).

5. CONCLUDING REMARKS

The capacity analysis results for the three selected roundabouts in Dhaka Metropolitan City indicate that most of the roundabouts are subjected to heavy congestion or are over-saturated (v/c ratio > 1.00). From the inspection in the actual field conditions, it was observed that traffic police generally were required to get involved with regulating the traffic, especially, during the peak hour. This is because heavy traffic at that time cause drivers to maneuver in a haphazard manner, violating traffic rules and causing unnecessary delay. Slower moving vehicles, for example, rickshaw and cycle vans noticeably affects delay and congestion in the roundabouts. However, during off-peak hour, a comparatively lighter traffic volume is observable at Doyel Chattar roundabout. The study revealed that the major problems are concerned with inadequate road width, small number of entry lanes and circulatory lanes, high traffic flow and unbalanced traffic on the approaches. These circumstances are not recommended for proper roundabout operation. The geometric elements of these roundabouts in Dhaka Metropolitan City should be altered and built accordingly as endorsed in design manuals of modern roundabouts since they prove to ensure reasonable capacity and traffic safety. Adequate number of entry and circulatory lanes and optimal entry angle based on size and purpose of roundabouts should be provided carefully. Kerbs and islands in the entries should be modified to allow greater entry flare. By gradually widening the approach (flaring) through the entry geometry, a greater capacity at the leg can be achieved. Besides, there are a number of important characteristic geometric elements of ideal roundabout, such as, deflection, splitter islands etc. that are not present in all of the roundabouts. Deflection is the most important geometric element which forces drivers to regulate their speed and to avoid collision between neighboring leg entry vehicles. The splitter islands on the roundabout approaches provide cues to the driver as to the entry angle and radius of the approach of the roundabout. In addition, dividers can prevent the drivers from frequently changing the lane which is one of the major causes of accident. Considering that the collected data for the analysis was limited to only three roundabouts, the proposition asserted in this research gives a substantial but preliminary insight on the geometric and operational defects of the roundabouts situated at Dhaka Metropolitan City, the most populous city of Bangladesh. However, this study also effectively helps to provide a detailed capacity estimation for planning new roundabouts or capacity improvements.

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EVALUATING THE LEVEL OF TRAFFIC CONGESTION AT GOALANDO MORE INTERSECTION IN RAJBARI

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ABSTRACT

Traffic congestion is an unfortunate reality that every major city has been affected. Long-standing traffic congestion specially in peak hour creates a tremendous situation. A growing urban area creates an undeniable problem in daily life with traffic as it has become a common scenario both in developing and developed countries. Bangladesh is one of them, suffering traffic congestion with unendurable proportions. The traffic congestion is rising faster because of socio-economic and population growth in Faridpur and Rajbari city. In order to evaluate the level of congestion at Goalanda More Intersection, this study was performed. This study was conducted by counting manual traffic volume. Geometric measurement was also accomplished to fulfill the study objectives. In this study, the level of traffic congestion in Goalanda More Intersection was evaluated by comparing the traffic volume of entry and exit legs and the level of service was measured by VISSIM software. The Level of Service was different for several legs of this intersection. Some of these were mostly congested. Moreover, there was also a different time of peak period for different approaches. The number of Auto Bike was also noticeable for its importance to travel a shorter distance. On-field observation, the heavy weighted and slow-moving vehicles are mainly responsible for congestion. A large number of slow-moving vehicles and scattered on-street parking which occupy the road, reducing roadway capacity and generating congestion. It is found that the traffic flow of the Ferryghat approach was higher than the others.

Keywords: *Transportation system; Traffic congestion; Level of service; Mobility; Unplanned deeds.*

1. INTRODUCTION

The role of transportation has become very important in a situation of rapid urbanization, which is increasing over time in the population of cities in relation to the region's rural population. Since the end of the Second World War, there have been rapid urbanization and economic growth activities in third world cities, resulting in high demand for mobility there. Urban transport in the third world countries is characterized by huge traffic growth along with a shortage of adequately maintained transport facilities, traffic system inefficiency and settlement structure thereby causing congestion. Urban transport technology mix and misuse in these countries are reflected in the coexistence of motorized and non-motorized modes often resulting in congestion and accidents. Similarly, ineffective traffic management and enforcement are reflected in the ignorance and disrespect for traffic rules and regulations *(*Aparajita, 2015).

One of the major problems in cities and municipalities in Bangladesh is traffic congestion. It makes life in cities uncomfortable for people. Every year governments spend huge budgets to solve this problem. The number of traffic is increasing day by day in Rajbari and Faridpur city. That's why traffic congestion occurs at major intersections in these cities and the congestion problem is rising faster. In order to assess the level of congestion at Goalanda More intersection, this study was carried out. Many urban centers in the southern part of Bangladesh from inadequate facilities that could ensure smooth urban movement.

According to the Joint Transport Research Centre of the Organization for Economic Cooperation and Development (OECD) and the European Conference of Ministers of Transport (ECMT), "Cities and traffic have developed hand-in-hand since the earliest large human settlements. The same forces that draw inhabitants to congregate in large urban areas also lead to intolerable levels of traffic congestion on urban streets and thoroughfares." (ECMT 2007:5). This captures the relationship between urban cities and traffic congestion as well as the world-wide dimension of the problem of traffic congestion in urban cities (Gabriel., 2013).
So far, the conventional approaches to traffic management have not been able to make the desired impact, judging from the traffic congestion patterns in Rajbari and Faridpur City.

1.1 Objectives of the Study

The congestion problem at major intersections and road sections in Rajbari and Faridpur City are growing faster. The specific objectives of the study are as follows:

- To identify the peak periods of traffic flow of the day in the study intersection.
- To measure the Level of Service (LOS) of the intersections by using VISSIM Software.
- To identify the most congested road and period of congestion at the study intersection by comparing the traffic volume of entry and exit legs.

1.2 Scope and Limitations

The scope of this study was limited to the Goalanda More intersection of Rajbari and other road sections and intersections of the city were not included in this study. Furthermore, the analysis was a segmented study rather than an area-wide or regional study. Hence, it focused mainly on the road segments at the entry of the intersection and the relative effect of the consecutive intersection was not discussed. Since the main objective of the study is to evaluate the Level of Service by VISSIM Software, the congestion management procedures and measures were not discussed as it needs a wider and comprehensive exploration.

The study was conducted by PTV VISSIM-11 (student version) where simulation time is limited to one hour.

2. LITERATURE REVIEW

Many researchers and professionals in the field of transportation agree that road traffic congestion is an ever-growing problem and the global phenomenon of major cities throughout the world. Further to this Lomax (1997) showed that traffic congestion is expanding toward the suburbs as commercial activities are being pulled out of the central business districts (Lomax et. al., 1997; Maitra et. al., 1999). In fact, it is almost certain that traffic congestion will also get worse during at least the coming decades mainly due to the increasing population number and the growing economy of nations. Traffic congestion is a negative output of a transportation system which has many detrimental effects on the performance of the road network, the traffic flow, the society, the national economy and the environment. Maitra et. al. (1999) summarizes some of the negative effects of traffic congestion as; considerable loss of travel time, higher fuel consumption, more vehicle emission and associated environmental and health impact, increased accident risk, stress and frustration on commuters and greater transportation cost.

Further to the above; many more researches have been conducted by different researchers and professionals to develop measuring parameters and models (Maitra et. al., 1999; Lomax et. al., 1997; Cottrell, 2001). So far, different congestion measures and models have been proposed and used to determine the extent, severity and duration of congestion and also transport professionals are still developing different models for congestion prediction and simulation (Moran et. al., 2010).

2.1 Peak Hour

Peak hour is a part of the day during which traffic congestion on roads and crowding on public transport is at its highest. Normally, this happens twice every weekday; once in the morning and once in the afternoon or evening, the times during which most people commute. The term is often used for a period of peak congestion that may last for more than one hour (Wikipedia, 2019).

The Peak Hour Factor (PHF) compares the traffic volume during the busiest 15-minutes of the peak hour with the total volume during the peak hour. It indicates how consistent traffic volume is during peak hour. The peak hour factor is used in HCM capacity and level of service analysis to account for the variation in traffic volumes during the peak hour (hcmguide, 2019)

The peak hour factor can then be computed as follows:

PHF = (Peak hour volume in an hour)/(4*Peak 15 min volume in the peak hour)

PHF $\leq$ 1

2.2 Definition of traffic congestion

Traffic congestion is a condition on transport networks that occurs as usage increases and is characterized by slower speeds. When traffic demand is great enough that the interaction between vehicles slows the speed of the traffic stream, this result is some congestion.

2.2.1 Types of Congestion

The three types of congestion are outlined by Brownfield et al (2003) as recurrent congestion, nonrecurrent congestion, and the pre-congestion state, as shown in Table1below. These types are based upon the frequency and predictability of the congestion – factors which will impact on driver behavior. The costs associated with each type of congestion are likely to be different. Non-recurrent congestion costs may be more difficult to quantify due to the inherent sparseness of adequate amounts of data needed – it may be argued that the costs could be higher as drivers have not been able to take the possibility of congestion into account in planning their journey or alternatively the costs may be less dramatic as drivers pre-developed strategies for coping with congestion will not have come into play. Some routes are increasingly subject to non-recurrent congestion however, for example with accident black spots. In these cases, drivers may 'learn' an expected cost in terms of likely delay and successful contingency routes. The Pre-congestion state will carry some costs similar to those of

congestion, including loss of control over drivers' environment, deterioration in the environment and other impacts.

Table 1: Type of Congestion

Congestion type	Definition
Recurrent congestion	This occurs at regular times at a site. It can be anticipated by road users that normally use the route during those times. Examples of recurrent congestion are morning or evening peak hour congestion or congestion due to a regular event such as a street market on a particular day each week.
Non-recurrent congestion	This occurs at non-regular times at a site. It is unexpected and unpredictable by the driver and is normally due to incidents such as accidents, vehicle breakdowns or other unforeseen loss of carriageway capacity.
Pre-congestion (Borderline congestion)	Occurs where free-flow conditions breakdown but full congestion has not yet occurred. This may occur either side of the time period when congestion occurs or upstream or downstream of congestion that is already occurring.

Source: (Brownfield, 2003).

2.2.2 Causes of Traffic Congestion

Different researches and reports identified many interrelated factors that cause traffic congestion in developed and developing countries where the road network and road users behavior are different" (Systematics, 2005) Accordingly, the results showed that in the United States of America the cause and their percentage share are; bottleneck (40%), traffic incidents (25%), work zone (10%), bad weather (15%), poor signal timing (5%) and special events contribute 5% of the traffic congestion.

Adedimila "(Aworemi, 2009) classifies the major causes of traffic congestion in Lagos metropolitan into five and the summary of his discussion is shown in Table 2.

Table 2: Major Causes of Traffic Congestion in Lagos Metropolitan

Item No.	Factors	Causes
1	Social & Economic factors	Rising population number together with the rural-urban migration. Unplanned land use which results in unidirectional traffic flow especially at pick hours Increased car ownership in line with the improved living standard.
2	Road factors	A smaller number of lane & Narrow road with Lack of sidewalk which results in occupation of traffic lanes by pedestrians Distressed pavement which results in reduced travel speed Uncontrolled traffic Intersections.
3	Vehicle factors	Size of vehicle Age of vehicles.
4	Human factors	Perception of drivers Perception of pedestrians.
5	Accident	The severity, number, and location of the accident.

Source: (Aworemi, 2009)

Traffic congestion occurs for limited road capacity, road parking, un-integrated urban planning, and lack of mass transit, accident, poor vehicle condition, and roadside illegal trade.

2.2.3 Congestion Indicators

It is essential to define or have indicators of the presence of congestion in the system. According to many other researchers, LOS is the best empirical indicator of congestion in the transport system.

2.2.4 Level of Service (LOS) as Congestion Indicator

The objective of the High way Capacity Manual is to provide a consistent system and techniques for the evaluation of the quality of service on highways and street facilities. HCM presents LOS as an easy-to-understand methodology of analysis and performance measure for single homogenous road segments.

HCM doesn't specify the boundary LOS for the congestion state but clearly states that the LOS F is defined as the worst state of flow and represents congested flow and A is defined as a congestion-free flow state. Though there are some reports using another level of service (D and E) as congested flow, LOS C is generally accepted as a state of traffic flow and hence LOS is the most appropriate congestion indicator.

The LOS criteria of HCM are summarized in Tables 3.

Table 3: Typical Highway Level of Service (LOS) Rating.

LOS	Description	Speed (km/hr)	Flow (Veh/hr/ln)	Density (Veh/km)
A	Traffic flows at or above the posted speed limit. Motorists have complete mobility between lanes.	Over 96	Under 700	Under 8
B	Slightly congested, with some impingement of maneuverability. Two motorists might be forced to drive side by side, limiting lane changes.	91-96	700-1100	8-13
C	The ability to pass or change lanes is not assured. This is the target LOS for most urban highways	86.5-91	1100-1550	13-19
D	Speeds are somewhat reduced; motorists are hemmed in by other vehicles. Typical urban peak-period highway conditions.	73.5-86.5	1550-1850	19-26
E	Flow becomes irregular, speed varies and rarely reaches the posted limit. This is considered a system failure.	48-73.5	1850-2000	26-42
F	Flow is forced; with frequent drops in speed to nearly zero km/hr. Travel time is unpredictable.	Under 48	Unstable	42- max

Source: HCM-2000.

3. METHODOLOGY

The intersection with three different approaches was selected where all vehicles are moved freely. The approaches are Faridpur leg, Rajbari leg and Ferryghat leg of the intersection.

3.1 Research Approach

The research approach in this thesis involves quantitative approaches. Quantitative data and analysis were used to determine the level of service of the intersection and to measure the congestion level. Observations and direct field measurements were the main sources of quantitative data. The level of congestion at the considered Intersection and road sections were evaluated by Observations, collected relevant data and subsequent analysis.

The congestion indicator parameters used in this research were the Level of Service (LOS). The LOS criterion was according to HCM-2000 and determined using the widely used **VISSIM** software.

3.2 Data Collection

Data collection is very important to find and understand the flow pattern, determine the peak periods. To attain the objectives of the paper, several data were collected in the type of quantitative such as traffic volume data, geometric data, and vehicle characteristics as it is extremely required to determine the Level of Service.

3.2.1 Traffic volume

The selected vehicles are Buses, Microbuses, Trucks, Car, Auto Bike, Motorcycle, and Bicycle. Directional traffic volume was calculated by counting the number of vehicles in both directions. And it is conducted with a manual traffic data collection system at the same time on each lane of each leg. Traffic volume count was conducted in vehicle per 15 min interval. Bicycles, Auto Bike was taken

as slow-moving vehicles. Traffic volume count was collected for a period of 10 hours (8.00 am to 6.00 pm) on the study day.
The traffic volume in the passenger car unit and the movement of traffic on each approach leg are also essential for the analysis. The passenger car equivalent factors are used to convert the number of vehicles in the passenger car unit. The PCU values given in the geometric design of Highways (MoC, 2010) are given in Table 4.

Table 4: PCU of Different Types of Vehicles in Bangladesh (MoC, 2010).

Categories	PCU
Passenger Car	1.00
Light Good Vehicle	1.00
Bus	3.00
Truck	3.00
Auto Rickshaw/ Motorcycle	0.75
Rickshaw/ Van	2.00
Bicycle	0.50

3.2.2 Geometric Data

Field measurement was done to collect data of geometric features of the road section. The geometric data of road sections were measured by using tape. These include a number of lanes, lane width, configurations of lanes, mattered and unsettled shoulders. These measures were done for the intersections whose level of service is going to be determined.

3.2.3 Speed calculation

From the selected site, average spot speed was measured by using Speed Radar Gun. Different speed was found for several vehicles tabulated bellow.

Table 5: Spot Speed of different vehicles

Vehicle	Spot Speed(km/hr)
Truck	17
Bus	21
Microbus	24
Car	23
Autobike	12
Bike	25

3.3 Description of study location

Road transport has been serving the major mode of transport for both national and international transport services. Goalanda more intersection has connected with two major cities and Daulatdia ferry ghat, connecting the southern part of Bangladesh with Dhaka. This channelized T-intersection accommodates mostly heavyweight vehicles, carrying goods and raw materials of various industries which have a tremendous impact on socio-economic conditions in the southern part of Bangladesh specially Faridpur and Rajbari.

Figure 1: Goalanda More intersection (Google, 2019).

Goalanda more intersection is located in south-western Bangladesh at 23°41'02.7" N 89°41'55.5"E.

4. RESULTS AND ILLUSTRATIONS

The peak hour volume was identified by the gathered quantitative data analysis with the trend of traffic flow within the day. The level of Service for the identified intersection was analysed by using **VISSIM** software.

4.1 Directional traffic volume analysis

Directional traffic volume data counted at 15min interval in all legs of this intersection for 10 hours (8.00 am to 6.00 pm). Traffic volume analysis is conducted for both directions for three legs. The road sections were considered:

- Faridpur approach
- Ferryghat approach
- Rajbari approach

Directional traffic volume analysis of each leg is discussed bellow.

Faridpur approach

In figure 2 it is seen that the most crossed vehicle is truck in both Faridpur to intersection and intersection to Faridpur. As the intersection connects the southern part of Bangladesh with Dhaka city, so it is the most used intersection to shipping heavy and light goods by tuck. It is also seen that the common vehicle is Auto Bike. People like to travel on Auto Bike from one place to another in a shorter distance. And it is getting popular day by day. It was seen that the car and microbus were very small in number. Motor Cycles are used in a mentionable number. Bus as Public transportation is also taking place to congest the road.

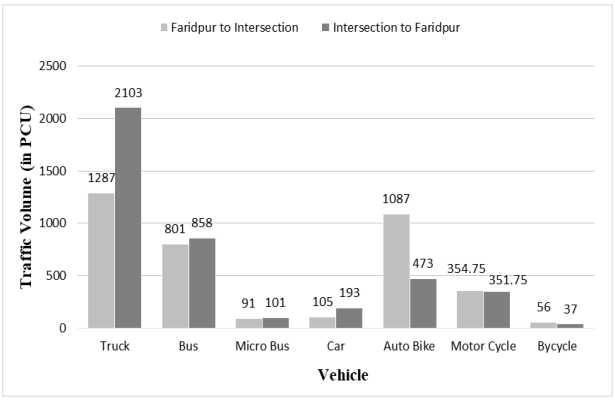

Figure 2: Traffic volume by vehicle type

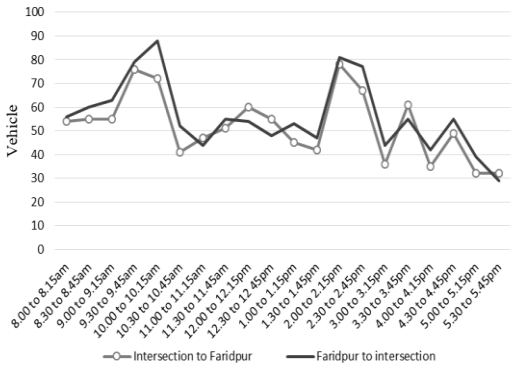

Figure 3: Traffic volume (veh/15min)

From figure 3 it is seen that both intersection to Faridpur and Faridpur to intersection approach, traffic volume is increasing after 9.00 am and it is maximum from 9.00 am to 10.00 am In the morning and 2.00 pm to 3.00 pm in the afternoon.

4.1.1 Ferryghat Approach

At the intersection of Ferryghat road shown in figure 4, it is seen that the number of the truck is also leading here in both Ferryghat to intersection and intersection to Ferryghat road. The number of busses is also dominating here. Auto Bike and motorcycle are also in considerable numbers.

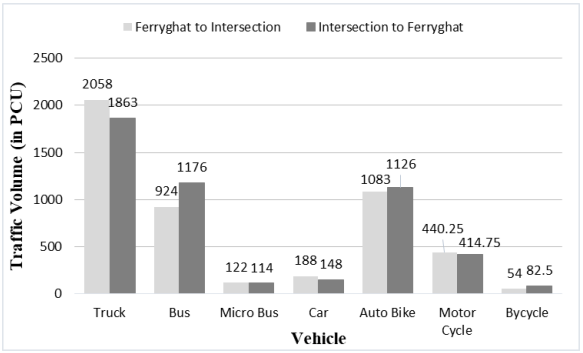

Figure 4: Traffic volume by vehicle type

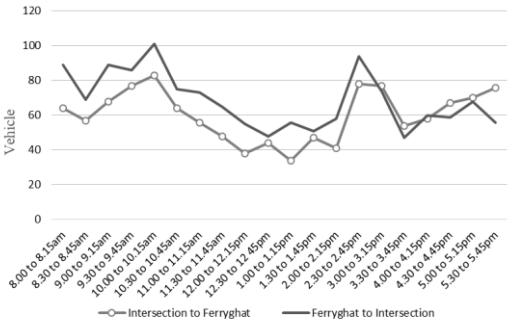

Figure 5: Traffic volume (veh/15min)

In figure 5 it is seen that intersection to Ferryghat and Ferryghat to intersection approach traffic volume are increasing after 9.00 am and maximum from 9.30 am to 10.30 am in the morning and 2.00 pm to 3.00 pm in the afternoon.

4.1.3 Rajbari Approach

From figure 6 it can be seen that Auto Bike is the most common vehicle in both Rajbari to the intersection and intersection approach to Rajbari. People like to travel by Auto Bike in one place to another quickly. Microbus and cars are very small in number. People like to travel in the Motor Cycle also.

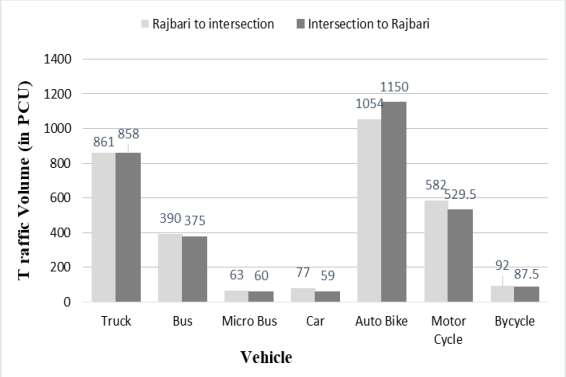

Figure 6: Traffic volume by vehicle type

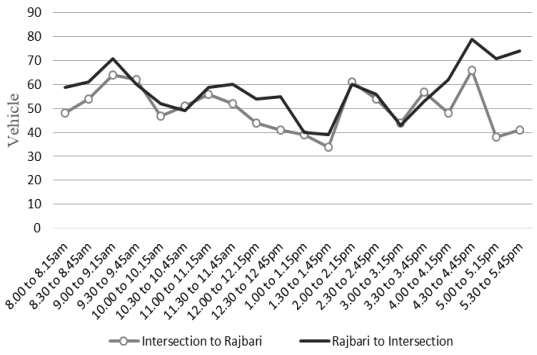

Figure 7: Traffic volume (veh/15min)

Figure 7 shows that traffic entry and exit on this intersection almost the same. Here the peak period is 8.30 am to 9.30 am in the morning and 4.00 pm to 5.00 pm in the evening. And it is noticeable that the overall traffic volume is less than the previous two approaches.

4.2 Estimation of Level of Service

In order to justify the level of traffic congestion, the analysis was made using VISSIM software. The analysis was performed with the left-hand driving rule and matric unit. As only the Level of Service will be determined for an indicative result leaving the other outputs of the program, calibration wasn't taken as an issue for the purpose. In order to conduct the analysis of the geometric and directional hourly traffic volume data were prepared as an input for the program as summarized below in Table 6. However, recommended and default values were taken for other input data.

Table 6: Level of Service for each route of Goalanda more intersection through **VISSIM**

Approach Route	Level of Service
Faridpur to Ferryghat	C
Faridpur to Rajbari	D
Ferryghat to Faridpur	A
Ferryghat to Rajbari	A
Rajbari to Faridpur	C
Rajbari to Ferryghat	E

Overall Level of Service of Goalanda more intersection was found C.

4.2 Comparison of total traffic volumes among the entry and exit legs

Figure 8 shows the comparison of the traffic volume counted for 10 hours in both directions on each leg. It shows that the highest traffic volume on the direction of the intersection to Ferryghat and the second-highest traffic volume is Ferryghat to intersection direction. From the figure, it is clear that Ferryghat's leg from the intersection carries the huge traffic volume from two other approaches. Rajbari leg shows the lowest volume of traffic throughout the day time in both lane Rajbari to intersection and intersection to Rajbari.

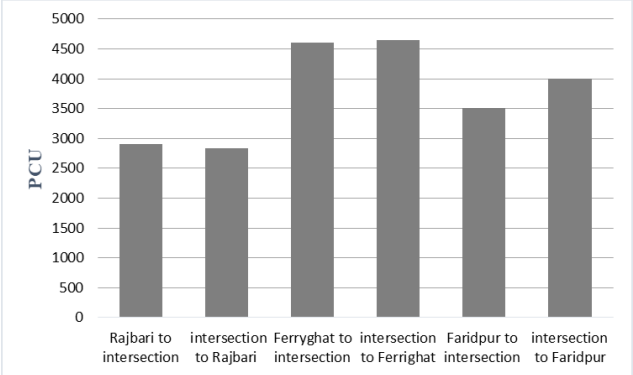

Figure 8: Total directional vehicle volume at the intersection.

Figure 9 shows the directional traffic volume pre 15 min for exit legs. And it shows that the maximum traffic volume in the intersection to ferryghat leg among the three legs. the highest traffic volume is nearly 85 vehicles per 15 min during the morning peak period it is greater than 75 vehicles during the afternoon period.

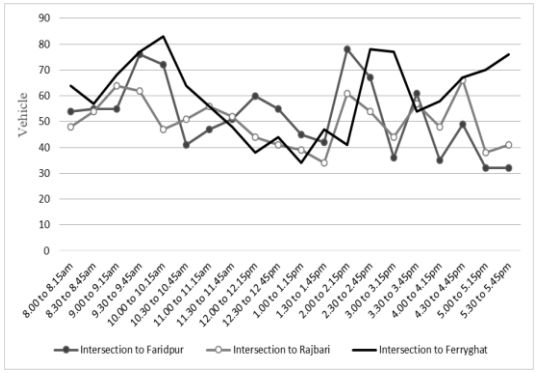

Figure 9: Comparison of traffic volume (veh/15min) of exit legs of three approaches

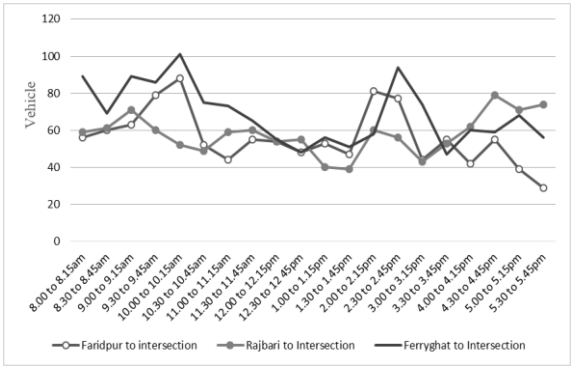

Figure 10: Comparison of traffic volume (veh/15min) of entry legs of three approaches

The chart shown in figure 10 represents the entry legs to the intersection. Here also seen that the Ferryghat to intersection leg is the most congested with traffic volume above 100 during the morning peak period. And greater than 95 vehicles per 15 min during the afternoon peak period.

5. CONCLUSIONS AND RECOMMENDATION

The findings of the research work concluded below in brief:

- The traffic flow of Ferryghat approach was higher than the others and the peak period was found from 9.30 am to 10.30 am.
- The overall Level of Service of the intersection was found as C. Which represents the stable flow, at or near free flow condition. Most experienced drivers are comfortable on this circumstance.
- By comparing the approaches, it was seen that the Ferryghat approach was more congested in both entry and exit legs. On the other hand, the Rajbari approach was less congested compared with others.

This study will facilitate further research and development to the respective authorities. The overall traffic condition would be alleviated by controlling on-street parking, scattered pedestrian flow and slow-moving vehicles.

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ON-STREET PARKING EFFECTS ON ROADWAY CAPACITY AND PARKING FACILITY BASED ON DEMAND AND SUPPLY

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ABSTRACT

Most of the cities in Bangladesh are facing the imbalance of demand and supply of parking space. Deficiency of adequate parking space in unplanned infrastructure caused on-street parking which is a common phenomenon in the rapidly growing Faridpur city, having a tremendous impact on roadway capacity. 80% of infrastructure does not have a parking facility according to Bangladesh National Building Code-1993 specification. Due to lack of proper management, operation, and maintenance the existing parking facilities have been affected which decreasing roadway capacity and creating severe problems like congestion, delay, accident probability, and some other relevant problems. Uncontrolled Auto-Bikes are occupied most of the roads and load unload the passengers over a short distance and park along the roadside, reducing roadway capacity also. 44% reduction in roadway capacity due to on-street parking is found on the road of Mujib Sarak, Janatar More. The percentage of reduction is 45% in the case of Thana Road in front of the New-market. 27% reduction in roadway capacity is found due to on-street parking on Goalchamat Road, Raffeles-Inn More. This study also shows the impacts of on-street parking on effective carriageway width, V/C ratio and level of service. It is necessary to ensure proper parking facility and prohibit on-street parking totally if possible; if not possible, proper parking operation management policy should be obtained for having a smooth flow of traffic. Before that unplanned land use and automobile usage should be controlled to reduce congestion and other traffic problem.

Keywords: *Parking demand and supply; BNBC; Traffic Congestion; Degree of Saturation (DOS); Level of Service (LOS).*

1. INTRODUCTION

The population growth in metropolitan cities of any country has resulted in an increase in travel demand. In the 21st century, due to the increase in population, income and improved quality of life, the propensity to own private vehicles is increased. Thus, travelers particularly in metropolitan cities preferred the private car as their favourite mode of transportation, which generated huge parking demand. Almost all Metropolitan cities are experiencing parking problems. The parking problem reduces the flow speed and creates congestion on the street, particularly in the CBD. The problem is more serious in the case of on-street parking (Debasish, 2016).

Parking is an essential component of the transportation system. The growing population of Bangladesh has created many problems, one of the challenging ones being car parking of the commercial areas which we confront almost every day. Parking is one of the major problems that is created by increasing road track and other vehicles. The availability of less space in urban areas has increased the demand for parking space especially in areas like the Central business district. The parking index of the building is an important basis for the construction of the city's parking facilities (Sudipta, 2014).

It is a basic type of requirement for any type of development. The areas with the development of shopping centers, hospitals, and other commercial buildings attract a lot of trips as well as increase the demand for parking. Due to the lack of adequate parking facilities, unauthorized on-street parking is practiced which affects the roadway capacity greatly and creates some relevant problems (Suthanaya, 2017).

1.1 Objective:

The objectives of the present study are the followings:

- To gather information about the parking capacity of selected shopping centers and hospitals to compare with the requirements as per BNBC.
- To gather geometric data to compare the capacity calculated from geometry with and without on-street parking.
- To compare the level of service (LOS) and operating speed with and without on-street parking.

1.2 Scope and Limitation

The scope of this study was limited to some selected hospitals, shopping centers, and roads and others were not included in this study. Furthermore, the analysis was a segmented study rather than an area-wide or regional study. Hence, it focused mainly on the on-street parking of those places and roadway capacity and the relative effect on operating speed was not discussed as it needs a wider and comprehensive exploration.

2. LITERATURE REVIEW

Parking denotes the basic requirement in a transportation system. But more often its impact on the efficiency of traffic movement evades our contemplation. This is because our perception of transportation is limited to the notion of movement whereas parking involves the condition when the vehicles are stationary. It has become a crucial issue in managing the transportation system since it affects the overall accessibility of a city (Litman, 2012).

2.1 Types of Parking

Parking facilities can be classified into 2 categories:

1. On-street parking
2. Off-street parking

On-street parking: This is also known by name curb parking. In this system, vehicles are parked along the curb, designed for this purpose. Since car parking may lead to traffic congestion and may also be the possible cause of several accidents they should be designed for adequate capacity while planning is being done for new townships.

Parking may be done parallel to the curb or at an angle with the curb named ad parallel parking and angle parking. Angle parking is done at 30^0, 45^0, 60^0 and 90^0 with the curb.

Off-street parking: When parking places are provided away from the road curb, it is known as off-street parking. This system of parking in most desirable as it does not harm the capacity of the road (Gurcharan, 2004).

2.2 Parking Demand

The parking demand may be evaluated by different methods.

a. By counting the number of vehicles parked in the area under study during different periods of the day. By noting the registration number of each parked vehicle at 30 minute or one-hour interval, it is possible to estimate the duration of parking of each vehicle at the parking area. This method is useful when the parking demand is less than the area available.
b. Another method is to interview the drivers of the parked vehicles and other vehicle owners of the area. This method is useful when the demand is higher than the available area in the study locality.
c. By doing the cordon counts of the selected area and the recording accumulation of vehicles during peak hours by subtracting the outgoing vehicles from the incoming vehicles (B. L Gupta, 2003).

2.3 Level of Service by V/C ratio

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).

In recent years, the level of service is become more familiar to represent the speed characteristics of the 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

Volume to Capacity Ratio	Level of Service
<=0.6	A
<=0.7	B
<=0.8	C
<=0.9	D
<=1	E
> 1	F

Source: (Kadiyali, 2006)

3. METHODOLOGY

To fulfill the objectives the study is conducted in different steps. First of all, data on parking supply facility and parked vehicles were collected from selected shopping centers and hospitals of Faridpur city. They are Newmarket, Diabetic Association Hospital, Lab Aid Hospital PVT. Ltd., Arogya Sodon

Hospital, Shamorita Hospital. Hourly parking demand data was collected from the field survey at Lab Aid Hospital PVT. Ltd., Arogya Sodon Hospital and Shamorita Hospital on Mujib Sarak. The geometric survey was conducted ion Mujib Sarak in front of Arogya Sodon Hospital, in front of Newmarket Thana road and Masjid Bari Sarak in front of Diabetic Hospital. Geometric data was collected using measuring tape from selected roads. Traffic volume was collected manually from those roads. The parking space facility survey data was collected by negotiating with selected building authorities and parking demand was calculated manually.

3.1 Description of study location

Our study was conducted in several selected places. For comparing with the BNBC requirement of parking facility we have selected three different hospitals in Faridpur city and Newmarket placed at the center of Faridpur. The hospitals are Dibatic Association Hospital, Lab Aid Hospital PVT. Ltd., Arogya Sodon Hospital, Shamorita Hospital. And the selected roads for analyzing roadway capacity are Mujib Sarak, Thana Road and Goalchamat Road.

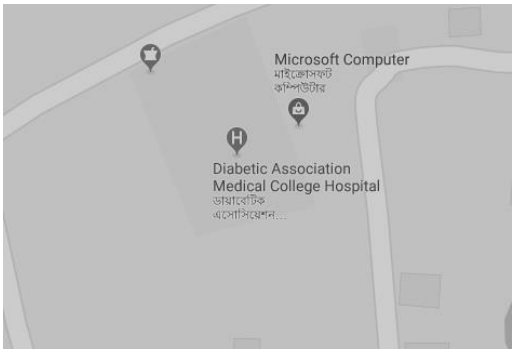

Figure 1: Diabetic Association Medical College Hospital (Google, 2019)

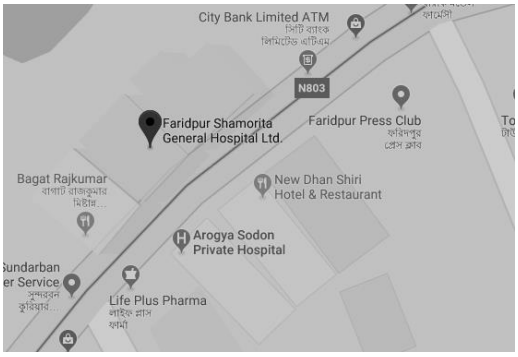

Figure 2: Shamorita General Hospital and Arogya Sodon Private Hospital (Google, 2019)

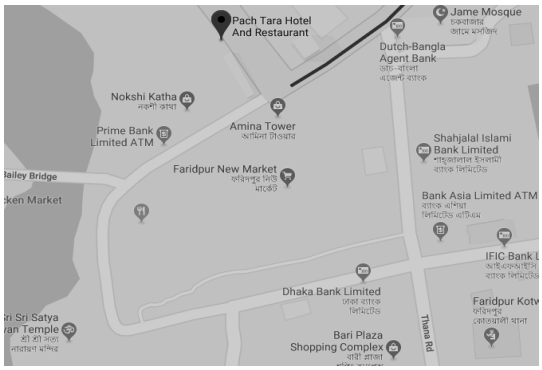

Figure 3: Faridpur Newmarket (Google, 2019)

3.2 Data Collection

To accomplish the objectives of this research several types of quantitative data such as traffic flow or volume data, vehicle occupancy data, travel time data, on-street parking data, road users ' congestion perception data, causes of traffic congestion and parking demand and supply data were required. But for this research, only traffic volume data, geometric data, parking demand, and supply data at selected places and on-street parking data were collected.

3.2.1 Traffic volume data

Traffic volume is very important to determine and understand the flow pattern in the facility, to determine the peak flow rates and peak periods, to assess the relationship between traffic volume and congestion. Furthermore, it is extremely required to analyze the level of service.

The traffic volume count was collected for a period of 8 hours (9:00 am 5:00 pm) on the study day.

Heavy Vehicles: Bus, Trucks

Light Vehicles: Cars, Pickup, Mahindra, Easy Bike, Rickshaw, Bi-cycle, Van, etc.

The traffic volume in the passenger car unit and the movement of traffic on each road are also essential for the analysis. The passenger car equivalent factors are used to convert the number of vehicles in the passenger car unit. The PCU values given in the geometric design of Highways (MoC, 2010) are given in Table 2.

Table 2: PCU of Different Types of Vehicles in Bangladesh." (MoC, 2010)

Categories	PCU
Passenger Car	1.00
Light Good Vehicle	1.00
Bus	3.00
Truck	3.00
Auto Rickshaw/ Motorcycle	0.75
Rickshaw/ Van	2.00
Bycycle	0.50

3.2.2 Service Volume

Design service volume is defined as the maximum hourly volume at which vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time period under the prevailing roadway, traffic and control conditions while maintaining a designated level of service.

Design service volumes for different categories of urban roads corresponding to above-referred conditions are given in Table 3.

Table 3: Recommended design service volumes (PCU per Hour).

S.No	Type of carriageway	Total design service volume for different categories of urban roads		
		Arterial	Sub-arterial	Collector
1	2-Lane (One way)	2400	1900	1400
2	2-Lane (Two way)	1500	1200	900
3	3-lane (One way)	3600	2900	2200
4	4-Lane Undivided (Two-way)	3000	2400	1800
5	4-Lane Divided (Two way)	3600	2900	----
6	6-Lane Undivided (Two-way)	4800	3800	----
7	6-Lane divided (Two way)	5400	4300	----
8	8-Lane divided (Two way)	7200	----	----

Source: IRC 1990

3.2.3 Geometric data

The width of the roads for capacity reduction calculation was collected by tape measurement. The parking space of selected hospitals and shopping malls is collected by negotiating with the building authority from an architectural plan and on field observation.

3.2.4 Parking data

The parking supply survey was conducted by counting the allotted parking space for the vehicles in the selected shopping mall and hospitals. And parking demand was measured by doing the cordon counts of the selected area and according to the accumulation of vehicles during the parked hours by subtracting the outgoing vehicles from the incoming vehicles

4. RESULT AND ILLUSTRATIONS

Due to the lack of adequate parking space, scattered on-street parking occurred, reducing the roadway capacity. This is a common scenario in Faridpur city and it is increasing day by day.

4.1 Comparison of parking supply and demand

According to BNBC-1993, space should be allotted for 1 car for every 200 m^2 for business purposes and 1 car for every 300 m^2 for health care purposes. A 23 m^2 parking space is required for 1 car. But 80% of the selected organization has not followed this standard.

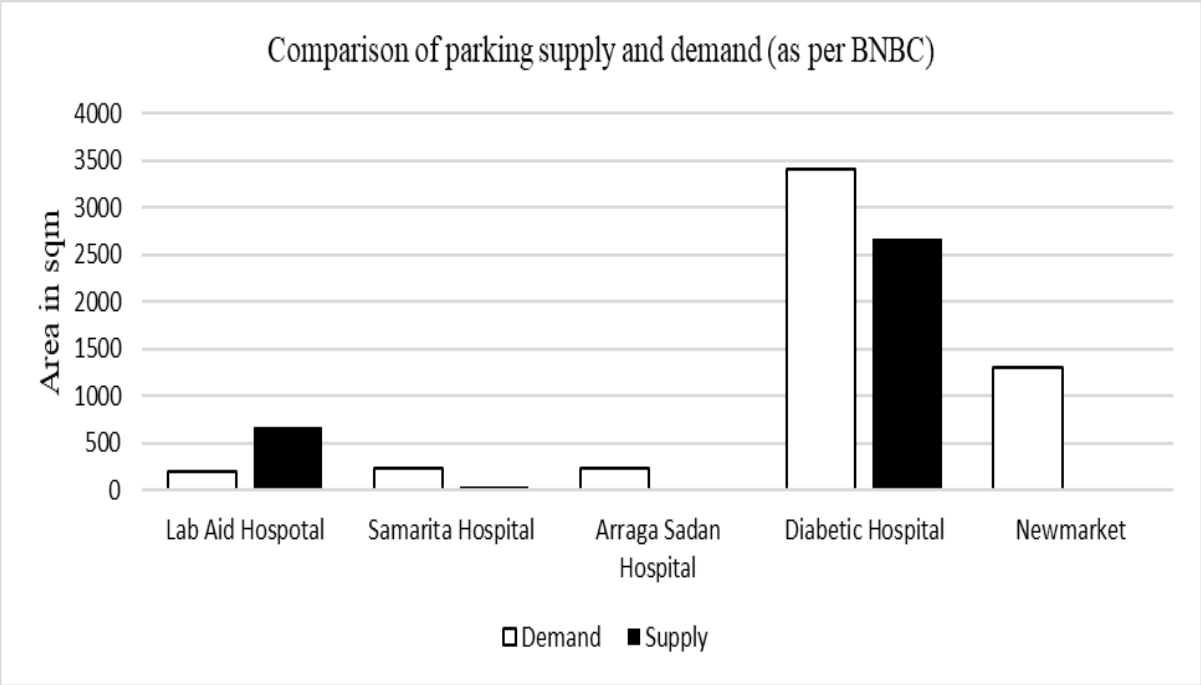

Figure 4: Comparison of parking supply and demand (as per BNBC)

Figure 4 shows the deficiencies of the parking supply of the selected shopping center and hospitals in Faridpur city. Even some organizations do not have a parking supply facility which is a common phenomenon in Faridpur. Besides this, space for loading-unloading purposes is not provided by the organizations except Diabetic Association Medical College Hospital. And most of the organizations are located onshore of busy roads. Due to on-street parking and loading-unloading activities on the busy roads, roadway capacity decreases greatly and creates a lot of congestion, accident potentialities hindrance movements of pedestrians and traffic.

4.1.1 Hourly parking Demand

Figure 5, 6 and 7 represents the hourly parking demand and Supply of Newmarket, Mujib Sarak and Goalchamat Roads balance respectively. There is no parking supply facility among those selected roads. At Newmarket road, it is shown that the maximum number of the vehicle was parked at 11 pm to 12 pm. In Mujib Sarak maximum parked vehicle was found at 10 am and at Goalchamat Road it was found 12 pm.

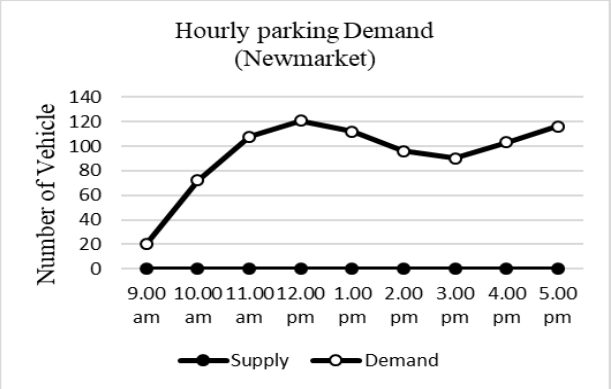

Figure 5: Hourly parking demand (Newmarket)

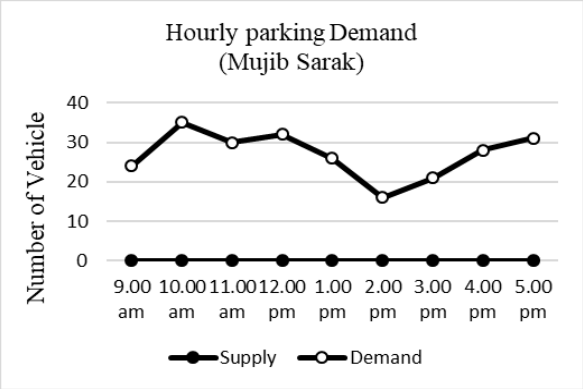

Figure 6: Hourly parking demand (Mujib Sarak)

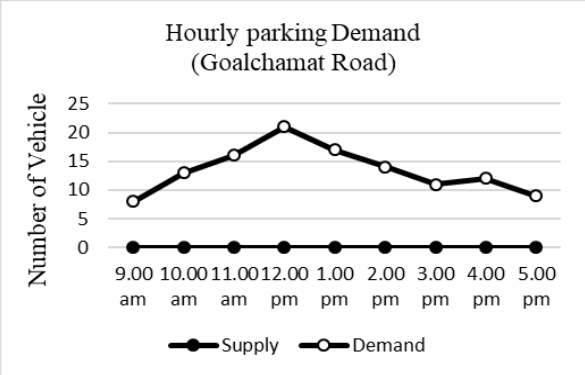

Figure 7: Hourly parking demand (Goalchamat Road, Raffeles-Inn More)

4.2 Calculation of capacity reduction

Due to the on-street parking in one row and sometimes more than one row on the roads of Mujib Sarak and Thana Road, the effective carriageway width is reduced greatly. Almost 45% of carriageway occupied by parking. On the other hand, in Goalchamat Road, the rate of roadway capacity reduction is low. This reduced roadway width is one of the major reasons of capacity loss and result congestion.

Table 4: Effects of On-Street Parking on Capacity

Road	Effective carriageway width (ft)	Capacity (PCU/hr)	Capacity reduction (%)
Mujib Sarak	27(without parking)	2529	44
	15(with parking)	1405	
Thana road	40(without parking)	1117	
	22(with parking)	614	45
Goalchamot road	30(without parking)	1796	
	22(with parking)	1317	27

4.3 Level of Service

Level of Services is affected by capacity reduction where on-street parking reduces the effective roadway width, having a great impact on the capacity that we found in Mujib Sarak. The effect of unauthorized on-street parking on Level of Service is shown in table 5 below.

Table 5: Effects of on-street parking Level of Service

Road	Effective carriageway width (ft)	Capacity (PCU/hr)	Service volume (PCU/hr)	Degree of saturation (Volume/Capacity)	Level of Service
Mujib Sarak	27(without parking)	2529	1500	0.6	A
	15(with parking)	1405	1500	1.01	F
Thana road	40(without parking)	1117	1200	1.1	F
	22(with parking)	614	1200	1.95	F
Goalchamot road	30(without parking)	1796	1500	0.84	D
	22(with parking)	1317	1500	1.14	F

The Level of Service of all roads was found F with on-street parking which is the indication of congestion.

5. CONCLUSIONS

Due to the lack of adequate parking facility, parking regulatory system and parking charges unauthorized on-street parking is practiced which affects the roadway capacity greatly and creates some relevant problems.

- Most of the organization didn't follow the BNBC code, as a result, scattered on-street parking developed noticeably.
- Though there were no on-street parking facilities on selected places, the on-street parking occurred which reduce roadway width, as a result, the roadway capacity reduced in almost half.
- All roads are facing long-standing traffic congestion which is the worst condition according to Level of Service.

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PERFORMANCE EVALUATION OF DHAKA CHAKA BUS SERVICE

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ABSTRACT

City is just like a living organism and the transportation system is just like the blood circulation system of that living organism. This transportation system consists of mainly roadway, waterway, airway and railway and bus is one of the most important public transport systems particularly for urban areas. Currently, total number of buses including mini-buses in Dhaka city is 10,214 whereas the total number of vehicles is 11,15,654 which means 2.57% of the total vehicle is bus according to Bangladesh Road Transport Authority (BRTA) data (upto April, 2018). Bus trips constitute 27% of total trips by mechanized modes and passenger kilometer traveled by bus is about 40% of passenger kilometer traveled by mechanized modes. Bus plays a vital role in road transportation system as it can carry a large number of passengers of 30-40% using less road space than a car where it can carry only 5-6% passengers occupying almost same space of road. Dhaka's existing bus operation is not organized and due to fragmented ownership of buses and multiple bus companies are operating along the same corridors, they are in fierce completion for passengers. Thereby, existing bus services causing unnecessary congestion and safety problems instead of providing transport solutions. On 10th August 2016, twenty air-conditioned buses were introduced (known as 'Dhaka Chaka') in Gulshan area, Dhaka which is a move taken to increase security measures in the Gulshan area that witnessed Bangladesh's worst terror attack on July 1, 2016. Among the two routes of Dhaka Chaka, one is commuted from Tejgaon-Gulshan Link Road to Banani via Shooting Club, Gulshan-1, Gulshan-2 and the other route is from Banani to US Embassy. This special bus service is introduced by replacing all the previous 15 bus operators those were providing service to that area to improve the level-of-service (LOS) of mass transport system, which is seriously lacking in all the major urban areas of Bangladesh. The introduction of single operator based zonal bus service gave a golden opportunity to evaluate the performance of this service with the multi-operator based services. To measure the performance of 'Dhaka Chaka' bus service as well to compare it's performance with that of other Bus services of Dhaka City, the paper will consider different performance indicators like trip time, travel speed, average distance between stoppages, passenger loading/unloading practice, passengers safety along with users perception of the services etc. In this work, 28 trip time studies of 'Dhaka Chaka' are conducted to determine average travel speed, trip time and to observe passenger loading/unloading practice as well as bus stoppage whereas questionnaire survey of 303 respondents is done to determine the safety perception of 'Dhaka Chaka' users. It is found from the trip study that there is very systematic practice during passenger loading/unloading execution, on the contrary, there exists ill practice in passenger boarding/alighting tradition in Lease type of bus service. From the trip time study, average travel speed is 7.5 km/hr and average trip time is 20 minutes in one direction. Almost all the passengers feel safe using 'Dhaka Chaka' and want this bus service to corporate in other areas of Dhaka city. This study suggests that driver behaviour should be linked with payment system which discourages them by additional passenger or will care about passenger comfort and safety as well as has made a path to recognize suitable franchising system to improve the quality of the service.

Keywords: *Dhaka Chaka, performance, safety, loading/unloading, level of service.*

1. INTRODUCTION

Transportation plays an important role in the smooth functioning of a city. It is an integral facet of urban life. As the city grows, demand for the vehicles and new roadway facilities and new routes also arise. Different modes of different speed, capacity, hiring system, and fare are seen in the city streets to suit the demand of various classes of passengers. Mass transit is patronized in the city to minimize traffic congestion, increase safety, and reduce the use of cars and parking space. It operates on an established schedule along designated routes with specific stoppages. Examples of mass transit include bus, light rail. Although mass transit is recommended for the smooth and efficient transport system in a city, still Dhaka is not planned enough to flourish bus service or light rail service or a rapid transit system in the city. Bus is the available mass transit in the city. Moreover, the income level of the inhabitants of the city is not high. So, a huge demand for traveling by bus is there. Overcrowded buses, huge waiting times at the stoppages, irregular arrival of buses, and an indefinite period for trip completion deteriorate the bus service in the city. The situation is same in both public and private-owned buses.

On the night of 1 July 2016, at 21:20 local time, five militants took hostages and opened fire on the Holey Artisan Bakery in Gulshan Thana. 29 people were killed, including 20 hostages (18 foreigners and 2 locals), 2 police officers, 5 gunmen, and 2 bakery staff. The incident was the worst terrorist attack in Bangladesh's history. After that event DNCC (Dhaka North City Corporation) launched the program of the special transport service named “Dhaka Chaka”. On August 10, 2016, almost 40 air-conditioned buses and 500 rickshaws have been introduced in Gulshan-Banani area; Dhaka’s diplomatic zone, a move taken to increase security measures in the area that witnessed Bangladesh’s worst terror attack on July 1. The surveillance system in the diplomatic zone has been changed and the special transport service is a part of it. The rickshaw-pullers have been trained in security, hospitality and emergency measures. Passengers in the new buses enjoy several facilities including WiFi and television. Moreover, even if the engine of the bus is turned off while sitting in a traffic jam, the air-conditioner stays on. Rajib Hossain, the 22-year-old college student who lost one of his arms in a bus accident in Dhaka on April 3, 2018, and after two weeks in coma, Rajib Hossain drifted off to death on April 17, 2018. A student of Government Titumir College in Dhaka, Rajib lost his right arm when a bus of Sajan Paribahan hit a BRTC double-decker bus parked at SAARC circle on April 3, 2018, and was a stupid race of two irresponsible drivers. So there is a crying need to systemize the public transport sector for public life and safety. Single operator based public transit can play an important role in this regard.

Barua, U., & Tay, R. (2010) studied safety issues of transit services in Dhaka city. There has been a general increase in the severity of transit bus crashes for 1998-2005. They utilized the transit crash data to understand the factors behind the collisions. They recommended a driver training and education program, traffic enforcement and more police control to be introduced to improve road safety in Dhaka city. Punctuality, or time performance, and regularity are two different aspects of the performance of transit service. It can be found in the literature that the importance of service measures varies between long headway routes and short headway routes. For headway routes, the most common measure of reliability is punctuality (Furth, P. G., & Muller, T. H. (2007)). However, for high-frequency routes, it is important to monitor headway regularity (Transportation Research Board. 2002; Van Oort, N., & van Nes, R. (2009); Trompet, M., Liu, X., & Graham, D. J. (2011)). “On-time performance is often measured only on routes with longer headways (e.g., longer than 10 minutes, while headway regularity is often measured for routes with shorter headway.” (Transportation Research Board, 2002, p. 207). On short headway routes, customers should not have to rely on the schedule. (Research Board, 2002).

In this paper, we evaluate the performance of Dhaka Chaka bus service in comparison with the “Lease-type” bus service currently running in the city. Lease type bus services are accident-prone; reckless driving, overtaking tendency are also common. This study is interested in finding whether

these drawbacks are found in this bus service or not. The specific objectives of the paper are as follows:

●To study the performance of newly introduced Bus Route franchise-based bus service in Gulshan area.

●To identify the problems and bottlenecks of the existing service.

●To recommend some guidelines for the improvement of the bus service of Dhaka.

The main objective of this research is to investigate the performance of bus service Dhaka Chaka in Dhaka city. Public safety and user experience study were taken into account to compare the service with Lease type bus service. Public satisfaction is an important parameter for any performance evaluation. In this study, this parameter was evaluated by doing a questionnaire survey. User opinion survey, trip study, passenger volume survey data are represented as tabular and graphical form and analyzed. The bus service was launched to make a sustainable solution for congestion and transportation in these areas. This study also desirous to evaluate if this service is up to the mark to meet its initial purposes.

2. METHODOLOGY

Methodology is the guidelines and logical framework for the researcher for conducting the research. To fulfill the objectives effectively and to carry out the entire study, some procedures and initiatives have been taken. The working process used in this project involved the following main steps; literature search, literature review, route selection, data collection such as route survey, passenger survey, interviews and data analysis, sorting of data, minimization or elimination of data errors. All these processes are compiled to achieve the objectives.

2.1 Surveys

As Dhaka Chaka buses are conducted on 2 routes, surveys were done mainly on these two routes. Traffic surveys were conducted on all 2 routes to find out route characteristics, bus-stops, passenger loading and unloading practice, travel pattern and performance of the bus service in the routes. To evaluate the performance parameters of the buses on these routes, field surveys would depict the existing situations. Mainly two types of surveys were introduced in these routes, namely

1.Travel Time survey of Buses

2.Sample Questionnaire Survey of Passengers

Interview of officers in Dhaka Chaka office was also conducted to get the trip information and other details of this bus services. Field and visual observation was done to ensure a first-hand experience.

Sufficient photos were taken for further attachment.

During the survey process, some problems were prominent. Some people were not co-operative at all. Even the authority was not supportive in that case at first.

2.1.1 Bus Performance Parameters Evaluation Procedures

The indicators of bus service which are considered are travel time, travel speed, average distance between stoppages, passenger loading/unloading practice and safety against user perception. Following methodological study have been taken to evaluate the performance parameters:

To get the basic understanding on the topic, literature survey was undertaken and information was collected from published and unpublished sources.

Basically, these buses are serviced in two routes in Gulshan and Banani area. So, the study routes were selected from google map. The locations of the starting bus-stops were also collected via google. According to recent study by the consultant under Bus Network Study at DTCA, lengths of the bus routes vary from 0.5 to 66 km, although 26.3% have lengths between 10 and 15 km, 24.3% between 15 and 20 km and 17.8% between 20 and 25 km. As mention earlier, there are about 289 permitted bus routes in the City. The number is very high as because there are many overlapping routes. Among these routes, one route is selected for analysing non-franchise system in Dhaka. This is Azimpur to

Mohammadpur bus stand. The route length is 4.9km and there exists four legal stoppage at Azimpur, Zigatola, Sankar and Mohammadpur. Fare was TK.12 and it was fix for any distance.
Route surveys were done to collect information on origin and destination of bus service, travel time components, travel speed, frequency of service, number of buses in the route, number of passengers carried per trip, number of trips per day, stoppage, congestion, passenger loading-unloading practice, passengers' safety. Sample questionnaire surveys were conducted among the user of the buses. The survey aimed to determine passenger safety and comfort along the ride. It also aimed at study the problems they face in and their opinion and recommendations for the improvement of the system.

Interview of authority in the office was held to get some information regarding this system. The information consists of number of trips per day, operation time, driver and helper's salary, accurate locations of bus-stops in both routes, average trip time, average travel speed.

Field observations of this bus system was done by visual and photographic observations. Photos has been taken to differentiate between the Dhaka Chaka bus service and Lease type.

In this study, for speed measurement, time mean speed followed. For measuring time to complete a trip, direct riding on bus was done. Travel time between two bus stops was taken at the start and the end as well as to complete a trip. Bus dwell time in any stop was also counted. Dwell time is the time interval between opening and closing its doors to serve passengers at the bus stop. To find the average distance between two stops google map application was used.

3. PERFORMANCE STUDY OF DHAKA CHAKA BUS SERVICE

The bus service usually operates at 8:00 AM to 10 PM. The surveys were conducted at different periods of the day to see and analyze the performance throughout the day. The author decided to carry out the survey at three different periods of the day to get a better idea. Four selected periods were
1. Morning (between 9:00 AM and 11:00 AM)
2. Noon (between 11:30 AM and 3:00 PM)
3. Afternoon (between 3:30 PM and 6:30 PM)

The respondents of the questionnaire survey in Dhaka Chaka bus service were 303. Among them 222 were male and 81 were female. There were 253 respondents in Lease type of bus service. The graphical representation of age and sex structure of the respondents of Dhaka Chaka Bus Service and Lease Type Bus Service are given in Figure 1.

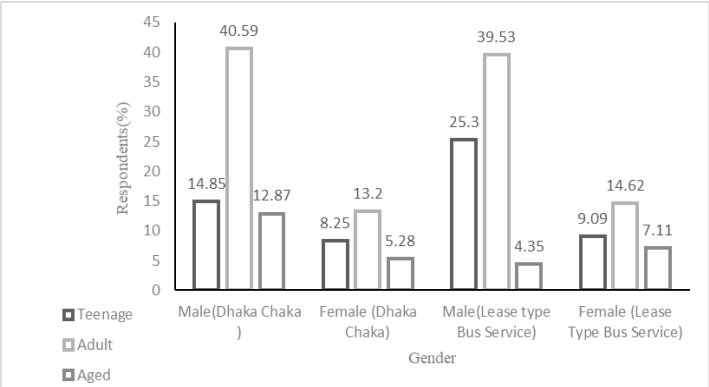

Figure 1: Percentage of respondent's age and sex

Figure 1 reveals that the adult respondents were in higher proportion both in Route 1 and Route 2 of Dhaka Chaka Bus Service and Lease Type Bus Service. However, in this broad category, the teenagers were larger than the age group in both cases. In both services, adult respondents are highest among the teenage and aged. The young passengers were using the Dhaka Chaka Bus Service in

greater proportions probably because Gulshan-Banani-Baridhara are commercial areas, so most of them come there for their office.
Figure 1 shows the sex structure of the respondents. Naturally, male passengers were much higher in proportion compared to female passengers in both the passenger group. Notably, female passengers were found to be in higher proportion in the case of Lease Type of Bus Service. There were 26.73% female passengers among the Dhaka Chaka Bus Service users against 30.82% among the Lease Type of Bus Service users. From the figure, it is also revealed that women were less responsive as mentioned before in 2.1 Survey.

Among 303 respondents of Dhaka Chaka bus service, 233 respondents were regular users of this bus service. From Figure 2, it is seen that most of the respondents were regular users. Among all the respondents, Dhaka Chaka passengers are more regular.

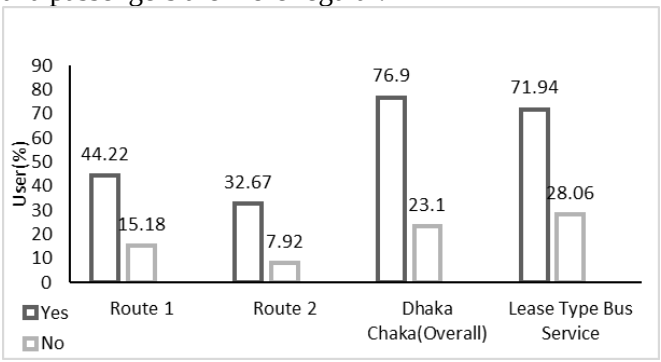

Figure 2: Respondent's using Type as Regular or Irregular

Dhaka Chaka Bus Service serves two routes in Gulshan-Banani-Baridhara area. The fare is fixed which isTk.15 and it fixed for all distances. Basically, it has access driven fare system. No passenger is allowed to get on the bus without a ticket. Performance parameters such as travel speed, trip time, average distance between stoppages, passenger loading unloading practice, passenger safety along with user perception of the service are evaluated in this section.

3.1 Average Travel Speed

Travel speed is measured by counting trip time in one direction. 16 trips were made in Route 1 and 12 trips were done in Route 2. Travel speed of this service is given in Table 1

Table 1: Average Travel Speed

Route Name	Average Speed(km/hr)	Maximum Speed(km/hr)	Minimum Speed(km/hr)
Route 1	7.39	11.08	2.40
Route 2	7.60	11.08	3.27

Source: Trip Time Study, 2018

From Table 1, it is defining that average speed was 7.5 km/hr. It is also seen that the average speed of Route 2 is slightly greater than Route 1 as Route 1 was more congested with traffic due to signal and route length is slightly larger than Route 1. Consequently, the maximum speed of both route is the same. On average, Route 1 travel speed was less than Route 2 as minimum speed also smaller than Route 2.

3.2 Trip Time

The study was conducted at different periods of the day to find out the condition at different situation of the day. It was conducted in both directions. Trip times were taken by 16 trips in Route 1 and 12 trips in Route 2. For the convenience of the author, the direction in Route 1 from Natun Bazar to Banani was considered DOWN and Kakoli to Natun Bazar was considered UP. The direction in Route

2 from Gulshan DCC Market to Police Plaza was considered DOWN and Police Plaza to Gulshan DCC Market was considered UP.

Table 2: Time to Complete a Trip

Route Name	Origin-Destination	Average Time(hr:min)	Maximum Time(hr:min)	Minimum time(hr:min)
Route 1	Natun Bazar-Banani(Down)	00:21	00:30	00:17
Route 1	Banani-Natun Bazar(Up)	00:22	1:00	00:13
Route 2	Gulshan DCC Market-Police Plaza(Down)	00:19	00:30	00:10
Route 2	Police Plaza-Gulshan DCC Market(Up)	00:24.33	00:44	00:15

Source: Trip Time Study, 2018

While going from Police Plaza to Gulshan DCC Market, the required time to complete a trip varied widely like as Route 1. From the study it was found that the maximum time required to complete a single trip was 1 hour and the minimum time required to complete the trip was 13 minutes, both in UP direction (Table 2) while in opposite direction (DOWN journey), travel time was fairly same. In the case of UP journey, the lowest time was found in afternoon as that period is working time and maximum time was found in the evening because of office closure time. For the same reason, DOWN time was found lowest in the afternoon and the highest time was found in the evening (Trip Time Study). The total average trip time (average for UP-DOWN journey) was found to be 22 minutes.

3.3 Average distance Between Stoppages

In Route 1, there were 6 stoppages and in Route 2, there were also 6 stoppages. The average distance of the stoppage is given in Table 3.

Table 3: Average Distance between Stoppages

Route 1 (Stoppage)	Average distance between stoppage(km)	Route 2 (Stoppage)	Minimum Speed(km/hr)
Natun Bazar	-	Gulshan DCC Market	-
Gulshan- 2	1.20	Agora	0.60
Kakoli	1.20	Jabbar Tower	1.00
Banani	0.45	Police Plaza	0.70
Gulshan- 2	0.90	Gulshan 1(Navana Tower)	0.80
Natun Bazar	0.85	Gulshan DCC Market	1.50

Source: Google Map

In Route 1, the route length is 2.4 km and in Route 2 the length is 2.3 km in one direction. Shortage distance between stoppages is 0.45 km in Route 1 which is between Kakoli to Banani. In Route 2 shortage distance is between Gulshan DCC Market and Agora which is 0.60 km. The longest route length is observed in Route 1 that is 1.20 km from Natun Bazar, Gulshan-2 and kakoli direction. As stoppages are situated in short range, it is convenient for the passengers to get the bus to board. People use this service instead of walking

3.4 Passenger Loading/Unloading Practice

In this bus service, passengers were boarded on bus only at stoppages but unloaded both in stoppage and without stoppage. Passenger got down from bus if his destination was before the stoppage or he had to change the route. It is seen in Table 4 that no passenger was loaded in middle of the road as illegal stoppage among 16 trips in Route 1 and 12 trips in Route 2. Table 5 shows among the observed passengers in 28 trips, 55.23% of the passengers getting down from bus at legal stoppage. Though in Route 2, passengers unloaded at illegal stoppage was greater than unloaded at legal stoppage

Table 4: Passenger Loading/Unloading Practice

Number Of Passenger				
Route Name	**Legal Stoppage (up)**	**Legal Stoppage (down)**	**Illegal Stoppage (up)**	**Illegal Stoppage (down)**
Route 1	563	345	0.00	218
Route 2	451	215	0.00	236

Source: Trip time Study, 2018

Table 5: Percentage of Passenger Loading and Unloading from Bus

Legal Stoppage(up)	Legal Stoppage(down)	Illegal Stoppage(up)	Illegal Stoppage(down)
100%	55.23%	0.00%	44.77%

Figure 3: Passenger loading and unloading practice on bus (Dhaka Chaka)

Figure 4: Passengers are in queue to get on the bus (Dhaka Chaka) and bus at stoppage

Figure 5: Passenger loading and unloading practice on bus (LBS)

3.5 Passenger Safety

In the questionnaire survey, respondents were asked about their safety when traveling through the bus and loading-unloading practice. Almost all the passengers in both Route answered the same that their answer was *Yes*. Table 6 shows the survey result.

Table 6: Passengers Perception about Safety

Route Name	Safety Along With User Perception(Total 303)	
	Yes	No
Route 1	179	1
Route 2	122	1

Source: Questionnaire Survey

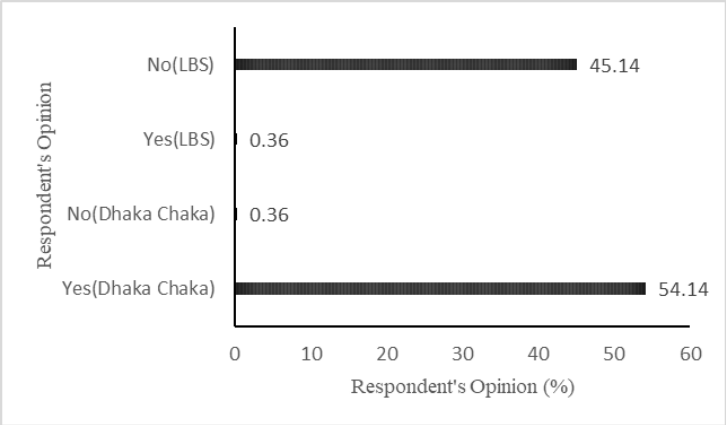

Figure 6: Passengers Feeling about Safety

In Table 6, only 2 respondents out of 303 respondents in both Route didn't feel safe from this service. But other than all the passengers felt safe as indicated in Figure 6 were 54.14% passenger of Dhaka Chaka gave their consent. It implies that the bus serviced safely to the passengers through their loading-unloading practice. On the other hand, 45.14% of respondents didn't feel safe using the Lease type of bus services. This is because of the unhealthy practice of boarding and alighting of passengers from the bus.

3.6 Driver's Remuneration

Table 7: Driver's Remuneration

Dhaka Chaka Bus Service (Bus Route franchise)	TK.1300/day
Lease Type Bus Service (Non-Franchise)	TK.200/trip

Remuneration of driver is different in two different bus services. Remuneration plays an important role in driver behaviour in the road along with driving. From Table 7, it can be seen that Dhaka Chaka bus driver usually gets TK.1300 per day for 14 hours duty. This remuneration is fixed which is independent of the number of trips and passenger served. On the other hand, drivers in Lease Type Bus Service get only TK.200 per trip. This is solely dependent on the number of trips a driver can complete per day. The higher the trip number, the more one can earn. This practice makes the unhealthy competition among drivers to reckless driving and to board on more passengers. Hence safety issue hampers of the passengers. This is one of the reasons for accidents in Dhaka city which causes serious injury such as separation of hand from the body even death. As Dhaka Chaka bus operates under franchise system, there is no unhealthy competition among drivers to complete as many as trips they can to earn more. How many trips they complete, they get a fixed amount. This practice brings mental calmness of a driver. So, he doesn't engage himself in competition and drives safely. This reduces accident rate and increases passenger safety. Passenger can safely get on the bus where driver does no harsh driving and safely alighting passenger to the desired stoppage. So, a

franchise system can bring discipline among the drivers for safely driving in the road. It derives the driver from competing with each other. Drivers have no hurry to complete many trips as they get a fixed amount. But in a non-franchise system, drivers want to complete many trips that lead completion and create passenger as well as road safety concerns.

Figure 7: No scratch on bus body (Dhaka Chaka) and scratches on bus body (LBS)

4. CONCLUSIONS

There is a little variation in average speed between two routes because of longer signal time and congestion. The maximum trip time is generally observed during peak hours. As stoppages are situated in the short-range, people use DCBS instead of walking. Passenger loading-unloading practice in Dhaka Chaka is very well organized compared to the Lease Type Bus service. Because passengers of the non-franchise bus service usually board/alight on/from the bus in the middle of the road, even when the bus is in motion. Most of the passengers consider DCBS as safe due to the disciplined loading-unloading practice. As a result, all the participants of the survey want this service (DCBS) on the other routes of the Dhaka City.

The process of forming a new company comprising of the existing operator is not an easy task. The formation of one or two operators from the existing company is a complex task and needs careful study and consultation. The behaviour of the local drivers needs to be studied as payment based KM operation. The driver behaviour should be linked with the payment system and a careful investigation is required for linking driver behaviour with the payment. Otherwise, they will not be inspired by additional passengers or will not care about passenger's comfort and safety. The cause and effect of the penalty system need to be carefully studied as penalty and rewards work only where adequate capacity is in place by the authority.

Creating omnibus operating companies should be done under the regulations of independent, strong, skilled and very capable regulatory body. If the regulator is weak, it will not be a feasible option to improve the quality of service. This study has made a path to recognize suitable franchising systems to improve the quality of the service and another study could be done on strategies to improve the applicability of selected franchising systems.

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IMPACT OF RIDE-SHARING ON PUBLIC TRANSPORT IN DHAKA CITY: AN EXPLORATORY STUDY

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ABSTRACT

The rapidly growing ride-sharing, an on-demand mode of transportation, is becoming more common amongst the daily commuters of Dhaka city, the capital of Bangladesh in recent years. This paper focuses on evaluating the impact of ride-sharing on Dhaka's existing transportation system; hence estimating the modal shift due to the introduction of ride-sharing transport.

In total 1007 ride-sharing app users of Dhaka city were interrogated in person with a well-structured questionnaire survey to assess their perception regarding this new mode of transportation. Respondents' basic demographics, trip purpose, trip origin and destination were also documented for comprehensive analysis. The effect of different aspects associated with travel behavior on modal shifting and induced travel was explored through analysis.

From socio demographic aspect of respondents it was observed that, high percentage of users are from middle income class who showed interest to pay extra charge in exchange of better service. The study perceives that around 28% of the respondents shifted from public transport to ride-sharing. Poor accessibility, lacking of reliability and comfortability are substantially decreasing the public transport demand day by day. Furthermore with the integration of a new facility, 'carpooling', to the ride sharing service, a significant percentage of the commuters who prefer public transport will avail this new provision due to its attractive fare schedule. This induced travel due to 'carpooling' has shaped the existing transportation system to a balanced one.

The research will provide a synopsis of the public perceptions to the concerned authorities to ameliorate the services of this promising transportation mode, along with the public transport, towards building a better sustainable transportation system.

Keywords: *Ride-sharing, Public transport, Modal shifting, Carpooling, Sustainable transportation system.*

1. INTRODUCTION

Rapidly growing ridesharing services have significantly influenced in transforming existing transportation system in Bangladesh. In recent years Bangladesh has been experiencing strong economic growth and simultaneously has an increasing internet penetration rate (Kamal and Ahsan, 2018). These have paved the way to ridesharing to be flourished conspicuously. Ridesharing in Bangladesh is no more a new emergence. E-hailing transport services have been spearheading in this sector since 2015. Now the impact of this service to the existing situation is needed to be assessed.
Though the country is experiencing rapid economic growth, it lacks in quality of public transport to satisfy people's demand. Poor quality services, unsustainable trend of development, proper integration problem are some of the reasons why public transportation in Bangladesh is still lagging behind whereas ridesharing, an on demand travel mode, has changed the travel behavior of city people (Palma, 2019). It provides door to door service and in no time it has become the most convenient and available mode of transportation of Dhaka city. Ridesharing is also expanding in other large cities like Chittagong and Sylhet. Thus a significant modal shift from public transport has been observed due to the influencing effects of ridesharing.

This study focuses on the results of public opinion to assess the impact of ridesharing. A constructive questionnaire survey was conducted for evaluating public opinion. The collected data include respondents' demographic, socioeconomic and trip related information. Besides existing scenario of ridesharing in Dhaka city has been developed assessing public opinion. A new terminology 'carpooling' has been introduced to the participants. And the response towards 'carpooling' was noteworthy. The probability of induced percentage to ridesharing from public transport has been identified by analyzing the effect of ridesharing on modal shift. The result of this significant modal shift highlights the lacking of public transport and other modes apart from ridesharing available in Bangladesh to attract commuter.

People's modal choice is shaped by various factors and among these- comfortability, trip completion, responsiveness (Rahman, Das, Hadiuzzaman & Hossain, 2016) and such other factors were taken as the influencing ones in this study. Based on their experience respondents rated the services provided by ridesharing. Thus a distinct idea about overall service quality provided by ridesharing has been developed.

The aim of the study is to provide information about this fast growing mode of transportation which can be used as supplement of public transport in Bangladesh. Transport is the key infrastructure of a city and the economic expansion depend on public transit option. Thus integration of ridesharing and quality public transport can lead towards a sustainable transportation system.

2. LITERATURE REVIEW

Shared transport is an on-demand vehicle-sharing arrangement, where travelers share a vehicle along with the cost of the journey, thereby creating a fusion between private vehicle and public transit. (Shared Transport, 2019; Agatz, Erera, Savelsbergh & Wang, 2012). Ridesharing is no more a new emergence. At present it is one of the most common means for commuting. For better understanding the impact of ridesharing on existing transportation system, researchers have begun to analyze the perception of commuters towards ridesharing (Amey, Attanucci & Mishalani, 2011).

Mahmoudifard, Kermanshah, Shabanpour & Mohammadian (2017) comprehend the characteristics, preferences and behavior of people who use ridesharing to assess it as a new mode of transportation. This paper aimed at studying the travel behavior associated with Uber riders by conducting an online survey in Chicago area. Another study (Azudin, Norhashim & Nachiappan, 2018) developed SERVQUAL model for evaluating consumers' perception of service quality provided by Uber. The findings of the paper provide that the Uber business model is viable in small city like Ipoh. Again the

perception of commuters and operators in Metro Manila of Uber and GrabCar was determined by another study (Paronda, Regidor & Gaabucayan-Napalang, 2017). This study assessed that Uber or GrabCar could be a convenient substitute of private cars and safety and reliability were the two top most reasons for using ridesharing. Limpin (2018) investigated the factors which positively influenced users attitude towards ridesharing in Philippines. Several studies analyze the service qualities that act behind the overwhelming popularity of ridesharing. Sharma and Das (2017) identified particular service qualities that affect customers' satisfaction in India. They explored that the appearance of physical facilities personnel and printed and visual materials were the significant factors for overall user satisfaction derived from online cab service.

Some studies make a comparison between ridesharing and existing transportation system like taxis or public transport (Sun & Edara, 2015). Rayle, Shaheen, Chan, Dai & Cervero (2014) made a comparison between taxi and ridesourcing trips in their paper. The results indicated the differences between taxi and ridesourcing in context to users and user experience. According to the paper shorter waiting time and consistent mode of travelling have made ridesourcing popular than taxis. Hoffmann, Ipeirotis & Sundararajan (2016) investigated the effects of ridesharing on public transit systems. Their study employed that an increase in ridesharing could counteract the declination in public transportation use, at least in response to subway system shocks in the U.S.

Ridesharing has invaded over the existing transportation system in Bangladesh also. Kumar, Jafarinaimi & Morshed (2018) examined the amendment of Dhaka's existing transportation system with introduction of Uber by practices and infrastructure of mobility across the city. Still there is a lack of comprehensive study about the impact of ridesharing on public transport in Dhaka city and riders' perception about it.

The current study aims at considering different aspects of ridesharing as a new alternative mode of transport in Dhaka city. Here the demographic of the respondents and existing scenario of ridesharing have been presented. This paper also attempts to identify the fact which have the potential to encourage users to switch from public transport to ridesharing. 'Carpooling' a new terminology for Bangladesh was being introduced among the respondents and induced travel to ridesharing was observed due to its shared travel cost.

3. METHODOLOGY

To assess users' perception regarding ridesharing, a well-structured questionnaire survey was conducted in Dhaka city. The selection of an appropriate questionnaire survey outline for this study was based on Mahmoudifard et al. (2017) and changes were made to fit with context in Bangladesh background. The survey was conducted in potential locations expecting high concentration of ridesharing users from January 2019 to April 2019. For easy access of data online based survey was carried through Google Forms whereas field based survey was adopted for collecting data along with real time passenger feedback. Bashundhara City Shopping Complex, general offices and banks, university areas and key locations of street with high concentration of ridesharing users (figure 1) were identified for survey purpose.

The questionnaire, comprising of 25 questions regarding basic demographics, trip origin and destination, trip purpose, car ownership and alternative modal choice, took an average of 5 minutes to complete. A total of 1041 questionnaires were distributed and a convenience sample of 1007 were accepted after excluding 34 respondents for their incomplete responses. Correlation between demographic characteristics of respondents and induced traffic along with modal shift were explored through analysis of the received data.

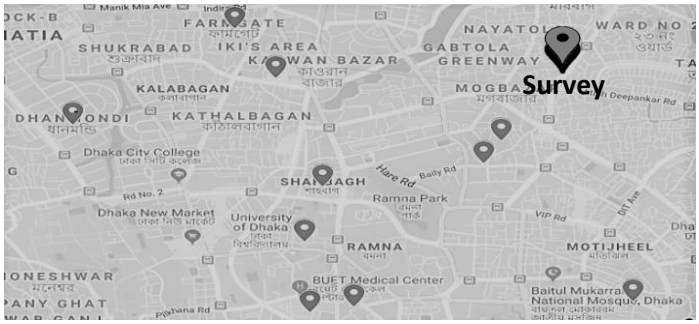

Figure 1: Survey Area

4. DATA ANALYSIS

In this section the key findings from the survey including respondents' demographics, existing scenario of ridesharing in Dhaka city, modal shifting to ridesharing and induced travel have been discussed.

4.1 Respondents' Demographics

Among 1007 respondents 65% of the total respondents were male and rest 35% were female. Though the percentage is male dominating, women participation in ride sharing service is increasing rapidly due to the poor existing transportation system of Bangladesh. The present safety and security condition in public transport for women in Bangladesh is alarming.

Among the respondents 52% were student that is 526 in number. This presences sampling bias. Again it also indicates that the rate of embracing and using new technologies among young generation is much higher. As ride sharing services are comparatively expensive than public transport, percentage of unemployed using ridesharing is the least that is only 45 in number.

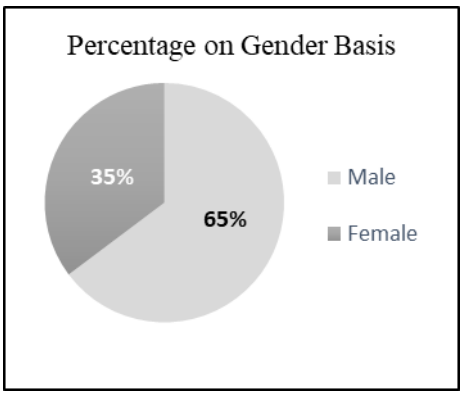

Figure 2: Relative Percentage of Respondents on Gender Basis

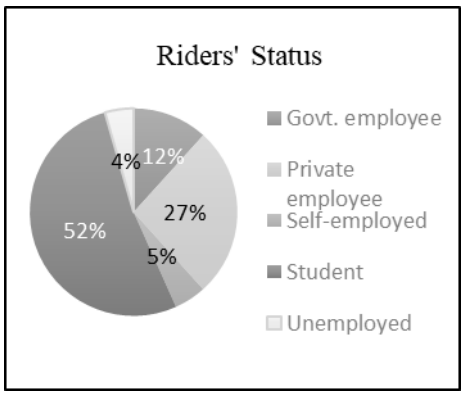

Figure 3: Percentage of Riders' Status

Based on riders' response, information about car ownership was collected. And it is noteworthy that 19% people use ride sharing services inspite of having at least one car. This is due to the parking problem in Dhaka city and also expenses of using private cars. This indicates decreasing dependence on personal vehicle. This is also an indication of mode shifting to ridesharing and reduction of idle time for vehicles.

In Bangladesh modes available for ridesharing are car, motorcycle and CNG. Among the modes car is the most popular. As highest percentage of ridesharing users are students, they prefer to make their

trip in group. So the car user percentage (44%) is higher than motorcycle (35%). 21% people use both car and motorcycle.

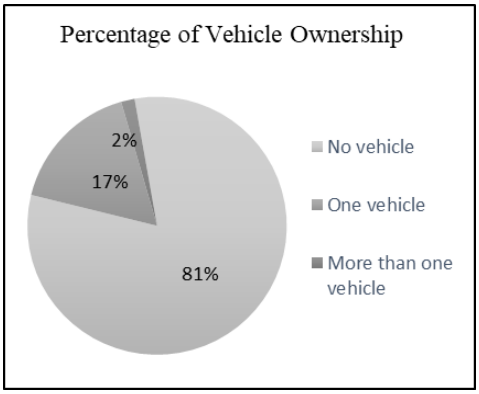

Figure 4: Vehicle Ownership Percentage

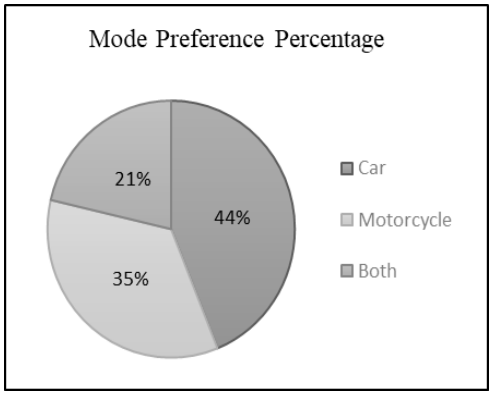

Figure 5: Percentage of Mode Preference

The questionnaire survey conducted among the 1007 app-based ride sharing service users shows that 44% users prefer international app (e.g.-Uber), 33% prefer national app (e.g.-Pathao, Obhai, Shohoz) and 19% use both national and international app. Uber service is slightly more popular than national services among people inspite of being launched later on national services (Pathao (2015), Shohoj (2014), Uber (2016)). Figure 6 illustrates the results.

Respondents were asked about their general purpose of using ridesharing. From figure 7 it is seen that work trip encompasses larger portion which is 35% of the total respondents. From respondents feedback it is known that students use ridesharing for variety of purposes like- going to school/colleges, shopping, outing with friends, going for restaurants and other social activities. For that, although highest percentage of ridesharing users are students, going for school/university is only 21% which is 271 of 1007 respondents.

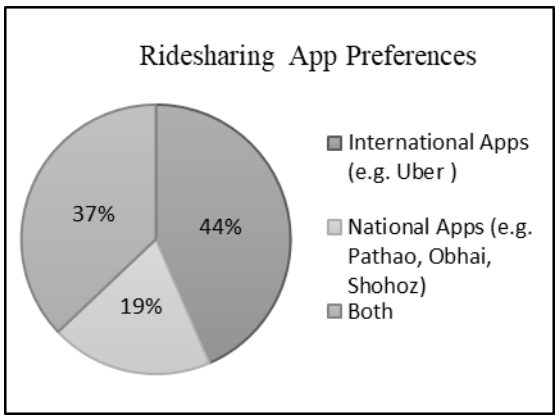

Figure 6: Percentage of Ridesharing App Preferences

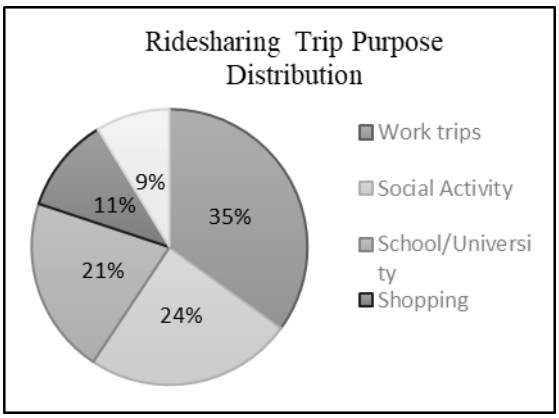

Figure 7: Percentage of Trip Purposes

4.2 Existing Scenario of Ridesharing

Respondents were also asked about their necessity of having a car when ridesharing is available. Among 1007 respondents 189 people have at least one vehicle. From these 189 people 22 replied that they don't need a vehicle now. From figure 8, it is seen that 13% of car owner don't feel the necessity of having personal vehicle anymore. This indicates mode shifting from personal vehicle to ridesharing. The idle time of ridesharing is less than personal vehicle as the vehicles need not to be parked.

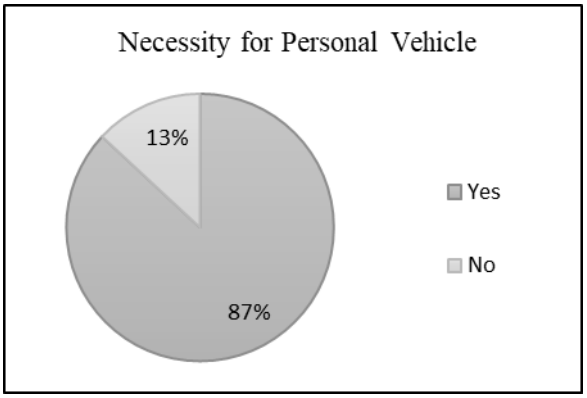

Figure 8: Necessity of Personal Vehicle Ownership

4.3 Modal Shift to Ridesharing

From analysis it is observed that, income range for most frequent ridesharing users are from 75-150 (in thousand). A systematic pattern is seen in frequency of using ridesharing with income range. Ridesharing user frequency increases with higher income but after a certain point, frequency starts decreasing with increase in income (figure 9). People with low income (0-25 thousand) prefer public transport for daily trip. Where people with income range 25-75 thousand and 75-150 thousand mostly prefer ridesharing for daily ride. In contrast people with high income (ranges from 150-300 thousand and greater than 300 thousand) use their personal vehicle for outing.

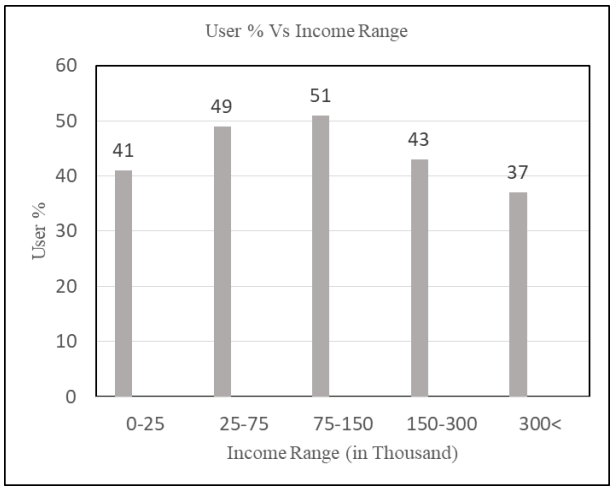

Figure 9: Ridesharing User Frequency with Different Income Level

Many factors can influence users' mode preference. Respondents were asked when there was no ridesharing service available what their preference for daily trip was. This result is presented as a comparison of mode preference between before and after launching ridesharing. 72% of 1007 riders replied they used public transport before launching ridesharing. Figure 10 shows that among the same respondents only 44% use public transport for daily trip now after launching ridesharing. Thus 28% public transport users have been shifted due to ridesharing. Similarly, percentage of other modes of transport (CNG/Auto rickshaw) users have been fallen from 13% to 8%. This huge shift from public transport definitely indicates the lacking of the Govt. to attract people by providing contemporary facilities. This will result in more vehicles on the road.

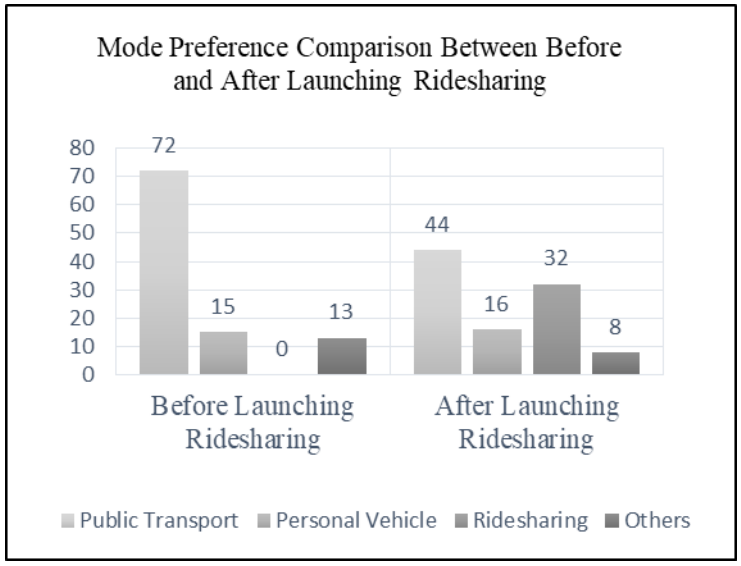

Figure 10: Mode Preference Before and After Launching Ridesharing

4.4 Carpooling and Induced Travel

A new feature carpooling (shared ride service) was introduced among the respondents which is currently not available in Bangladesh. 44% people of the total respondents prefer public transport for their daily trip. From respondents' feedback it is known that cost is their main reason behind not using ridesharing. But after introducing carpooling a significant change has been noticed in their response. Among these 44% people, 69% responded positive towards using ridesharing after knowing about carpooling which gives the opportunity of sharing ride as well as cost. Thus, induced percentage to ridesharing is around 30%. As a consequence, this 32% ridesharing users (Figure 10) will jump to 62%. Nonetheless this substantial percentage can affect on the existing transportation system.

Based on ridesharing users' feedback the following features were found which directed them to ridesharing-

- Quality of the Vehicle- About quality of vehicle 64% riders feel satisfied with the quality of the vehicle. Riders termed it as one of the major influencing characteristics for choosing ridesharing. A few user experienced low-quality vehicles specially car.
- Cleanliness of the Vehicle- About overall cleanliness of the used vehicle with ridesharing 59% responded as satisfactory or very satisfied. And another 16.5% people are dissatisfied with the cleanliness. About cleanliness issue motorcycle users mentioned about the problems of using same helmet.
- Riding Safety- About safety issue car users feel safer than motorcycle users. Among the car users 72% responded satisfied or highly satisfied whereas among motorcycle users 57% responded satisfied. A few riders face hijacking during a ride.
- Female Security- Riders were asked to comment on female security in ridesharing according to their perspective. 43.6% riders were satisfied about female security issue. They termed it far better than Dhaka's existing public transport. Due to this percentage women are focusing on ridesharing rather public transport. Another 25.1% riders think that ridesharing is not women friendly. The environment of ridesharing should be improved.
- Upgradation of Ridesharing Applications- For giving improved services ridesharing applications are upgraded. 56.2% riders were satisfied with upgradation. But 14.3% riders responded negative towards existing upgraded version.
- Charges of Ridesharing- In case of the charges of ridesharing service, 32.1% riders had no comments. However, they said the charges are within their affordable range. This percentage is willing to pay even extra charges but be comfortable on their trip. But 32.2% riders termed the charges 'too high' whereas 35.9% people are satisfied with the charge. They use ridesharing on a regular basis.

5. CONCLUSIONS

This paper represents the results based on current research to analyse the impact of ridesharing on Dhaka's existing transportation system as a new mode of mobilization. This new mode has shifted consumption habits of commuters and induced travel due to carpooling. To identify the impact of this new mode, a questionnaire survey was conducted in Dhaka city.

From the analysis, it is found that the maximum number of ridesharing users are from middle income commuters. Lower income groups are prone to be more sensitive to the expense and thus they are reluctant to pay high value for commuting. Besides, the higher income group have more flexibility on mode choice because of their car ownership (Lane, 2005; Katzev, 2003). Therefore, the percentage of ridesharing user is much affected by middle income commuters as they have less flexible work schedule and willing to pay high value for commuting (Shaheen, 2012). These results match with the real scenario quite fairly.

Moreover, the study shows a statistically significant decline in percentage of public transport users. Pojani and Stead (2015) stated that minimum cost and high quality got the maximum preferences among the commuters for trip purpose. Here 'cost' denotes to expense for travelling and fast speed associated with safety, comfortability, punctuality and reliability are the criteria for specifying 'high quality' (Chen, 2018). Though ridesharing is expensive compared with public transport, but high quality of ridesharing has seized out the commuters (Furuhata et al., 2013). The declining percentage of public transport users captured from the analysis reflects the above-mentioned scenario.
The findings in response to 'carpooling' among the public transport users have been found to be positive towards ridesharing. On account of carpooling, a major percentage of public transport users will be induced to ridesharing as carpooling not only reduces fare of travelling but also saves time, interest and energy. This induced percentage will undoubtedly impart effect on Dhaka's existing transportation system. Further investigation on this induced travel is required for an overall development of existing transportation system of Dhaka city.

This study focuses on assessing impact of ridesharing on existing transportation system based on users' perspective. It is recommended that future studies should explore this impact using more representative data from both users' and drivers' perspective. Future studies could also investigate to obtain detailed information regarding the falling rate of public transport users so that this could be a potent solution to several transportation issues. Comparing the effect of other modes of transportation with ridesharing will enhance this research as well as ameliorate towards building a sustainable transportation system.

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TRAFFIC NOISE AND ITS EFFECTS ON HUMAN HEALTH AND BEHAVIOR IN SOME SELECTED INTERSECTIONS OF KHULNA CITY

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ABSTRACT

Traffic noise has reached in an unacceptable level with the growing number of vehicles in urban areas. Exposure to traffic noise causes significant health and behavioral risks for the people who are vending or working along the roadside. This research explores the traffic noise levels at six selected intersections of Khulna City and identifies its effects on human health. So, noise level (in dB unit) was measured by Sound Meter, an android application which supports calibration to achieve actual reading. Using a cluster random sampling technique, a total of 120 respondents were surveyed through questionnaire together with collecting noise levels' data of different times at all selected intersections. Questionnaire of this study included issues related to demographics, health and exposure to noise. Then appropriate statistical analysis was carried out by using Statistical Package for the Social Sciences (SPSS) and R Studio. Among the six intersections, highest (111 dB) level of traffic noise was found in Dakbangla and lowest (51 dB) in Moilapota. In fact, noise levels at all the intersections are greater than expected level. Intersections with inadequate carriageway width to accommodate all traffic flow along with low level traffic management can be considered as one of the major causes of high traffic noise levels at the intersections. High noise levels have been found to be correlated with rising risk of noise related physical and mental health issues. Most of the people got affected by several health related problems simultaneously such as hearing impairment, communication problem, sleeping disturbance, cardiovascular and psychophysiological issues, mental health problems and performance related problems. Among them, some people were found with diabetes mellitus who were affected by traffic noise while working along the roadside of these intersections. It is also observed that age is moderately correlated with noise related health problems. Although the study didn't withstand effects of other factors on health related problems, but it has explored something on this aforementioned issuse that creates an enormous scopes for clinical research and upgrading relevant policy.

Keywords: *Traffic Noise, Noise Effect, Human Health, Human Behavior, Khulna City.*

1. INTRODUCTION

Noise can be defined as unwanted sound which is perceived as stressor or disturbance to the adjacent community (Stansfeld & Matheson, 2003). It is very regular for a person experiencing sound at levels that can cause unfavourable wellbeing impacts except people from very countryside area. People living in a typical urban environment hear a broad range of sounds in many places during a single day, including stations, road intersections, markets, shopping malls, classrooms, office, recreation canters and home. The most pervasive noise related issue refers to road traffic in most cities around the world. World Health Organisation (WHO) described noise as one of the most important health threats for the working-class population (Hansen, 2018). Noise-induced hearing impairment has been marked as the most prevalent irreversible occupational hazard.

Modern world is facing severe noise pollution due to over urbanization during the 21-century. Booming population growth, depletion of rural land area and rapidly growing transit infrastructure are of the main reasons behind the issue of noise pollution. It is a matter of concern for both developed and developing countries worldwide (Hoque, Basak, Rokanuzzaman & Roy, 2014). As a developed country, about 22 million U.S. workers are exposed to hazardous noise levels at work every year (Tak, Davis & Calvert, 2009). In Bangladesh, millions of people are exposed to a number of health risks due to noise pollution. Around 11.7% of the population in Bangladesh have lost their hearing due to noise pollution by 2017, according to the Department of Environment (DoE) study. It is also found that sound levels are far beyond the acceptable threshold for the human ear in all divisional cities of Bangladesh where Dhaka and Khulna are in the same position (Mamun, 2018).

Traffic noise is the principle source that is making Khulna city increasingly objectionable every day. Traffic noise exposure is responsible for a range of effects on human health and behavior including interference with communication, noise-induced hearing impairment, sleep disturbance effects, cardiovascular and psychophysiological effects, mental health effects, effects on performance, annoyance responses and effects on social behaviour (Berglund, Lindvall & Schwela, 1999). According to the Noise Pollution (Control) Rules 2006, the acceptable sound level for the Bangladesh is 50dB for daytime and 40dB for night in silent areas; 50dB for daytime and 45dB for night in residential areas; 60dB for daytime and 50dB for night in mixed areas (residential, commercial and industrial localities); 70dB for daytime and 60dB for night in commercial areas, and 75dB for daytime and 70dB for night in industrial areas (Bangladesh Department of Environment [BDE], 2006). Khulna city is going to deal with huge number of traffic after completing the Padma bridge in near future. So, Khulna may face shocking level of traffic noise soon. In fact, no recent research on traffic noise and related health issues is found for Khulna city which suggests the importance of this work.

In response to the alarming degree of traffic noise, this research attempted to find out the current traffic noise condition and its impact on human health and behaviour at some selected intersections in Khulna city. For this, available handheld mobile device was used in a systematic way to measure the noise level. Adjacent people around the intersections who works along the roadside were surveyed to extract information about traffic noise and their health based on perception.

2. METHODOLOGY

2.1 Study Area

Six intersections were selected to conduct this research in Khulna City Corporation (KCC) area, the main city of Khulna division. Geographically, it is linear shaped and lies at 22"49'north latitude and 89"34'east longitudes. Its area is 59.57 km^2. Khulna is Bangladesh's third-largest economic centre. It is a hub of Bangladeshi industry hosting many national companies. Khulna is served by the Port of Mongla (the second-largest seaport in the country). Its population density is about 19,000 inhabitants per square kilometre (49,000/sq. mi). The selected intersections for this research are Dakbangla, Shibbari, Sonadanga, Gollamari, Nirala and Moilapota which are shown through Figure 1. These are the major working along the roadside, well-known and important intersections in Khulna City.

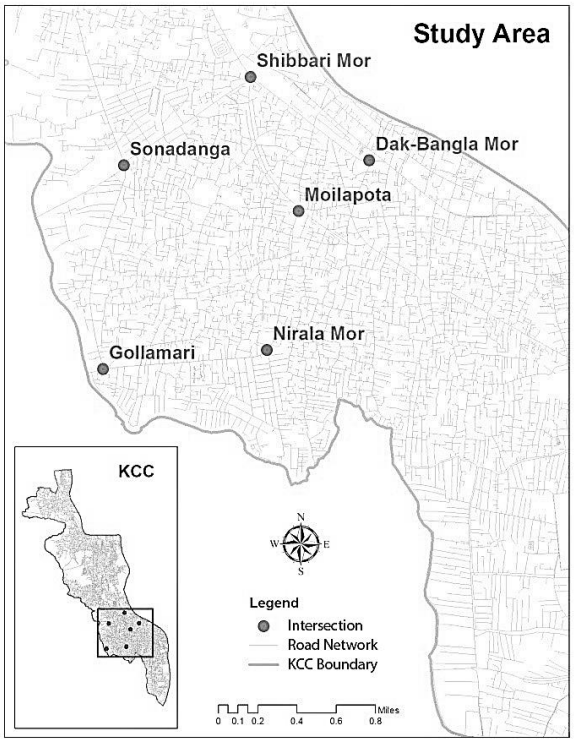

Figure 1: Study area

Source: Authors, 2019.

2.2 Sampling, Data Collection Tools and Techniques

2.2.1 Questionnaire Survey Data

Questionnaire survey data comprised demographic and health related data of every respondent. The sample size was calculated using the simplified equation provided by Taro Yamane where the confidence level was taken as 91 percent (Yamane, 1967). The resulted sample size was 120. So, total 120 respondents were surveyed through cluster random sampling technique for six selected intersections. 20 respondents were selected randomly for each of the intersections. A questionnaire was developed considering all necessary related aspects to collect data from the respondents. All respondents were picked in a way that their working place is situated within 50 meters buffer zone of the corresponding intersection (noise measuring point).

2.2.2 Noise Data

Using an application called Sound Meter (Version: 3.2.6, Abc Apps), noise data was collected through android mobile device. It has calibration functionality which is very useful to get noise data in decibel (dB) unit as same as sound level meter. Calibration was done using UT353 Mini Sound Meter (UNI-T) where the error was around 17dB. Noise data was collected from all six intersections for three times a day covering peak (9AM to 10AM, 5PM to 6PM) and off-peak (3PM to 4PM) hours. This process was followed for three days at each of the intersections. Noise was measured (Maximum, Average and Minimum) for ten minutes duration every time.

2.3 Analytical Procedure

Several analytical tools and techniques have been applied to analyse traffic noise along with its impact on human well-being and behaviour. An overall and time-wise estimation of noise level (dB) has been made for all of the intersections and then, descriptive and inferential statistics have been used to analyse noise level (dB) along with data collected through questionnaire survey. Statistical Package for Social

Sciences (SPSS) and R Studio have been used to perform those. Firstly, association between noise level and health issues were assessed through Pearson's Chi-square test while both were taken as categorical variable. Then, Univariate Binary Logistic Regression (UBLR) analysis was used to examine the impact of traffic noise on human health and behaviour. Finally, appropriate descriptive statistical analysis was used to clarify and justify the circumstances on the basis of the UBLR's result.

Univariate Binary Logistic Regression (UBLR) is used to characterize information and to illustrate the relationships between one dependent binary variable and one or more independent nominal, ordinal, interval or ratio-level independent variables (Schüppert, 2009). Here, noise related health problem (Two category: Yes or No) has been taken as dependent variable and the noise data in dB unit has been taken as independent variable to conduct UBLR. Here, equation (1) shows the UBLR with proper depiction (Figure 2).

$$P(Y) = \frac{1}{1+e^{-(b_0+b_1X_1)}} \quad (1)$$

P: probability of *Y* occurring
e: natural logarithm base (= 2.7182818284…)
b_0: interception at y-axis
b_1: line gradient
X_1 predicts the probability of *Y*.
Here, Figure 2 shows that *P(Y)* ranges from *0* to *1*, the logit ranges from -∞ to +∞.

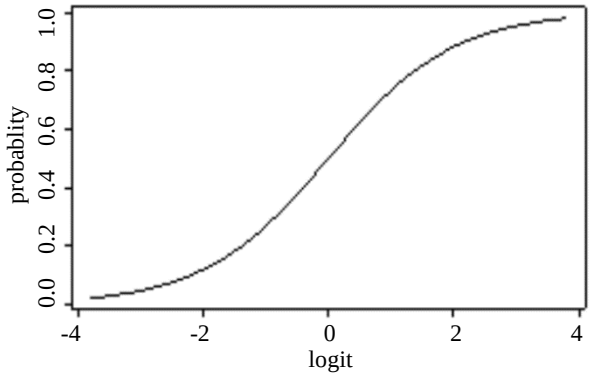

Figure 2: Logit transformation

Source: Rodríguez, 2019.

The regression model is acceptable when the p-value is below 0.05 and a high R^2 value means a better model fit. However, Figure 3 illustrates the analytical procedure of this study below.

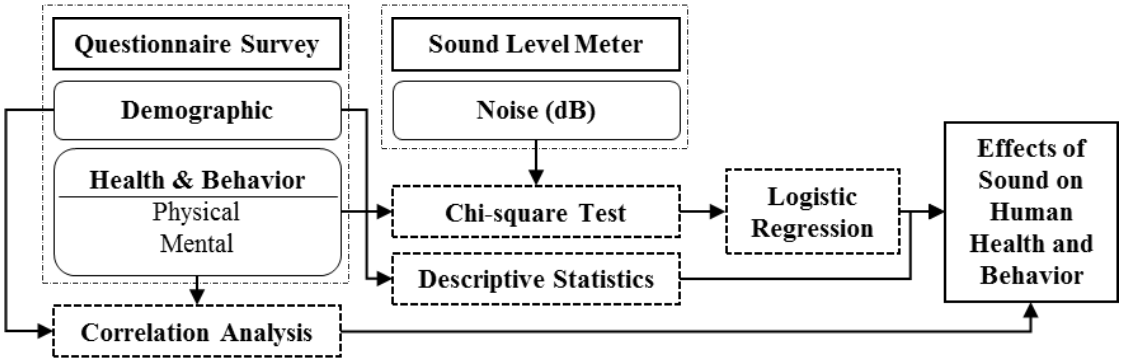

Figure 3: Analytical framework

3. RESULTS AND DISCUSSIONS

3.1 Traffic Noise Condition at Six Intersections

This study found the average, minimum and maximum noise level of three times a day for all six intersections. An overall estimation has been conducted from the daily three times' data to see the simplified scenario of the intersections. Table 1 shows that the minimum sound is 51 dB (Moilapota) and the maximum sound is 111 dB (Dakbangla). Because, Moilapota intersection has a roundabout which is quite spacious. Here, the traffic management is relatively better as well. On the other hand, Dakbangla intersection is the most overcrowded and busy place in Khulna city. It is the main commercial zone next to the railway station and launch terminal in the city boundary. It is also observed from the overall average noise levels of these two locations. Overall average noise at Shibbari (76 dB) shows the second lowest level. Shibbari connects northern and western part of Khulna with the central part. It has to deal with huge number of vehicles but its large spacious roundabout contributes to keep noise level comparatively lower. The second highest overall average noise level has been found at Gollamari (82 dB). It is the entrance intersection towards Khulna city centre with relatively narrow street. As a result, traffic jam is very common in this intersection during peak hour and noise measurement during off-peak hour shows high level of noise as well. From the overall noise data, it is seen that Dakbangla, Gollamari and Sonadanga (overall average noise level is 81 dB) are nearly placed. Sonadanga is the main bus terminal in Khulna city. It is another entrance to Khulna city via Sonadanga bypass road with heavy traffic. Nirala is a well-known residential area in Khulna city. Nirala intersection has to carry traffic with its narrow street and intersection from Gollamari to Moilapota and vice-versa. So, it's usual to see Nirala's overall average noise level (78 dB) in moderate level comparing to the other intersections. However, all of these intersections' noise is higher than the accepted normal noise level (70dB for daytime and 60dB for night in commercial areas) defined by appropriate authority (BDE, 2006).

Table 1: Noise levels in all intersections

Location	Overall (Sound in dB)			Morning (Sound in dB)**			Noon (Sound in dB)*			Evening (Sound in dB)**		
	Min	Avg.	Max	Min	Avg.	Max	Min	Avg.	Max	Min	Avg.	Max
Sonadanga	66	81	107	69	79	106	66	82	107	69	82	107
Gollamari	58	82	110	58	79	106	63	85	107	65	83	110
Nirala	58	78	110	58	77	106	60	81	110	60	77	110
Dakbangla	61	83	111	61	81	109	64	84	111	69	85	110
Moilapota	51	73	110	51	73	103	57	75	110	56	73	109
Shibbari	59	76	110	60	75	109	59	75	110	65	77	107

**Peak hour, *Off-peak hour

Source: Field Survey, 2019.

3.2 Respondents' Demographic Information

This study found that the majority of respondents were male. They were primarily involved in various types of business such as tea stall, fruit shop, departmental store, stationary shop, electronics shop, medicine store, restaurant and various small scale road side business. Table 2 shows the respondents' age range from 22 years to 60 years where the average age is 38 years old.

Table 2: Respondents' demographic information

	Age (Years)	Service Time (Hours Per day)	Monthly Income (BDT)
Mean	38.27	13.56	35275
Median	38	13	25000

	Age (Years)	Service Time (Hours Per day)	Monthly Income (BDT)
Mode	38	13	25000
Standard Deviation	8.47	1.91	25590.49
Minimum	22	7	8000
Maximum	60	17	120000

Source: Questionnaire Survey, 2019.

All of them are adult and there is a necessary variation in ages as well. Standard deviation refers to majority's age range is from 30 years to 46 years. Every day, they spend about 13 hours on an average in their own working place. Their monthly earning ranges from 8000 BDT to 120000 BDT where the average earning is 35275 BDT. Here, the standard deviation of monthly income indicates heterogeneity among the respondents.

3.3 Traffic Noise and Related Issues

Association between traffic noise level and noise related health issues has been tested through Pearson's Chi-square test. Noise level is divided into six categories in a level of 1 to 6 based on their noise intensity. On the other hand, noise related health issue has been considered as binary variable with YES=1 or NO=0 value. The result is shown through Table 3.

Table 3: Chi-square test's result from health effects of traffic noise and noise level

Number of Valid Cases	Pearson Chi-Square			Cramer's V	
	Value	Asymptotic Significance (2-sided)	df	Value	Approximate Significance
120	21.052632	0.001	5	0.418854	0.001

Source: Questionnaire Survey, 2019.

The null hypothesis of the Chi-Square test is that no relationship exists on the categorical variables in the population; they are independent. Here (Table 3), the Chi-square result can be expressed as $X^2(5) = 21.05$, $p = 0.001$ which indicates that Chi-square value is greater than the critical value (11.07) at df=5 and $p \leq 0.01$. So, the null hypothesis is rejected and there is a significant association between traffic noise level and noise related health issues. Cramer's V is a number between 0 and 1 that indicates how strongly two categorical variables are associated. Here (Table 3), the resulted value (0.42) shows a significant moderate association between the variables.

As the association has been found through appropriate statistical analysis, it is important to find out how traffic noise affect human health and behavior. Univariate Binary Logistic Regression (UBLR) has been used to do so with the aforementioned two variables (2.3.2). Table 3 shows the result of UBLR.

Table 4: Univariate Binary Logistic Regression (UBLR)'s result

Independent Variable (N=120)	B (Beta Coefficient)	S.E. (Standard Error)	Wald Chi-Square	Sig.	Exp(B) Odds Ratio
Traffic Noise Data in dB Unit	0.940	0.443	4.505	0.034*	2.560

Dependent Variable: If Any Noise Related Health Problem (*YES=1, NO=0*).
$X^2(1) = 17.008$, $p \leq 0.01$
Nagelkerke R Square = 0.403
* Significant at $p \leq 0.05$.

Source: Questionnaire Survey, 2019.

Here, Univariate Binary Logistic Regression (UBLR) was performed to ascertain the effects of traffic noise on the likelihood that participants have noise related health problems. Table 4 indicates that UBLR model is statistically significant, $X^2(1) = 17.008$, $p < 0.01$. The model can explain 40.3% (Nagelkerke R^2) of the variance in noise related health problems and correctly classify 95.0% of cases. Table 4 also shows that increasing traffic noise (dB) is associated with an increased likelihood of exhibiting noise related health problems in Khulna city.

Due to traffic noise, people of the adjacent intersection are suffering from various health and behavioural problems. This study found (Table 5) about 94 percent of the respondents who were suffering from mental health related problems like mental stress as well as bad headache. Noise-induced hearing impairment affected 90 percent of the respondents. 88 percent respondents belong to groups sensitive to interference with communication. Noise tends to interfere with auditory communication, where the most important signal is speech (Berglund, Lindvall & Schwela, 1999). Around 53 percent of the respondents are suffering from sleeping problem. Cardiovascular and psychophysiological effects due to traffic noise seem very lower in percentage. Also, impact of traffic noise on performance is very low among the respondents. There are many people having multiple problems simultaneously.

Table 5: Noise related health and behavioral problems

Name of the Problems	**Percentage of Affected People* (Individual Percentage, N=120)**
Noise-induced hearing impairment	90.00%
Interference with communication	88.33%
Sleep disturbance effects	53.33%
Cardiovascular and psychophysiological effects	25.00%
Mental health effects	94.17%
Effects on performance	10.00%

*People have multiple problems simultaneously.

Source: Questionnaire Survey, 2019.

Generally, aging is a strong risk factor for many types of diseases (Atella et al., 2019). Figure 4 shows similar scenario from the perspective of traffic noise related health problems. Plotting between number of noise related health problems and corresponding respondent's age gives an upward trend line. Considering these two factors, a Pearson Correlation was conducted where a positive moderate correlation coefficient value as 0.413 was found that is significant at 0.01 ($p < 0.01$).

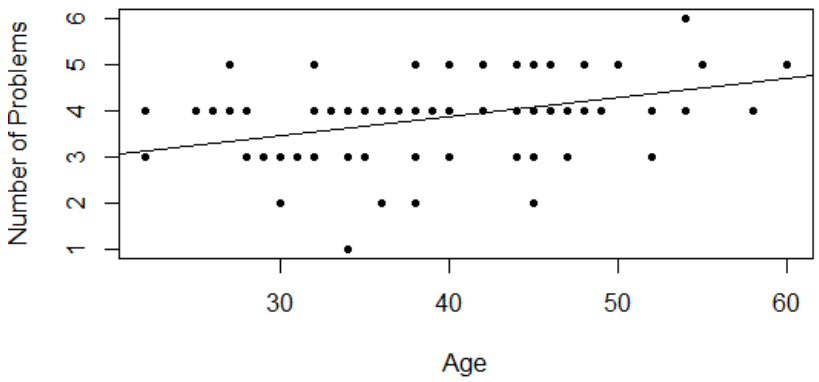

Figure 4: Plotting age with number of problems due to traffic noise.

Source: Questionnaire Survey, 2019.

Again, number of health problems are shown through boxplot according to each of the intersections which shows that number of health problems is the highest at Gollamari and the lowest is at Shibbari (as shown in Figure 5). Here, larger interquartile range (Shibbari and Gollamari) indicates large variation in number of problems among respondents in the corresponding intersection. Also, Shibbari

holds the lowest median which indicates that most of the respondents at Shibbari have lower number of problems. In contrast, narrow interquartile range (Sonadanga) indicates smaller variation in number of problems among respondents in the corresponding intersection. While considering the medians, boxplots of all intersections except Dakbangla are skewed. Dakbangla holds a symmetric (roughly the same on each side when cut down the middle) data set that indicates the median roughly in the middle of the box. So, almost half of respondents from Dakbangla have 3 problems and the rest half have 4 problems. Nonetheless, the average number of problems is 3.80 where both median and mode value is 4 and standard deviation is 0.85. This scenario is similar to the boxplot's (Figure 5) scenario for all intersections.

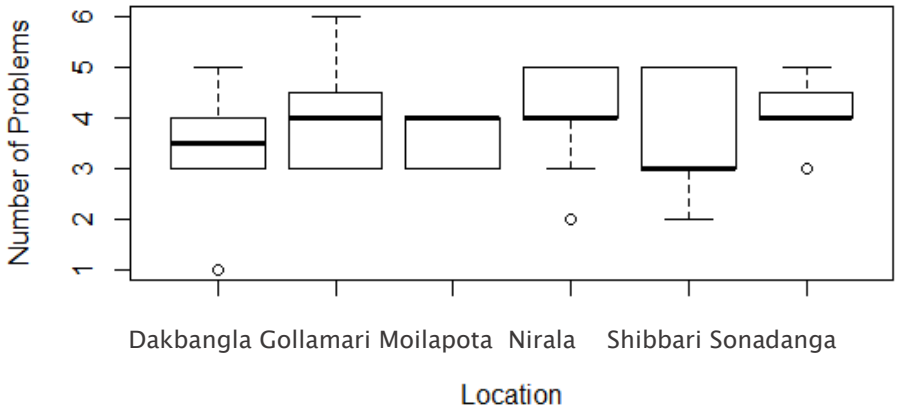

Figure 5: Boxplot of the six intersections considering number of problems due to traffic noise.
Source: Questionnaire Survey, 2019.

It is also found that people (appx. 7%) are suffering from other health related problem like diabetes and their age range is from 44 years to 60 years. This study shows that all of them got affected by diabetes mellitus (DM) after coming to their present workplace. Several researchers also found that an increase in traffic noise of 5 dB was associated with an increase in DM risk of 7 percent (Sakhvidi, 2018). They are also suffering from 3 to 6 traffic noise related health problems simultaneously. Their very common noise related health problem is mental health effects.

3.4 Overall Discussion

Traffic noise levels at all six intersections were found comparatively higher than the normal accepted noise level (70 dB) specified by Department of Environment. Highest average level was observed at Dakbangla where the lowest was observed at Moilapota. Considering the other intersections' noise levels, it can be said that intersections with inadequate carriageway width having efficient traffic management generates higher level of traffic noise. Respondents' age range is from 30 years to 46 years (nearly) who works 13 hours on an average daily. Analysis shows that people are suffering from various types of health and behavioral problems due to higher level of traffic noise at all six intersection in Khulna. It is expected that scenario of other well-known and important intersections in Khulna may be same as those selected intersections.

Here, most of the people are suffering from hearing, communication and mental health related problems. Others problems are also found but not as higher percentage as those while majority people are affected by multiple problems. Most of the people are affected by 3 to 4 noise related problems and people at Gollamari intersection are affected by the highest number of noise related problems. A significant association has been found between age and respondents' number of noise related problems. Some of the respondents were found with diabetes mellitus while working at their present working place beside the corresponding intersection. Here, traffic noise can be considered as potential cause of diabetes mellitus.

4. CONCLUSIONS

This research was conducted to find out the present condition of traffic noise and its effect on human health and behavior in Khulna. It included a wide range of people who works around 13 hours a day in noisy environment continuously. As a consequence of higher noise level, their mental health is affected more than their physical health. Often, issues in mental health lead to physical health problems. There are scopes of in-depth clinical research regarding this aspect as soon as possible. Nonetheless, in Khulna, intersections with inadequate carriageway to accommodate all traffic flow having low level traffic management, lead to higher traffic noise which is above the normal and acceptable level. So, it is urgent to impose strict traffic regulations in related options that can help noise reduction. Appropriate authority has wide scopes to review the rules and regulations relating to noise, taking into account from a range of related perspectives.

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A COMPARATIVE STUDY ON FLY ASH, BAGASSE ASH AND RICE HUSK ASH USING AS A SUB-GRADE MATERIAL IN EXPANSIVE SOIL

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ABSTRACT

Expansive soil generally occupy volumetric changes when subjected to variation in moisture content. As the soil is very active and it shrinks and swells with change in moisture contents so low bearing strength and high compressibility behavior of most soils can cause severe damage to subgrade. In this research we evaluate the strength of soil by adding different types of ground improvement materials like as fly ash, bagasse ash and rice husk ash in order to overcome such types of damages. CBR tests were performed with fly ash, bagasse ash and rice husk ash separately at different percentage variations with the increment of 2.5% by weight in order to find out which one is most suitable for stabilization of subgrade material. The results show that initially the California bearing ratio value (CBR) of soil was 6.63% and for addition of fly ash, bagasse ash and rice husk ash separately up to 12.5% it increased up to 15.11%, 13.21% and 18.40% respectively. Initially the CBR value of soil is 6.63%. For addition of bagasse ash up to 7.5% the CBR value of soil has become in increase up to 13.87% and after then for addition of 12.5% bagasse ash it has become in decrease 13.21%. For fly ash the CBR value for 10% is 15.29%, which is larger than the bagasse ash and CBR value for adding 2.5% of rice husk ash is 17.15% and up to adding 10% of rice husk ash it increased up to 18.67% after which in 12.5% CBR value got decreased. So as getting some point of view of making a comparison between the CBR values of Fly ash, Bagasse ash & Rice husk ash the respective highest values are 15.29%, 13.87% & 18.67%.

Keywords: *Expansive Soil, Fly Ash, Bagasse Ash, Rice Husk Ash, Swelling Index, MDD, OMC, CBR.*

1. INTRODUCTION

Expansive soil generally defines as a type of clay soil. Preparation and construction of highways and runways over expansive soils is one of the remarkable civil engineering burning issue over the world considering to the fact expansive soils having the characteristics of shrinking and swelling with variation in moisture content. In monsoon expansive soil generally absorbs water and expands in volume. Similarly, in summer it shrinks because water leaves away (Somaiya, et al., 2013). In semi-arid and arid regions of the globe, expansive soils shows the characteristics of destruction to the nature unless it is treated, causes acute damage to the structure built on it as well as loss of human life (Mohanty, 2015). The properties of soil can be improved by stabilization with admixtures such as lime, cement, fly ash, bagasse ash and rice husk ash are used to improve the qualities of various types of soils such as Lateritic Soil, Clayey soil. In this research fly ash, bagasse ash and rice husk ash are differentially used for the purpose of stabilization of expansive soil.

A waste material extracted from the gases emitting from coal fired furnaces generally called fly ash. Again, fly ash is a waste by product from thermal power plants. The main goal of volcanic ashes in ancient periods were the use of it as hydraulic cements and fly ash carries almost same property to these volcanic ashes. These ashes occupied as one of the best binding agent used in the world. But it requires thousands hectares of farming land for its disposal and also causing both severe health problems and environmental hazards. So, the proper management of this is inevitable for our sound survival. But having both great availability and its low cost, the chances of its usage is investigated here. (Ahmed, 2014; Mohanty, 2015; Anu, et al., 2016)

About 40–45% of the fibrous waste from sugarcane after crushing and extraction of its juice is termed as ‘‘bagasse”. Basically, it is regenerated as fuel in boilers for heat generation which leaves out 8–10% of ash, known as Bagasse Ash, which is treated as residue and unused. Sugarcane bagasse consists of approximately 50% of cellulose, 25% of hemicelluloses and 25% of lignin. Bagasse ash is a non-cohesive material having a low specific gravity. It contains a massive amount of silica and at burnt it behaves as binding material. On the contrary, the disposal of this material is the reason of causing environmental problems around the sugar industries. After realizing the overall facts it can be used as for the stabilization of road subgrade material (Najar, et al. 2017; Murali, et al. 2018).

Many researches have showed in the recent past years on the use of fly ash and sugarcane bagasse ash in the development of road subgrade. Goliya, H. S., Faraz, M. I. and Singune, V. (2018) reviewed various papers where researcher are used various stabilizer. In which some mixtures are expensive and some mixtures are economical. Cement, chemical, bituminous mixtures are expensive and saw dust, fly ash, rice husk, bagasse ash are cheaper. So the cheap stabilizer are used to minimize the project cost and the result will come in the form of improvement in active or black cotton soil properties, CBR value, stability and bearing capacity of soil value will be increased. The characteristics of an expansive soil can be found by using fly ash stabilization. Phanikumar and Sharma (2004) showed that by using 20% fly ash the plasticity of soil reduced by 50%. Also optimum moisture content is increased with the addition of ash in the compaction tests by increasing the soil great specific surface and decreasing the maximum dry density because of a lower specific weight. Ahmed also indicates that the fly ash can be applied in soils containing a high percentage of moisture resulting in greater compaction because of the evaporation of a considerable quantity of the contained moisture (Ahmed, 2014). Another paper showed that maximum dry density obtained from modified Proctor test decreases with increasing fly ash content and there is no consistent variation in optimum moisture content with increasing fly ash content (Ozdemir, 2016).

Rice Husk Ash (RHA) is the by-product of the burning of rice husk. By weight, 10% of the rice grain is rice husk. On burning the rice husk, about 20% becomes RHA. This RHA contains around 85% to 90% amorphous silica. Rice husk ash is basically termed as the agricultural waste products obtained from the rice milling. Rice husk ash is used in many application due to its versatile properties. Rice husk ash is used in different applications such as building and construction, steel, ceramic and refractory, silica manufacturing and others. Use of RHA in building and construction industry governs the market with more than 40% in period of applications. Also, RHA is widely applied in production of high strength concrete by replacing silica fume, in term of mineral admixture. RHA to be used in powder form as an admixture in soil. Bhasin et al. (1988), made a laboratory research work on the stabilization of black cotton soil as a pavement material using RHA, along with other industrial by-product wastes like fly ash, bagasse ash, lime sludge, black sulphite liquor independently. The RHA causes greater improvement rather than other wastes due to presence of higher percentage of reactive silica in chemical formation. In combination with lime, RHA improved the properties of black cotton soil effectively. Ms. Aparna (2014), has presented a research work delineates information about soil which is stabilized with different percentages of Rice Husk Ash and a small amount of cement. This application showed that the increase in RHA content increases the Optimum Moisture Content but decreases the Maximum Dry Density in quantity. Also, the CBR value and Unconfined Compressive Strength of soil are considerably developed with the Rice Husk Ash content.

2. METHODOLOGY

2.1 Materials and Methods

The expansive soil used in this research work was collected from Godagari Upazila in the district of Rajshahi in Bangladesh. The soil sample was collected about 5 feet below from the surface level. The admixtures utilized in this research are fly ash, bagasse ash and rice husk ash. Fly ash sample was accumulated from the Bangladesh Barapukuria Power Station and sugarcane bagasse ash sample was accumulated from Rajshahi Sugar Mill. Alongside the Rice Husk Ash sample was accumulated from the Haque Auto Rice Mill, Cantonment road, Rajshahi. After that the collecting samples were dried for 24 hours for the laboratory works. Then the sample was prepared and subjected to various laboratory tests including specific gravity test, liquid limit test, plastic limit test, shrinkage limit test, modified proctor test and California bearing ratio (CBR) test to find out the engineering properties of the samples. California Bearing Ratio (CBR) value of sub grade is used for design of flexible pavements and determination the stability of subgrade soil by adding mixtures. AASHTO and ASTM standards are projected in order to determine and evaluate the engineering properties of soil. The Soil sample is adulterated and compounded with various percentages of fly ash and bagasse ash and rice husk ash separately and subjected to modified proctor test to get the optimum moisture content and maximum dry density of soil sample pros and cons mixing with admixtures. Then CBR test is supervised in unsoaked condition. The soil sample is concocted with its optimum moisture content and compacted and condensed in 5 layers by giving 56 blows to each layer by 4.89 kg hammer. After then it is assigned on the penetration test machine to find out the CBR value.

2.2 Properties of expansive soil sample

The soil sample was fully oven dried, weighed and placed in room temperature for storing. After that, the general properties and prominences of the soil were experienced in the laboratory. Then

the soil sample was tested for liquid limit, shrinkage limit, plastic limit, plasticity index, optimum moisture content, maximum dry density and finally CBR test delineated in Table 1.

Table 1: Fundamental engineering properties of expansive soil

Properties	Value
Textural classification	Loam
Sand content (%)	35
Silt content (%)	40
Clay content (%)	25
Specific gravity	2.65
Liquid limit (%)	58.43
Plastic limit (%)	30.21
Shrinkage limit (%)	17.36
Plasticity index (%)	28.22
Optimum moisture content (%)	13.5
Maximum dry density (gm/cm^3)	1.88
California bearing ratio (%)	6.63

Kinjal, S., Desai, A. K., and Solanki, C. H. (2012).studied, the expansive soil contains a lot of percentage of clay content as well as silt content for the strong hydrophilic properties. Again the liquid limit of the expansive soil should be more than 40% and plasticity index of expansive soil should be higher than 20. So, our test soil sample can be classified as expansive soil containing liquid limit 58.43% and plasticity index 28.22%.

2.2 Preparation of Admixtures

The above considered materials such as expansive soil, fly ash, bagasse ash and rice husk ash was collected. After collecting the fly ash it was dried in the oven. Alongside Sugarcane Bagasse ash and Rice Husk Ash was dried in air for 3-4 days. Then the admixtures were sieved through IS Sieve No.200 (75μ) in order to achieve a uniform powdery for identifying the variations.

Table 2: Chemical composition of Fly Ash

Oxide	Percentage
SiO_2	54.4
Al_2O_3	35.6
Fe_2O_3	2.9
TiO_2	3.2
Mn_3O_4	0.11
CaO	0.56
K_2O	0.66
Na_2O	0.06
MgO	0.18
P_2O_5	0.46
SO_3	0.13

Wardell Armstrong (1991)

Table 3: Chemical composition of Bagasse Ash

Oxide	Percentage
SiO_2	78.34
Al_2O_3	8.55
Fe_2O_3	3.61
CaO	2.15
Na_2O	0.12
MnO	0.13
TiO_2	0.50
MgO	1.65
P_2O_5	1.07
K_2O	3.46

Corderio, et al. (2004)

Table 4: Chemical composition of Rice Husk Ash

Constituent	**%**
SiO_2	90.23
Al_2O_3	2.54
C	2.23
CaO	1.58
MgO	0.53
KaO	0.39
Fe_2O_3	0.21

3. RESULTS

The subsequent grain size distribution curve is established by using the data acquired from sieve analysis and hydrometer analysis of soil delineated in Figure 1 showing silt content 40% and clay content 25%

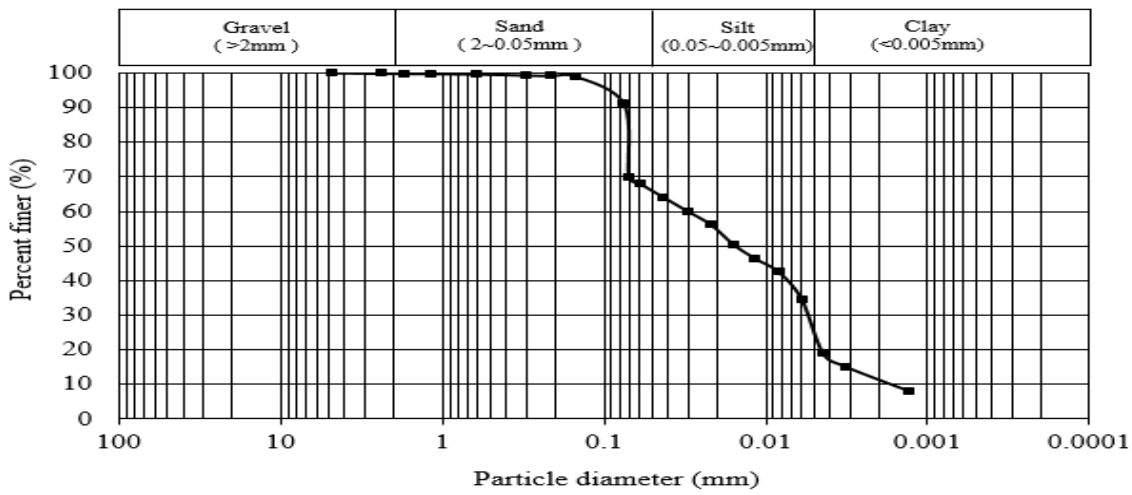


Figure 1: Grain Size Distribution Curve

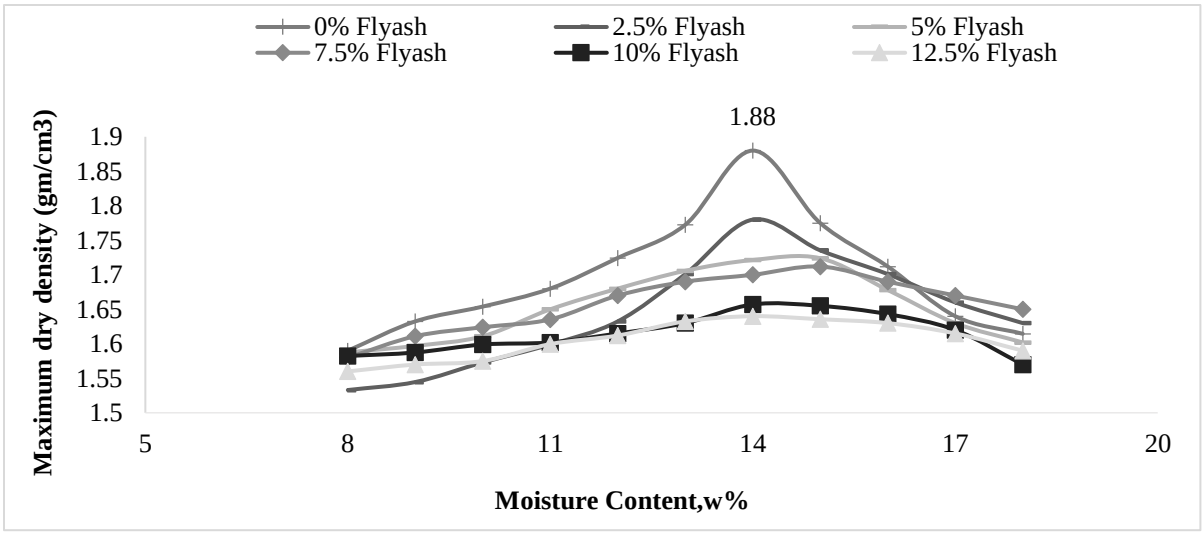


Figure 2: Moisture Content & Maximum Dry density of soil with different percentage of Fly Ash

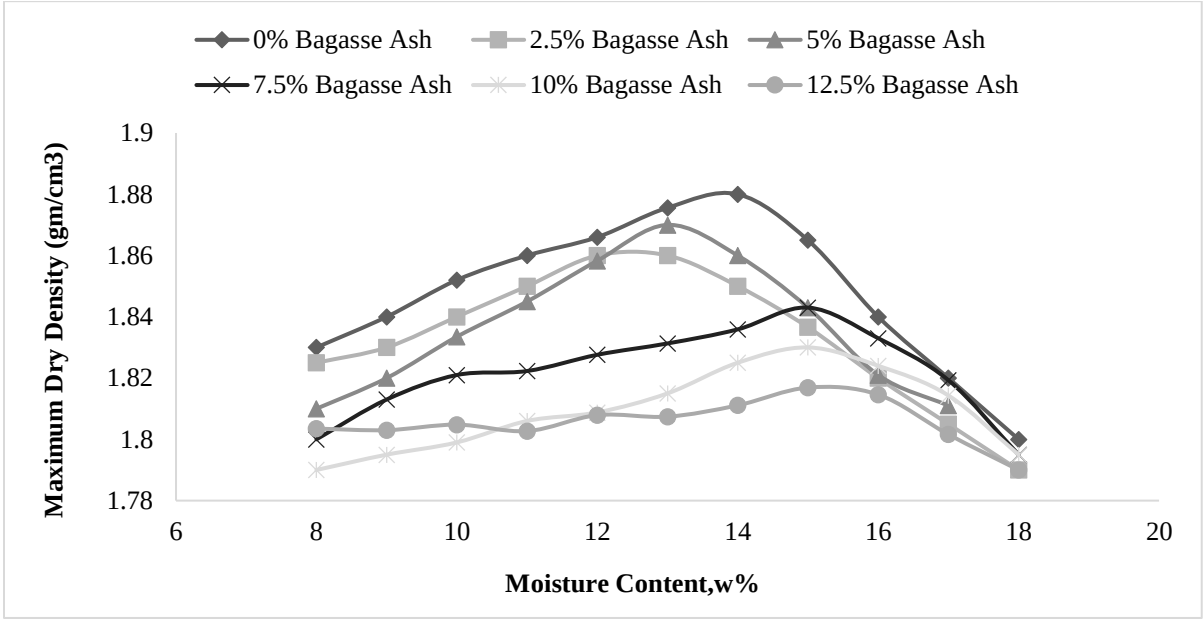


Figure 3: Moisture Content & Maximum Dry density of soil with different percentage of Bagasse Ash

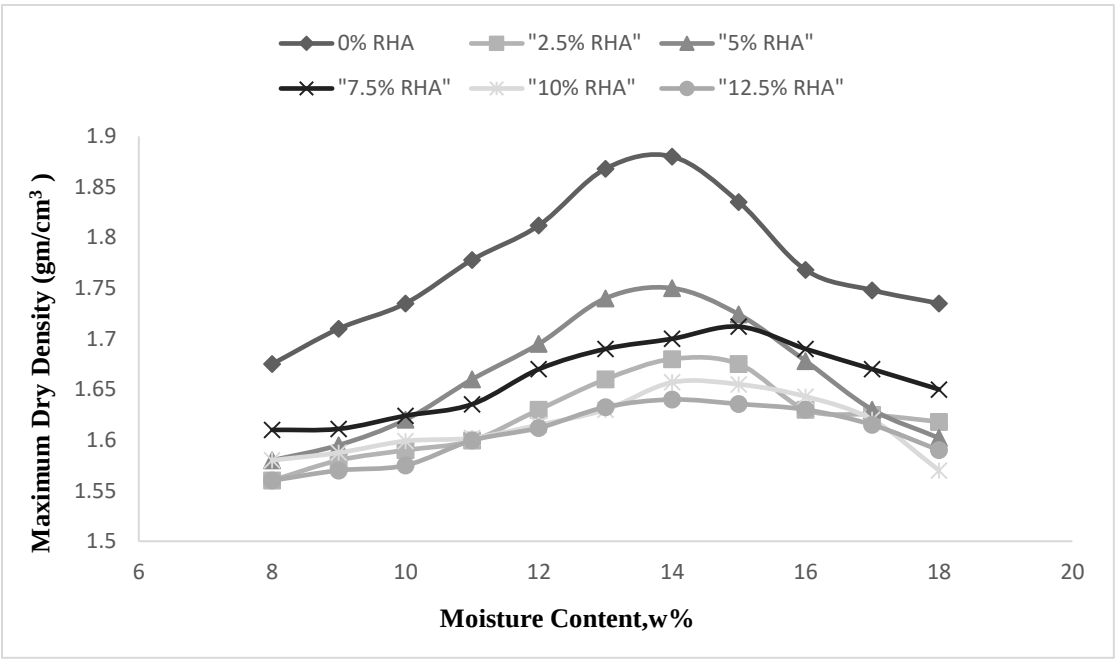
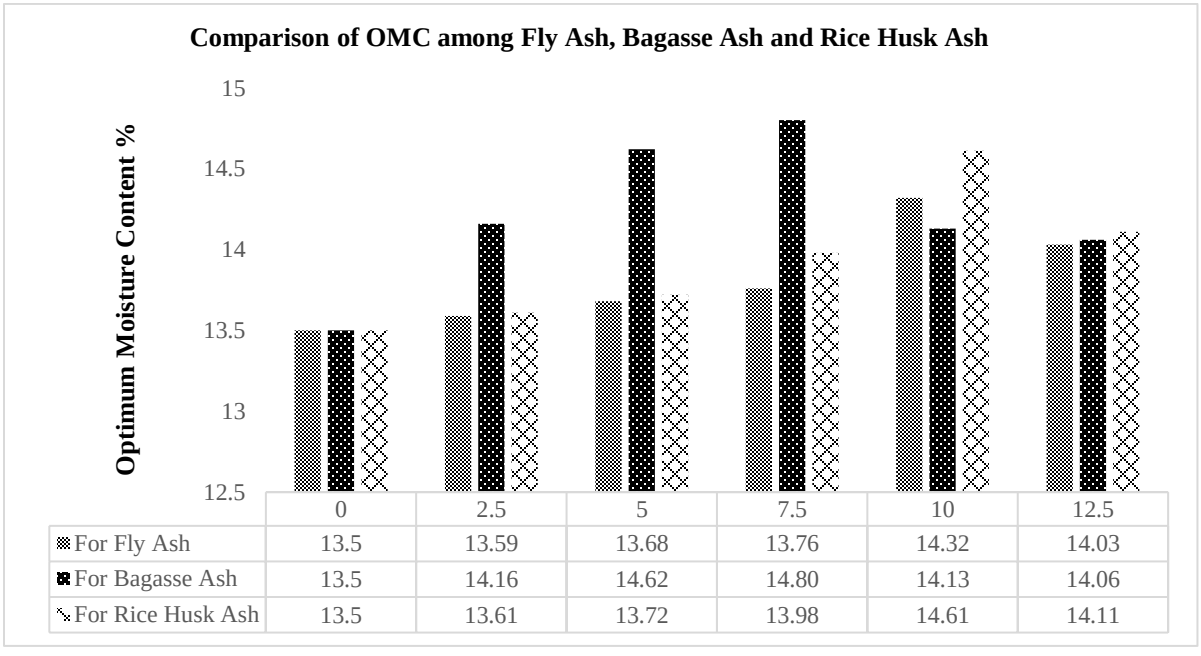
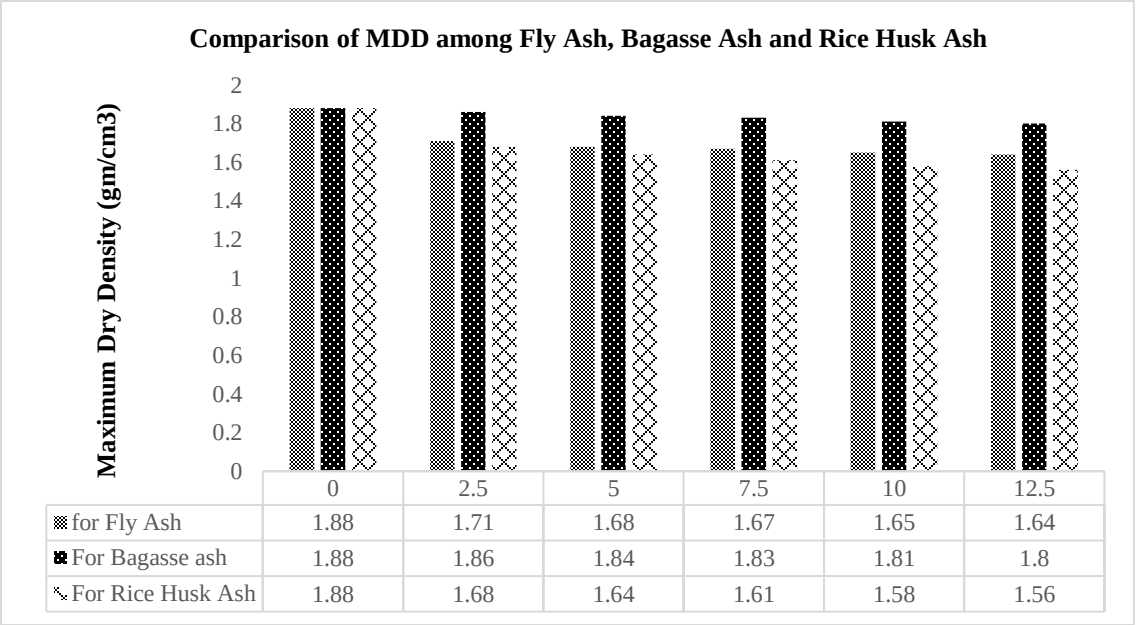


Figure 4: Moisture Content & Maximum Dry density of soil with different percentage of Rice Husk Ash (RHA)



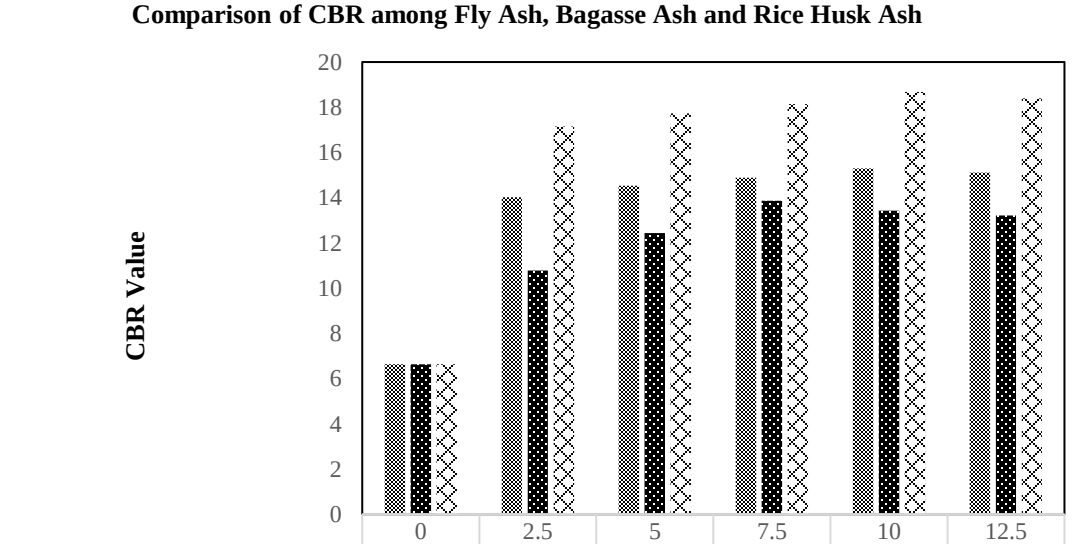
	0	2.5	5	7.5	10	12.5
For Fly Ash	13.5	13.59	13.68	13.76	14.32	14.03
For Bagasse Ash	13.5	14.16	14.62	14.80	14.13	14.06
For Rice Husk Ash	13.5	13.61	13.72	13.98	14.61	14.11

Figure 5: Optimum moisture content of soil with various percentages of Fly Ash, Bagasse ash and Rice Husk Ash



	0	2.5	5	7.5	10	12.5
for Fly Ash	1.88	1.71	1.68	1.67	1.65	1.64
For Bagasse ash	1.88	1.86	1.84	1.83	1.81	1.8
For Rice Husk Ash	1.88	1.68	1.64	1.61	1.58	1.56

Figure 6: Maximum Dry Density of soil with various percentages of Fly Ash and Bagasse ash and Rice Husk Ash



	0	2.5	5	7.5	10	12.5
CBR of soil using Fly Ash	6.63	14.02	14.53	14.88	15.29	15.11
CBR of soil using Bagasse Ash	6.63	10.78	12.44	13.87	13.42	13.21
CBR of soil using Rice Husk Ash	6.63	17.15	17.73	18.14	18.67	18.4

Figure 7: CBR values of soil with various percentages of Fly Ash, Bagasse ash and Rice Husk Ash

4. DISCUSSIONS

Corresponding to Textural classification (U.S. Bureau of Soil and Public Road Administration (PRA) classification) from grain size distribution curve describes as the following soil sample is clay loam. And from the plasticity chart the liquid limit of soil is 58.43% and resembling plasticity index is 28.22%, so it has been identified that it is a medium plastic soil.

From the Figure 2, Figure 3 & Figure 4 the addition of fly ash, bagasse ash and rice husk ash separately by weight (0%, 2.5%, 5%, 7.5%, 10% and 12.5%) to the soil sample caused an increase in the optimum moisture content and caused a decrease in maximum dry density. But for Rice Husk Ash the rate of increment of OMC is relatively higher than the others. In case of maximum dry density for different percentages of mixing admixtures, bagasse ash gives the greater value compared to the fly ash and rice husk ash.

In Figure 5 it is stated that after applying the various percentage of ashes the OMC value of soil slightly got increased up to an optimum value. As early it was 13.5 and by adding 10% of fly ash it got increased up to 14.32 and after 10% of fly ash it tends to decrease. Bagasse ash shows an increment up to adding 7.5% of ash and the OMC value is 14.80 after which it is going to be decreased. In case of rice husk ash the optimum value of OMC is got 14.61 for 10% of product. So here the optimum value for rice husk and fly ash is 10% whereas the most OMC is got for bagasse ash in 7.5%.

In Figure 6 the histograph representation showing a clear indication that with increasing the various percentages of Fly ash, Bagasse ash and Rice husk ash the corresponding MDD value got decreased as well. And the decrement of MDD value is higher for Rice husk ash than the other by products. In addition of 12.5% of admixtures the MDD value is 1.56% which is certainly the lowest value among all the corresponding values. On the contrary in case of MDD value the lowest value for Fly ash is 1.64% and for Bagasse ash is 1.8% for same amount of 12.5% subgrade materials addition. From the Figure 7 it has been identified that the addition of Rice Husk Ash gives better CBR value than the fly ash and bagasse ash. With the increasing percentages of Rice Husk Ash and Fly ash CBR value is continuously increasing up to 10% after that it tends to reduce. And after 7.5 % addition of bagasse ash the CBR value starts to decrease also. For that reason, 7.5% is the optimum percentage value for bagasse ash. On the contrary, for fly ash the optimum percentage is about 10% up to which CBR value got improved.

And in the case of rice husk ash the CBR value of the expansive soil for 2.5% of admixture is 17.15% which got increased up to 18.67% for adding the rice husk ash 10% after which it is to be reduced. On the contrary the value of MDD got a decrement of 0.32% which is 1.88% to 1.56%. and in the term of the governing factor that is CBR value for adding 2.5% of Fly Ash is 14.02% and up to adding 10% of fly ash it increased up to 15.29% and after which it is also got decreased. In case of Bagasse Ash CBR value shows variation from 10.78% to 13.87% for respectively 2.5% to 7.5% where the CBR value shows reduction in 10% and in 12.5% mix. So as getting some concerned of making a comparison between the CBR values of Fly ash, Bagasse ash & Rice husk ash the respective highest values are 15.29%, 13.87% & 18.67%.

In terms of choosing subgrade material based on CBR value Rice Husk Ash (RHA) is just ahead of Fly Ash (FA) and Bagasse Ash (BA).

5.CONCLUSIONS

All Fly ash, Bagasse ash and Rice husk ash are suitable for expansive soil stabilization. And Rice husk ash is more suitable than the Bagasse ash and Fly ash for soil stabilization. With the increasing percentages of fly ash, rice husk ash the governing factor CBR value is continuously increasing up to 10% after which is shows reduction. The research work shows the optimum percentages for Bagasse Ash is 7.5%. For Fly ash and Rice husk ash it is 10%. For same percentage the CBR value for Rice husk ash is slightly improved than others. That shows a clear statement that the most suitable sub grade material for same percentage of admixtures is Rice husk ash rather than the Fly ash and Bagasse ash.

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ASSESSING THE PERFORMANCE OF FLYOVERS IN CHITTAGONG CITY

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ABSTRACT

Efficiency of the city transportation network has greatly influenced by traffic volume, roadway capacity, traffic composition, geometric design, road side land use etc. At present, Bangladesh Road Transport Authority (BRTA) source shows that the total number of registered vehicle in Chittagong city is 84391. This huge amount of vehicles along with the non motorized vehicles create congestion in different roads of Chittagong city. Due to mitigate the effect of congestion Govt. has built four flyovers to enhance the mobility and ensure trustable transportation solution according to them. In this research, surveys and analysis have been conducted to find out how far the objectives have been met to construct the flyovers in Chittagong city. The aim of this study is to find out the traffic volume, average vehicle speed, queue length of Akhteruzzaman- Chowdhury flyover and Kadamtali flyover located in Chittagong metropolitan area.To assess the temporal variation, traffic flow is determined under and over the flyovers for different time frames (weekdays & weekends; for day & night). Kadamtali flyover has represented maximum mobility of vehicle flow (about 64%) at only night time but fewer flow (about 29%) at day time. In addition, a small percentage of the flow (about 37%) are observed in Akhteruzzaman Chowdhury flyover at different time frames. It is also found that less percentage of public buses (< 20 %) are using flyovers as they need to drop off the passengers at different locations under the flyover. In contrast, higher percentages of cars, CNG, bikes are using flyovers as it will take less time to travel. It is found that time mean speed along the flyover corridor is significantly low (<20 km/hr at-grade and <60 km/hr above-grade). Non-motorized vehicles (about 98 %) are forced to use at-grade road which will create long queue under the Kadamtali flyover and delay along Akhteruzzaman Chowdhury flyover corridor. Flyover are giving benefits to a small number of people rather it will creating narrow road at- grade, make public transportation unpopular, transfer traffic congestion form one spot to another, abate the future prospect of coordinated public trasportation system. Both the flyovers of Chittagong city would not serve the purpose of abating traffic jam at rail crossing under it. It is also recommended to build full grade separated flyovers along with other traffic engineering measures to reduce the conflict of rail road traffic.

Keywords: *Flyover, rail road, performance evaluation, congestion, queue length, level crossing.*

1. INTRODUCTION

Population is increasing rapidly in Bangladesh with the increasing number of motorized and non-motorized vehicles. But due to insufficient road-network it is not possible to abate the intensity of traffic jam in city area with the limited number of roads (Rahman, Mamun, Kabir & Mannan, 2015). Due to unplanned existing road network this traffic decreases free flow speed of vehicles and make the road network congested. New infrastructures i.e. flyover, mass rapid transit (MRT), bus rapid transit (BRT) have been built to abate the traffic impact of city area. But due to insufficient funding it is not possible to fulfill the required demand. In addition, developing infrastructure also a time-consuming issue and sometimes building flyovers will make road under it narrower for vehicle movement and flyover itself might not fulfill its' desired purpose of construction. Chittagong is the second largest cities of Bangladesh, is listed as the second worst livable city in Bangladesh after Dhaka. Unfortunately, Chittagong Development Authority (CDA) and other traffic decision makers have overlooked the traffic management tools i.e. eliminating illegal parking, removing non-motorized vehicle from major roads, denoting zebra crossing and constructing foot over bridge or tunnel for pedestrian movement at intersections etc. Rather, four flyovers have been built to mitigate congestion in Chittagong city. The main aim of this research is to assess the functional effectiveness of the existing flyovers constructed over level crossing and assess how far they are successful in extenuating congestion and enhancing mobility in Chittagong city.
The specific objectives of this study are:

1. To assess the comparative level of operation of road space under and over the flyovers.
2. To find the utilization of flyover spaces by non-motorized vehicles and public transportation.
3. To assess the effectiveness of flyovers in terms of abating the intensity of traffic congestion levels.

It is a matter of surprise that there is no study related to flyovers in Chittagong to understand the impact of flyovers over the city transportation system. In the study, researchers concluded that flyovers will not bring any solution in Dhaka in the aspect of social, financial and economical point of view (Islam, Anwari & Hoque, 2018). So, it is obvious that flyovers will not bring a sustainable solution to Chittagong city if succient precations are not taken. Flyovers constructed in Chittagong city without any feasibility study is nothing but useless for reducing congestion and transport crisis. Simulation software like VISSIM can be used to evaluate the alternative measures before building flyovers to assess the existing and future performance (Mamun, Mohammad, Haque & Riyad, 2016).

2. METHODOLOGY

This study had considered two flyovers (Akhtaruzzaman Chowdhury and Kadamtali flyover) with rail crossing displayed in figure 1. In figure 1, blue color marking presented the rail crossing and red color marking presented the flyover location. These rail crossings are incompatible with at-grade road. Because of the partially grade separated flyover it is tough to terminate conflicts between railroad traffic on at grade traffic movement. At first, reconnaissance survey was performed before real data collection to know the geometric features and rush hour information (Shah, Rahman, & Mamun, 2015). Traffic survey was conducted by using video camera and manual observation at peak period to measure traffic data (i.e. variation traffic volume, queue length and average speed) at under and above flyover (Shah, Rahman, & Mamun, 2015).

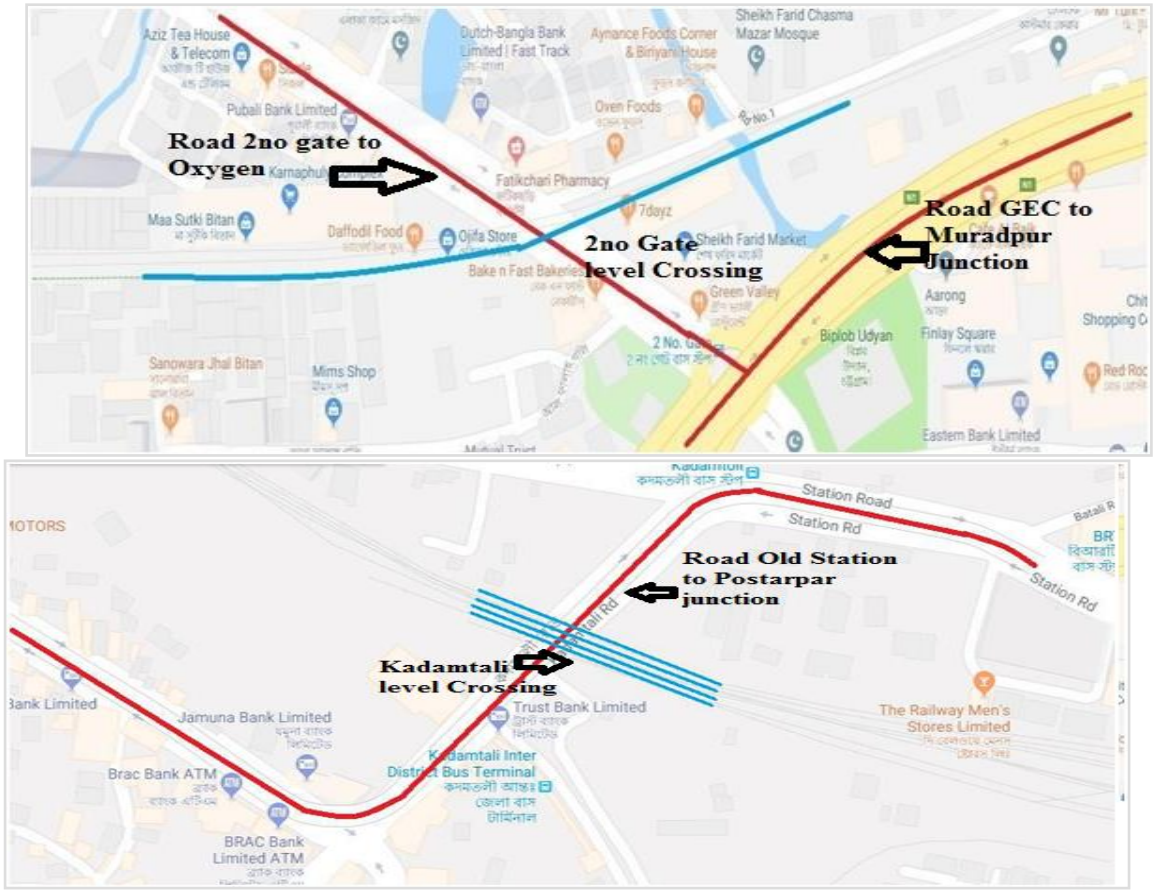

Figure 1: Layout of the Akhtaruzzaman Chowdhury and Kadamtali Flyover with level Crossing

Details of these flyovers are given in table 1.

Table 1: Features of Studied Flyovers

Name	Grade Separation Type	No. Of Lanes	Length (km)	No of Ramps	Construction Cost (crore Taka)	Date of Commencement of Traffic Operations	Implementing Authority
Akhtaruzzaman Flyover	Partial	4	5.2	5	697.00	01, June 2018	CDA
Kadamtali Flyover	Partial	2	1.57	2	58.20	30, January 2016	CDA

Source: (Mahmud, 2015 and Staff Correspondent, 2017)

The peak time period (15 min. interval) for collecting data in weekday, day; weekday, night; weekend, day and weekend, night identified from the traffic survey then converted to equivalent hourly rate (PCU/hr) for both of these flyover travel corridors. Survey time is presented in the table 2.

Table 2: Selected Peak Time Interval of Akhtaruzzaman Chowdhury and Kadamtali Flyover

Name of the Flyover	Survey Time	Survey Month and Year	Selected Peak Time (15 min. interval)			
			Weekend, day	Weekend, night	Weekday, day	Weekday, Night
Aktaruzzaman Flyover	Friday, Saturday and Wednesday	October, 2018	5.15 pm - 5.30 pm	8.30 pm - 8.45 pm	5.15 pm - 5.30 pm	6.30 pm - 6.45 pm
Kadamtali Flyover	Friday, Saturday and Wednesday	October, 2018	5.15 pm - 5.30 pm	8.30 pm - 8.45 pm	5.15 pm - 5.30 pm	6.30 pm - 6.45 pm

3. RESULTS AND DISCUSSION

3.1 Variation of traffic flow

Table 4.1 shows the relative usage by vehicles of road space above and under the Akhtaruzzaman flyover. The greatest disparity in traffic flows between different grades is at weekday, day, with 65.46% vehicles traveling at-grade and only 35.35 % vehicles traveling above-grade. Overall percentage shows that most of the vehicles (more that 60%) are moving under the flyover. Moreover, the ratio of above-grade to at-grade flow is less than 0.60 in all cases. This will imply that Akhtaruzzaman flyover did not efficiently fulfill its purpose of reducing traffic conflict with rail road traffic.

Table 3: Traffic Volume Condition of Akhtaruzzaman Flyover at different time segments

Aktaruzzaman Flyover	Above/Under	Total Equivalent Flow (PCU/hr)	Percentage (%)	Ratio Between Above and Under
Weekend, Day	Above	1798	38.77	1:0.63
	Under	2839	61.22	
Weekend, Night	Above	1913	39.41	1:0.65
	Under	2941	60.32	
Weekday, Day	Above	1934	34.53	1:0.53
	Under	3666	65.46	
Weekday, Night	Above	1833	35.92	1:56
	Under	3270	64.07	

Figure 2 shows that a profuse number of vehicles are traveling through under the flyover compared to the above grade condition. It is also observed that the highest traffic flow at above-grade (1934 PCU/hr) occurs at weekday (day) and at at-grade (3666 PCU/hr) occurs at weekday, day. This implies that maximum flow both at-grade and above grade-occur at weekday period.

Flyover is necessary to construct if more than 8,500 vehicles/ hr cross the the intersection. But from our survey data, it is found that total equivalent hourly rates (PCU/hr) are much lower than standard value which eliminates the need for both flyover in Chittagong.

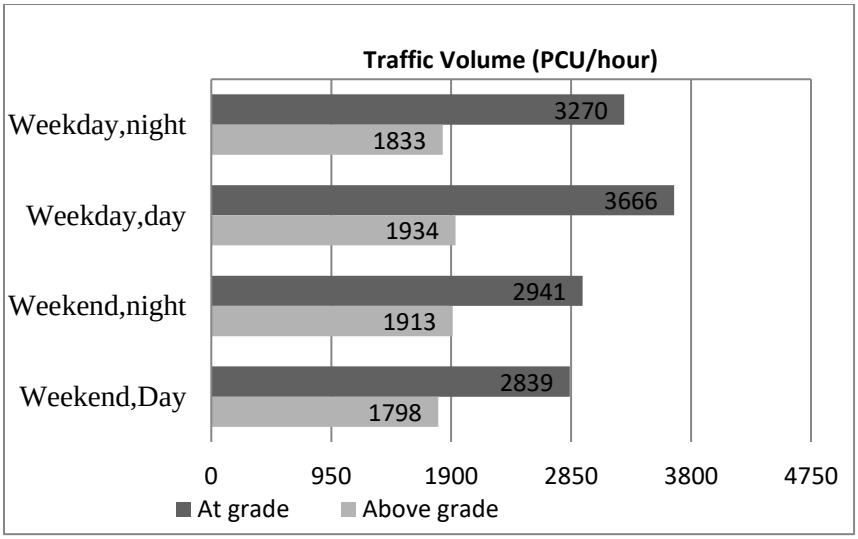

Figure 2: Comparison of vehicle flow at Akhtaruzzman Flyover at different grade condition

Table 4 shows relative usage by vehicles of road space over and under the flyover clarifies that at day time most of vehicles are using at grade road but at night large proportion of vehicles are using flyovers for both week day and weekend. The ratio of above-grade to at-grade flow also reflects that. The greatest disparity in flows between different grades is at weekday, night, with 77.66% vehicles travelling at-grade and 22.33 % vehicles travelling above-grade.

Table 4: Traffic Volume Condition of Kadamtali Flyover at different time segments

Kadamtali Flyover	Above/Under	Total Equivalent Flow (PCU/hr)	Percentage Total	Ratio Between Above and Under
Weekend,Day	Above	629	25.46	1:0.34
	Under	1841	74.53	
Weekend, Night	Above	1288	66.46	1:1.98
	Under	650	33.53	
Weekday, Day	Above	575	22.33	1:0.28
	Under	1999	77.66	
Weekday, Night	Above	3270	64.07	1:3.79
	Under	863	29.62	

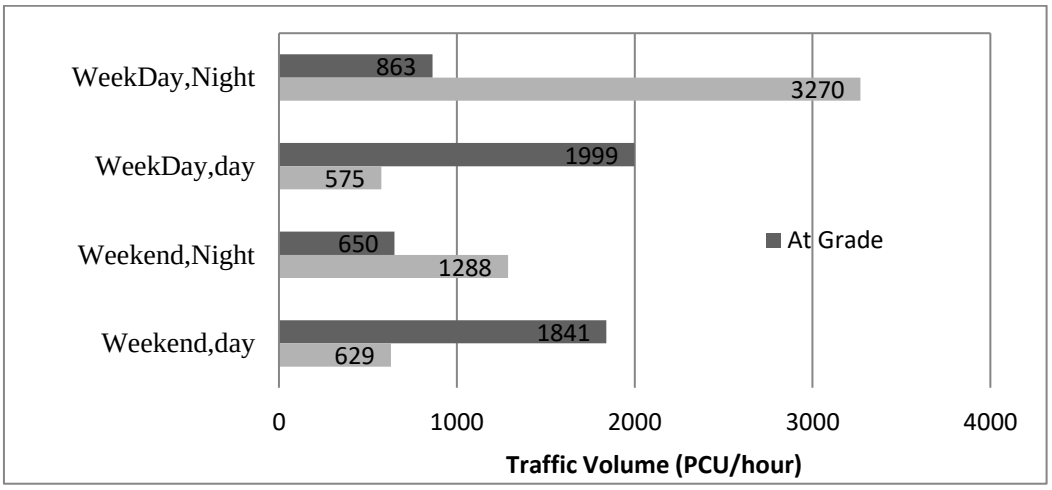

Figure 3: Comparison of vehicle flow at Kadamtali Flyover at different grade condition Flyover

From figure 3 it is observed that the highest flow at at-grade (1841 PCU/hr) occurs at weekend, day which is lower compared to flow (3270 PCU/hr) at above-grade occurs at weekday, night. This implies that most of the traffic moves through flyover at night compared to day time at weekend but at weekday the condition is opposite. It may be due to the fact that at night time, the vehicular flow at this flyover corridor tends to be lower at-grade level and hence, road users feel comfortable to use at-grade road rather using flyover to save their fuel and time.

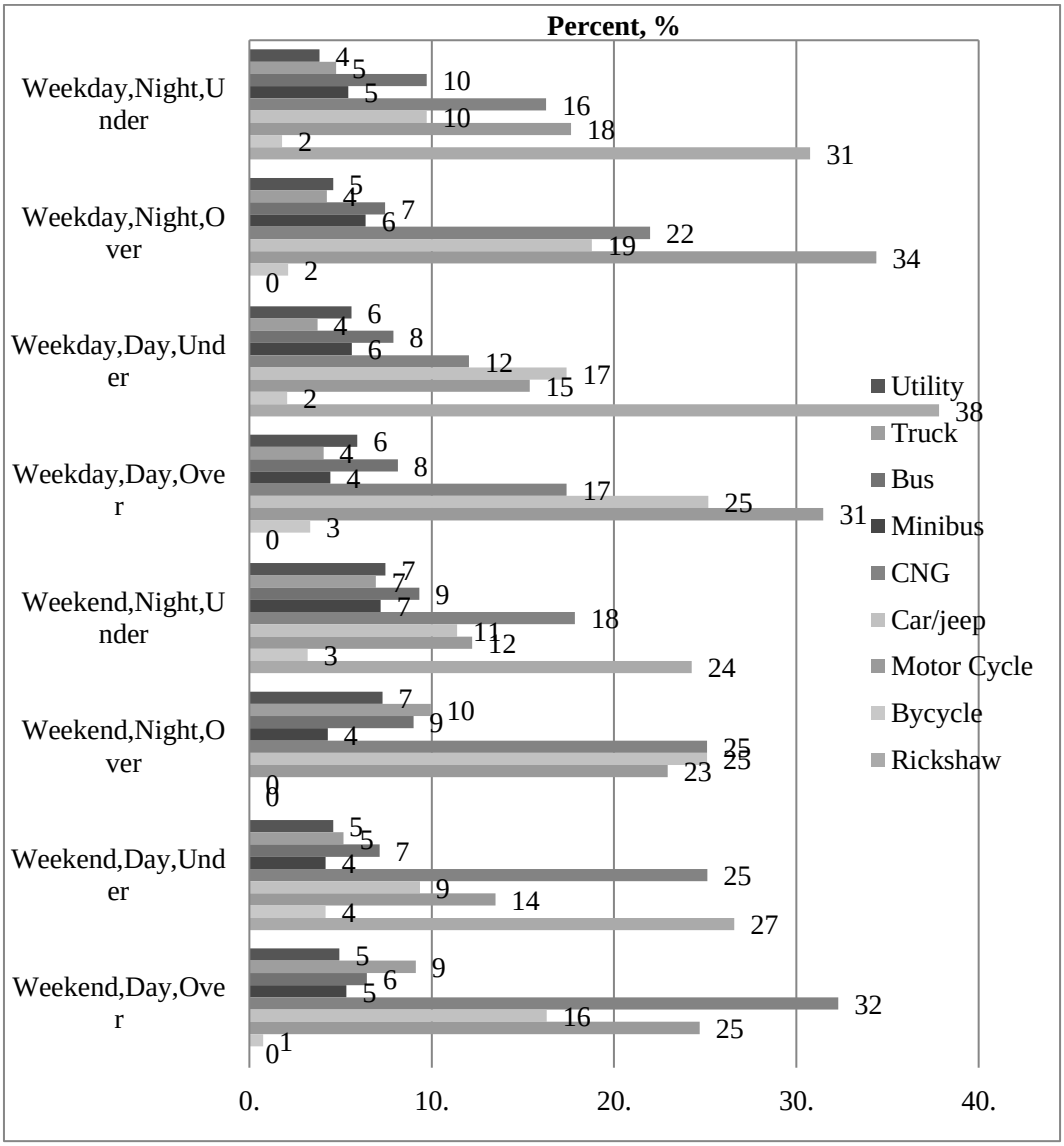

Figure 4 : Temporal Variation of Different Types of Vehicles in Aktaruzzaman Flyover

Figure 4 shows that NMVs are the most contributing vehicles among others and uses mostly (about 100 %) the road under the flyovers. It is also observed that Car and CNG prefers to use flyover about 44% to 120% compared to the at grade condition. In terms to the condition of public transportation about 15 to 25% is preferring to use at grade condition compared to flyover. This research implies that most beneficiary of constructing flyovers is private car, CNG and motorcycle. As percentage of public transport is trifling, it can be concluded that public transport are getting negligible benefits from this flyover. Rail crossing of Akhtaruzzaman flyover is near to the busy intersection 2 number Gate. So, public transport will continue to serve people at-grade.

Figure 5 represents that most beneficiary of constructing flyovers is CNG, private car and motorcycle. The percentage of public transport is insignificant. Hence, it can be concluded that public transport are getting negligible benefits from this flyover. Since there is significant land usage beneath flyover, including residential and commercial spaces, people will continue to use at-grade facilities. Hence, public transport will continue to serve people at-grade. In addition to that the percentage of NMVs in this flyover is negligible Further analyses have been performed to understand the NMVs fact more clearly.

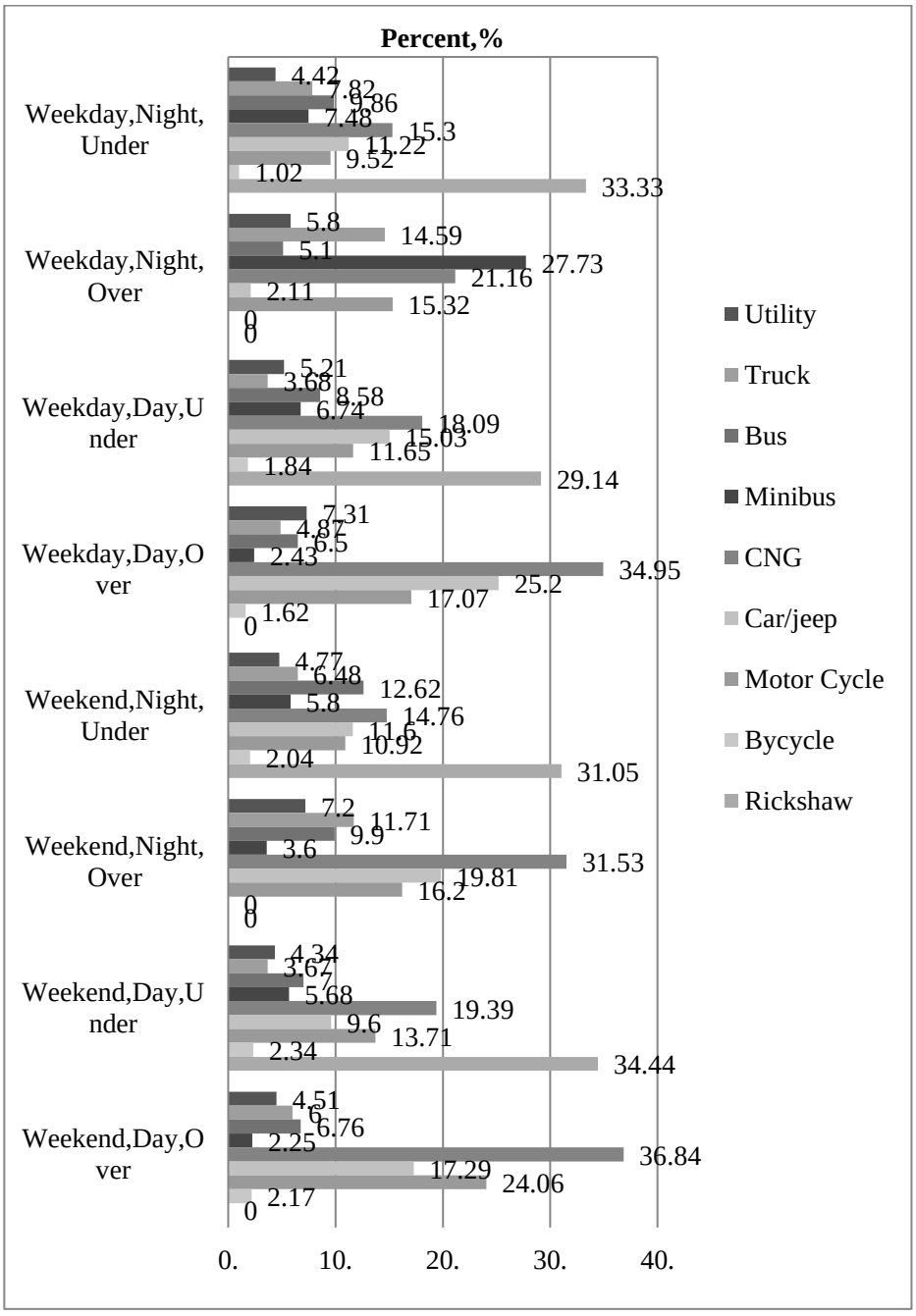

Figure 5: Temporal Variation of Different Types of Vehicles in Kadamtali Flyover

3.2 Mobility Condition

To determine the mobility of vehicle speed is measured for the flyover corridor at different grade condition. Time Mean Speed of each type of vehicle was measured at Aktaruzzaman and Kadamtali Flyover to assess the mobility conditions of vehicles both at-grade and above grade. Time Mean Speed

has been calculated by dividing the segment length of the studied road segment by the sum of total time in motion, and then divided by the number of total vehicles.

Table 5: Time Mean Speed Above Grade and At-Grade at Aktaruzzaman and Kadamtali Flyover

Vehicle Name	**Aktaruzzaman Flyover**		**Kadamtali Flyover**		**Aktaruzzaman Flyover**		**Kadamtali Flyover**	
	Time Mean Speed (km/hr)		Time Mean Speed (km/hr)		Free FlowSpeed (km/hr)		Free FlowSpeed (km/hr)	
	Above Grade	At Grade	Above Grade	At Grade	Above Grade	At Grade	Above Grade	At Grade
Bike, Bus, Bus, Truck, CNG, Car	57.49	19.87	40.06	17.78	85	65	65	45

3.3 Congestion level (Queue Length)

In this study, congestion level has been assessed in terms of queue length, where queue length is defined as the length of the line of motor vehicles that have been stopped at a level crossing in order for the trains to pass. It was measured taking photograph through mobile camera then taking the length manually.

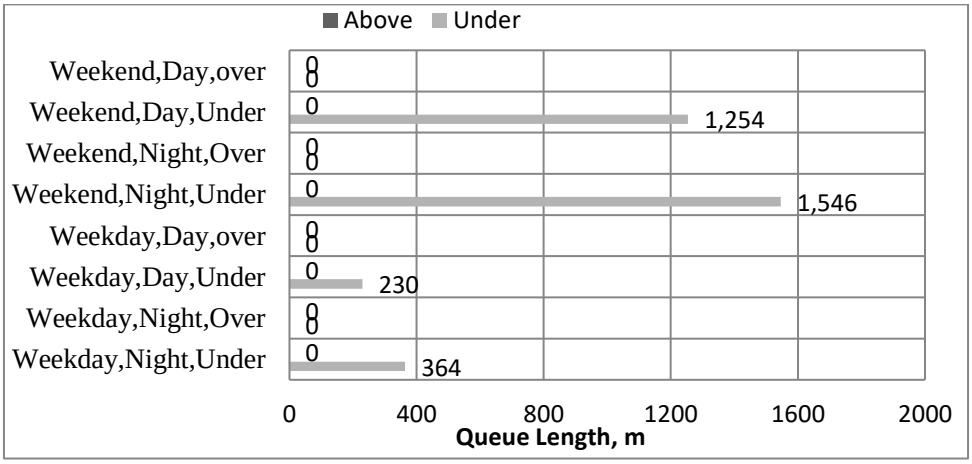

Figure 6: Temporal Comparison of Queue Length at Aktaruzzaman Flyover

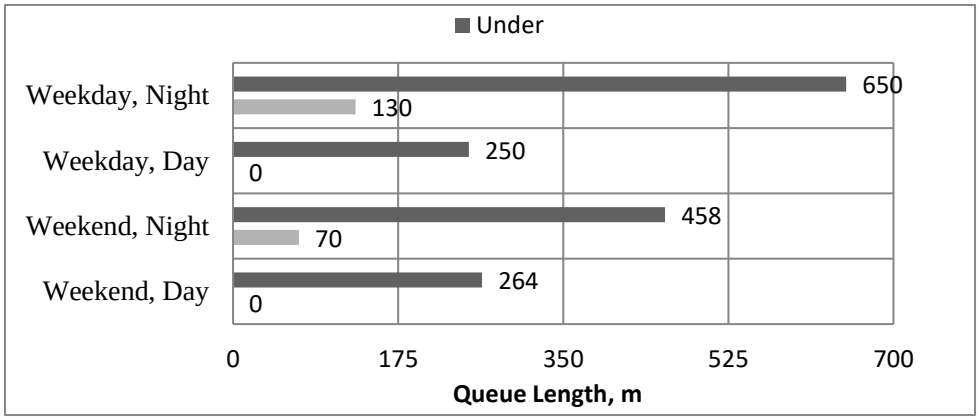

Figure 7: Temporal Comparison of Queue Length at Kadamtali Flyover

Figur 6 represents that the flyover has failed to reduce congestion, as most of the vehicles are using at grade road and creating a lengthy queue i.e. 1546 m at weekend night. From figure 7 the longest queue length at above-grade was recorded at weekday night (650 m) compared to other conditions which opposite to Akhtaruzzaman flyover. This is surely the worst case and it implies that both these flyovers have completely failed to fulfill its demand of traffic.

4. CONCLUSIONS

It is concluded that partially graded flyovers cannot reduce the upcoming traffic impact on rail crossings of Chittagong city area. Assessing the usage of at-grade and above grade road of the partially graded flyovers (Akhtaruzzaman and Kadamtali Flyover) of Chittagong city shows that flyovers are not efficiently accomplish the purpose of reducing congestion in Chittagong city area. Rather it creates huge traffic jam in rail crossing area by creating longer queue length of vehicles and huge number of heterogeneous traffic volume. Moreover, it will create advantages only for cars and CNGs to avoid the rail crossings under the flyovers. But most of the NMV and public transportation are using at-grade road which will create huge congestion, reduce the average speed and make the implementation purpose of flyovers failed. It is suggested that Bus Rapid Transit (BRT) and Mass Rapid Transit (MRT) can bring sustainable solution to reduce the volume of cars and smaller sized vehicles on road (Islam, Anwari, Hoque & Amin, 2018).Due to insufficient source of fund it is recommended to build low cost traffic engineering measures to control conflicts between vehicle-vehicle, vehicle-pedestrian. Otherwise, only full grade separation can resolve the conflict of rail-road traffic which is time consuming and very expensive.

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SETTING OF OPTIMUM SIGNAL TIMING USING VISSIM SOFTWARE TO IMPROVE THE EXISTING TRAFFIC OPERATING CONDITION OF T AND FOUR LEG INTERSECTION OF CHITTAGONG CITY

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ABSTRACT

Now a day's traffic congestion issues in Chittagong city is becoming worse day by day. This happens due to the slow-moving vehicles, occupied footpath, unauthorized car and bus/truck lay over, traditional traffic signal timings Government authorities are building flyovers to abate the intensity of congestion which is not always a great solution but cost a huge amount of money. Saturation flow in any intersection is huge to control with traditional traffic signal system. The aim of this paper is to assess and develop the traffic operations at the AK Khan (T) and Alongkar (four leg) intersection which are situate near the most congested portion of Chittagong city due to bus terminal area. Traffic count studies are conducted to determine the number, movement and classification of vehicles at an intersection. In this study, an improved traffic signal timings i.e. green time, amber time and red time have selected for continuous movement of vehicles through the intersection to ameliorate the situation of delays, average speed and queue length to do that videography survey has conducted at 15 minutes of intervals during estimated peak hour. In addition, geometric, traffic and signalized data were collected during peak time periods. In this study, we calculated the signal timings (Green time, Yellow time, Red time, Cycle time and Lost time) and it is optimized by VISSIM which is a traffic simulation software. Delay time and average speed are determined manually and compared after optimization in VISSIM. Another alternative solution is given i.e. construction of one through overpass for one direction (from AK Khan to Alongkar) for through vehicles to have more improved traffic condition. These solutions will be advantageous for the signalized intersections especially during rush hours, decreasing the travel cost, greenhouse gas emission & number of accidents, increasing the efficiency of the road network, improving traffic flow and traffic operations.

***Keywords**: VISSIM, Intersection, Chittagong, Optimization, Traffic Signal.*

1. INTRODUCTION

In Chittagong city of Bangladesh, congestion has been a serious problem for the past few years. With the rapidly growing population and consequent vehicle increment, the problem is worsening day by day. A modern city should have 25 percent of its total area devoted to road use but Bangladesh has only 7.5 percent, which is one of the main causes of traffic congestion (Shah, Rahman & Mamun, 2015). It is needed to improve traffic operating condition of the existing road networking by applying signal optimization technique, building new flyovers, mass rapid transit (MRT), bus rapid transit (BRT). But building these developments are time consuming and also needs huge fund. In this research, an attempt has been taken to improve the traffic operating condition of AK Khan to Alongkar road by setting appropriate signal timing at the intersections along this road which is not that expensive compared to building new flyover.

As AK Khan to Alongkar road is one of the major bus terminal area of Chittagong city which is directly connected with N1 highway, it is not possible to implement the appropriate signal timing and analyze the operation of complex transportation systems under congested conditions in this road practically. Therefore, in order to implement the appropriate signal timing, we use simulation software and the whole analyses are performed in VISSIM simulation software. The software allows us to test the impacts of changes before implementing in real life. Traffic simulation replicates the roadway existing travel pattern with least effort and greater accuracy and gives a way to perceive the situation clearly and devise our thoughts and analyze the operation of complex transportation systems under congested conditions in a more realistic way.

The main objective of the study is to improve the traffic operating condition of Alongkar to AK Khan intersection (i.e. T and 4-leg) by setting optimum signal timing at the intersections along this road. Other objectives are discussed below.

1. To evaluate the existing delay and capacity of the intersection.
2. To adjust the cycle length, timing (green time, amber time and red time) of intersections to reduce the delay and increase the average speed for different situation.

2. LITERATURE REVIEW

For any emergency situation, demand responsive and well-planned traffic signal system is needed for satisfactory management of traffic (Rahman, Mamun, Basit & Rahman, 2017). TRAMS (Transit Route Animation and Modeling by Simulation) can simulate light rail transit operations but not applicable for large volume of bus operation (Shah, Rahman & Mamun, 2015). CORSIM is able to simulate transit operations while considering car-following and lane- changing behavior (Shah, Rahman & Mamun, 2015).

TSIS-CORSIM is a microscopic traffic simulation software package for individual traffic signal set ups, highway, freeway, as well as combined signal, highway and freeway systems. CORSIM consists of an integrated set of two microscopic simulation models. These models represent the entire environment of the traffic.

VISSIM is a microscopic, time step and behavior-based simulation model developed to model urban traffic, public transport operations and flows of pedestrians. The program can analyze private and public transport operations under constraints such as lane configuration, vehicle composition, traffic signals, thus making it a useful tool for the evaluation of various alternatives based on transportation engineering and planning measures of effectiveness (Roy, Barua & Das, 2015). VISSIM can be applied as a useful tool in a variety of transportation problem settings. The simulation package VISSIM consists internally of two different parts, exchanging detector calls and signal status through an interface. The simulation generates an online visualization of traffic operations and offline the generation of output files gathering statistical data such as travel times and queue lengths (Uddin, Hasan, Rony, Alam, Ghosh & Zaman, 2019).

3. STUDY AREA AND DATA COLLECTION

A reconnaissance survey was done from 20 January to 26 January, 2019 to find out the position of building to setup the camera for the purpose of filming the traffic data. The peak hour of these intersections was 5:00 pm to 6:00 pm. Traffic volume data was recorded for 15-minute interval at 4:00 pm to 6:00 pm for the month of February and March, 2019 for both AK Khan and Alongkar intersection. A video graphic survey has been completed at AK Khan and Alongkar intersection. At AK Khan intersection there is no suitable elevated place for traffic survey and survey is conducted from at-grade condition. But there is an elevated place to count the vehicle movement at Alongkar intersection. Finally add them together to show the volume with percentage details in result and analysis section and converted the values into PCU/hr. A student version of VISSIM is available in Port City international University, Transportation Engineering Lab which is used as the micro simulation tool for calibration and validation of the model. Geometric data of the survey area were collected manually for the purpose of drawing links and connectors in VISSIM. AK Khan intersection and Alongkar intersection are shown in the figure 1.

a) AK Khan intersection (T-intersection)

b) Alongkar intersection (four leg intersection)

Figure 1: Selected intersection (a and b) for data collection.

Mobile phone and action camera used to collect the data. The video was then analyzed at a speed of one-eighth of the actual speed to enable recording and measurement of traffic volume data. Besides traffic volume several traffic parameters can be obtain from recorded film. This indirect data collection method is applicable when volume is high. A suitable elevated place is required for filming operation. Data cannot be used immediately after collection. This process is time consuming and tedious but calculation quality is good enough. We selected indirect data collection method as we can get correct and exact data by this method. Any kind of research work related to transportation, traffic volume or vehicular composition analysis is mandatory since variation of average speed of vehicle, overtaking maneuver, traffic congestion is directly related to the traffic volume.

4. DATA ANALYSIS AND RESULT

After collecting data, they were checked, verified, cleaned and finally edited. Table 1, 2 and figure 2 were prepared as required. Data from different videos were also analyzed and compared in the same way. Tabulated and presented data were scrutinized carefully and critically to interpret in an accurate and tidy format. Moreover, all traffic volume and speed data were examined in terms of the research objectives.

a)

b)

Figure: 2 Traffic volume and flow direction at Alongkar (a) and AK Khan (b) intersection

Table 1 and 2 showed that maximum traffic volume is found for through vehicle movement for all directions at both intersections except east bound vehicle movement at Alongkar intersection. There is no way for movement in east (through) direction and traffic volume is 0 for AK Khan intersection presented in table 2.

Table 1: Traffic Volume (PCU/hour) at Alongkar Intersection

(**East bond**)

Left turn	Through	Right turn
76	80	384

(**West bond**)

Left turn	Through	Right turn
32	48	24

(**South bond**)

Left turn	Through	Right turn
40	492	60

(**North bond**)

Left turn	Through	Right turn
280	464	36

Table 2: Traffic Volume (PCU/hour) Data at AK khan Intersection

(**East bond**)

Left turn	Through	Right turn
112	0	380

(**South bond**)

Left turn	Through	Right turn
0	308	100

(North bond)

Left turn	Through	Right turn
268	428	0

In this paper, a model of traffic flow on AK Khan and Alongkar intersection on Chittagong city by evaluating Passenger Car Unit (PCU) of different vehicle categories at different volume levels is developed by using the micro-simulation model, VISSIM. Simulation on VISSIM is shown in figure 3.

Figure 3: VISSIM Simulation Model of Alongkar Intersection

Table 3 represented the traffic parameters after traffic signal design manually at AK Khan and Alongkar intersection which is used to model in VISSIM.

Table 3: Parameters for AK Khan and Alongkar intersection from manual signal design

Parameters	**AK Khan Intersection**	**Alongkar Intersection**
Saturation Flow Rates (veh/hr/lane)	1125	1178
Yellow interval (sec)	2.4	2.4
Red interval (sec)	11.6	12.7
Effective green time (sec)	48.4	47.3
Lost time (sec)	14	16
Minimum Cycle length (sec)	37	42
Desirable Cycle length (sec)	54	70

Table 4 represented the delay time before and after signal timing optimization which is improving by 37.5 % and 35.71% for Alongkar and AK Khan intersection respectively.

Table 4: Comparison of delay time at Alongkar and AK Khan intersection

Delay Time	Alongkar intersection	AK Khan interesection
Manual signal design (sec)	16	14
VISSIM Signal Timing design (sec)	10	9

Table 5 represents the signal timings for manual signal design and optimized signal timing for the improvement through VISSIM.

Table 5: Manual and Optimized Signal Timing

Phase Name	Manual signal time (sec)			Improved signal time by VISSIM (sec)		
	Green	Amber	Red	Green	Amber	Red
Alongkar- Colonel Hut	82.8	22.8	75	126	12	66.6
GEC- AK Khan	85.2	19.2	66	129	9	32.4

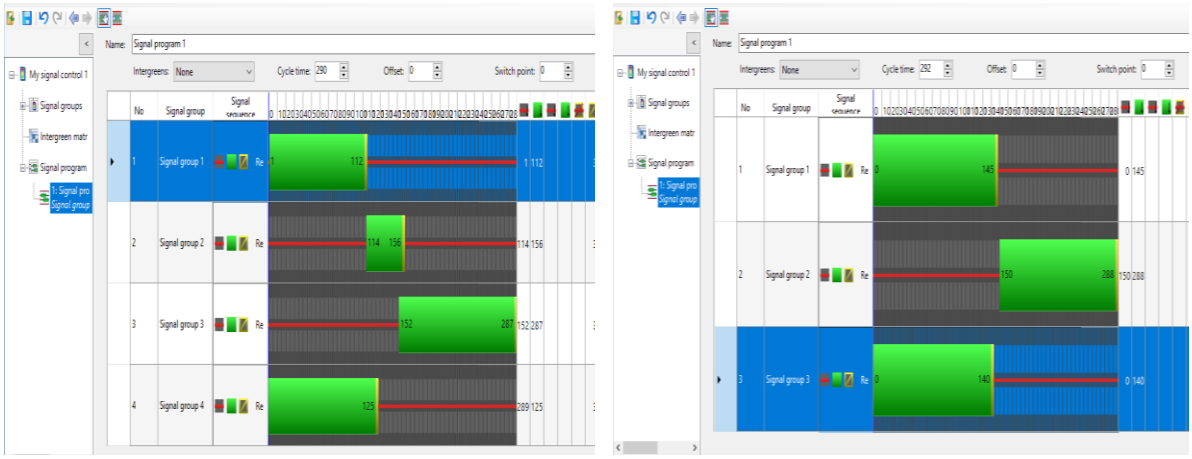

Figure: 4 Optimized signal timing for Alongkar and AK Khan Intersection.

Table 6 and 7 represented the average speed and delay of different intersections at different scenario described below.

- Existing condition represents the scenario of intersection without improvement.
- Scenario 1 is optimized signal timing at Alongkar intersection and
- Scenario 2 is constructing an overpass from AK Khan to Alongkar intersection for through vehicle movement. After that signal optimization is done again to observe the performance.

Figure 4 represents the optimum signal timing (Scenario 2) of both intersections.

Table 6: Comparative studies among different alternatives for Alongkar Intersection

	Average Speed (km/hr)	% Increase of average speed	Delay (sec)	% Decrease of delay
Existing Condition	19.95	N/A	18	N/A
Scenario 1	22.76	14.06%	14	22.22%
Scenario 2	37.42	87.57%	2	88.88%

From table 6 it was observed that Scenario 1 which means improvement through signal optimization only increases the average speed and delay by 22.76 % and 22.22 %. Overwhelming improvement observed for Alongkar intersection was observed in scenario 2 by constructing flyover from AK Khan to Alongkar for through vehicles i.e. 87.57% increase in average speed and 88.88% increase in delay compared to exiting situation.

From table 7 it was observed that Scenario 1 and 2 presents very similar improvement for AK Khan intersection as compared to Alongkar. Though scenario 2 shows maximum improvement for both intersections, in future it is recommended to build flyover to reduce the traffic congestion level and make the road operation more efficient.

Table 7: Comparative studies among different alternatives for AK Khan intersection

	Average Speed (km/hr)	**% Increase of average speed**	**Delay (sec)**	**% Decrease of Delay**
Existing Condition	19.35	N/A	21	N/A
Scenario 1	21.87	13.02%	16	23.81%
Scenario 2	36.11	86.61%	2	90.48%

Output of delay result from VISSIM was shown for existing and improves condition in table 8 and 9. It was observed for that the delay in the main road has been extravagantly improved after signal optimization. Though the number of vehicles passing and the number of passengers passing have increased but efficiency of intersection has improved i.e. reduced each person's average delay, average parking time per vehicle and average number of stops per vehicle.

Table 8: Status "delay" result output for AK Khan intersection

Existing Situation						
Time(s)	**Delay(s)**	**Stopd**	**Stops**	**#Veh**	**Pers.**	**#Pers**
Time: 600 sec	34	6.7	0.2	123	26	86
Improved Situation						
Time(s)	**Delay(s)**	**Stopd**	**Stops**	**#Veh**	**Pers.**	**#Pers**
Time: 600 sec	9	5.4	0.00	272	11	109

Table 9: Status "delay" result output for Alangkar intersection

Existing Situation						
Time(s)	**Delay(s)**	**Stopd**	**Stops**	**#Veh**	**Pers.**	**#Pers**
Time: 600 sec	36	6.8	0.22	132	27	92
Improved Situation						
Time(s)	**Delay(s)**	**Stopd**	**Stops**	**#Veh**	**Pers.**	**#Pers**
Time : 600 sec	10	5.48	0.00	266	10	118

Meaning of Symbols:
(1) "Stopd" is the average parking time per vehicle (unit: s);
(2) "Stops" is the average number of stops per vehicle;
(3) "# Veh" is the number of vehicles passing;
(4) "Pers." For each person's average delay (unit: s);
(5) "# Pers" is the number of passengers passing.

5. CONCLUSIONS

The results of the intersection analysis showed that the best alternative is constructing one overpass. Frequent bus stops, random pedestrian crossing, unauthorized parking and road side cart near intersection also initiate of construction flyovers to reduce the congestion at intersection. As during peak hour traffic volume is very high it is not possible to reduce the congestion by only signal timing optimization. But as temporary traffic measure it can be adopted to control the vehicle flow. Though there are some benefits are obtained by optimization of signal timing, but in future it is desirable to build a flyover from AK Khan to Alongkar direction to abate the intensity of vehicle on at grade level. As there is huge pedestrian activity at both 4- and T- intersection because of random and irregular crossing, it is also a reason which makes the road operation unsuccessful. Foot over bridge along with other small traffic engineering initiatives can improve the traffic operating condition of both intersections.

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AN EXPLORATIVE STUDY ON STUDENTS USING BICYCLE IN KHULNA CITY

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ABSTRACT

Khulna is the 3rd largest city in the southwestern part of Bangladesh having a population of 1.5 million. Among them, 32 percent have their own vehicle. The number of bicycle users is constrained to 5.9 percent in the city. The demand for transport facilities contrasts due to need, purposes and aptitudes from person to person. As bicycle act as a safe and economical mode of transportation, students prefer much about their daily uses. Because of the undeveloped public transit system and people's low socio-economic conditions, there is great potential for cycling as a mode of transport in Khulna city. This research analyzes the overall scenario of the students using the bicycle and their travel behavior in the northern part of Khulna City. Moreover, this study focuses on how bicycle trip generation is affected by different socio-economic parameters. Five wards (ward no: 6,7,9,10,14) of Khulna City Corporation were selected as a study area of the research which covers almost northern part of the City. 100 students were randomly chosen for collecting primary data through a questionnaire survey. Data was collected on their travel time and distance, origin-destination, trip generation and other social & economical condition. Six focus group discussions (FGDs) and five key informant interviews (KIIs) with different bicycle groups and teachers of schools and coachings respectively were conducted. Secondary data was collected through desktop research and literature review. Students having age of 15-20 year of middle and lower-middle income family uses bicycle most for the fast and economical travel. The average travel distance is 2.71 km per trip with average travel speed of 16.30 kmph in rush whereas 10.68 kmph in normal condition. Maximum number of trips are originated from Pabla and Khalishpur which is under ward no. 6 & 10 and maximum destination is in ward no. 9 & 14. The main purpose of using a bicycle is going to school and coaching centers, which is almost 77 percent of the total trip. Beside some of the respondent use bicycle for going to market, recreation, playing and other purposes. 115 BDT is spent every month by each student for maintenance of bicycle on an average. Teenagers of age 13-15 years, having rush speed of 19.61 kmph faces more accident than other age group. Around 45 percent bicycle rider lose their control over the bicycle and causes an accident. Student prefers walking and rickshaw for short distance travelling. They usually use other mode of transport in bad weather and for mechanical problem of the cycle. While for travelling long distance, they prefer Mahindra and auto. The regression model indicates travel distance has negative influence on the number of trip generation. On the other hand family income and cost of other transport mode have a positive influence on it. Inadequate parking, safety and road facilities are the main problems for cyclist. This study has rarely discussed about the influence of the built environment on the uses of the bicycle. This research may help the concern authority and policy makers for improving and redesigning transport policy and other related problems of Khulna city.

Keyword: *Bicycle, Travel Behavior, Transportation Mode, Trip Number, Travel Speed.*

1. INTRODUCTION

Transport is one of the vital components of economic activity all over the world. In fastest growing economic country like Bangladesh, growth in motorized vehicles is increasing rapidly (Tiwari, et al., 2008). On the other hand, country's travel demand is still predominantly met by non-motorized modes like walking, rickshaws-vans and bicycles. Bicycle is considered safe and effective popular transport modes in rural and urban streets. During traffic congestion, bicycles are more efficient and faster than cars or public transport (García-Palomares, et al., 2012; Larsen & Geneidy, 2010; Munley & Daniel, 2006). Traffic congestion and speedy urban lifestyle make bicycling a mainstream mode of transport. Bicycling's benefits are multidimensional. It can reduce the total travel time in congested urban areas and take a little time for parking near the destination site. Bicycles have become a popular mode of urban transport worldwide due to ensuring sustainable urban mobility. In Netherlands, nearly 30% of all trips were made by bicycle, while Denmark had nearly 20% trips (Dey, *et al.,* 2014). Where there is no option of separate paths or lanes, traffic calming initiatives play an important role in safe bicycling. For example, the speed limit has been lowered to 30 km/h in most residential areas in Denmark, Germany and the Netherlands (Rana, *et al.,* 2016). Bicycles are commonly seen in both rural and urban areas in Bangladesh. Bicycle trips are primarily used for work and school trips. Around 6.3% trips on arterial road of Dhaka City are completed by bicycle. Medium-sized cities have a bicycle share of 4.3-7.1% of total trips and a high share of the cycle in intercity and small towns in Bangladesh (Tiwari, *et al.,* 2008).

Khulna is the third largest city of Bangladesh and has significant numbers of bicycle users. Here, bicycle is an important mode of transport at individual level. The number of bicycle users is constrained to 5.9% (Rana, *et al.,* 2017). In Khulna City, there is great potential for cycling as a mode of transportation due to the undeveloped public transit system as well as the socio-economic condition of the residents. The potentials of bicycling in Khulna City have not yet been clarified, so it is not obvious which benefits are actually found by bicycling. This research analyzes socio-economic condition of students and their bicycle trip number and the reasons behind using bicycle in the Khulna City. The objective of research is to investigate the relation between number of bicycle trip generated by students and their socio-economic parameters. The findings of the research might help the concern authority in decision making especially for the transport related issues to solve the city traffic problems.

2. DATA AND METHODS

Five wards (i.e., ward 06, ward 07, ward 09, ward 10, and ward 14) under the Khulna City Corporation (KCC) were selected and finalized as study area (see Figure 1) based on field visits and reconnaissance survey. According to Bangladesh Bureau of Statistics 2014, the study area has an area of 9.67 square kilometers with 128,130 population and density of 13,250 per square kilometer. The main focus of the study was to find out the scenario of the students using a bicycle. As it was found that the concentration of students using bicycle (maybe origin or destination) was more in those areas because of schools and coaching. So, these areas are considered as a study area.

Secondary data from relevant organizations including physical features (i.e., boundary, roads, structures, river etc.) from KCC, and satellite images from Google Earth were collected. 06 Focus Group Discussions (FGDs) with the bicycle groups and 05 Key Informant Interviews (KIIs) with school authority and coaching stuffs were also conducted for finding the exiting condition bicycling. A questionnaire survey was also conducted among the 100 randomly selected bicycle user students visiting various schools and coaching in the study area. The questions were based on bicycle trips (i.e., number of trips, origin-destination, travel time etc.) and socioeconomic conditions (i.e., family income, age, gender, education etc.). Origin-Destination and speed variation in different routes were shown in map where trip distribution, speed, accident and other transport mode choice scenarios were presented by different charts and tables. Correlation analysis was done among different parameters to show the relation between the various types of data.

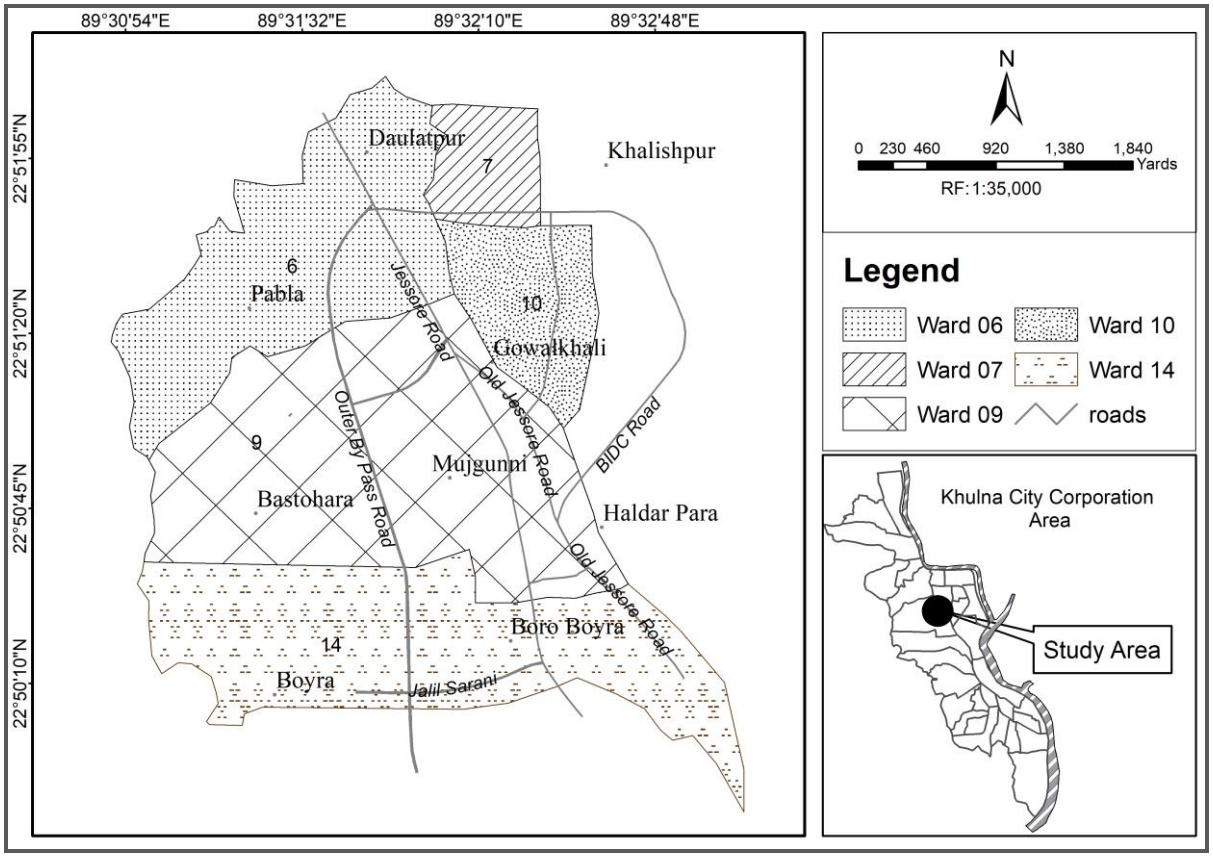

Figure 1: Location of the Study Area

A relation was established between the numbers of trip generated with other socio-economic parameters. In order to establish the relation, linear regression model was used shown in equation 1.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \ldots\ldots\ldots + \beta_p X_p \quad (1)$$

Where, Y = the dependent variable (i.e., number of trips generated by bicycle), X = the independent variables (i.e., socio-economic parameters like family income, travel cost and travel distance) and β = coefficient.

3. RESULTS AND DISCUSSIONS

3.1 Scenario of Bicycling

As found by the survey, most of the bicycle user students were teenagers. The average speed of the bicycle was found 10.68 kmph and 16.30 kmph for normal and rush case respectively. Covering an average travel distance of 2.71 km a student usually gave 10 trips per week (Table 1).

Table 1: Average of different parameters of bicycle users in the study area

Average Age (Years)	15-20
Average Distance Cover (km)	2.71
Average Speed (km/hr)	10.68
Average Rush Speed (km/hr)	16.30
Average Trip Number (per week)	10
Average Maintenance Cost (tk per month)	115

3.2 Origin and Destination Analysis

Though the study area were selected as ward 6,7,9,10,14 but it was found that the origin and destination covered almost half of the KCC areas. In figure 2 (a), the number of origins were more in ward 06, 07, 08 and 10. Maximum trip origins were in Pabla and Khalishpur areas. In ward 09 and 14, the number of destinations were more. Maximum coaching centers and schools were situated in these two wards. So, the students from ward 06, 07, 08 and 10 came to ward 09 and 14 for coaching or other educational purposes.

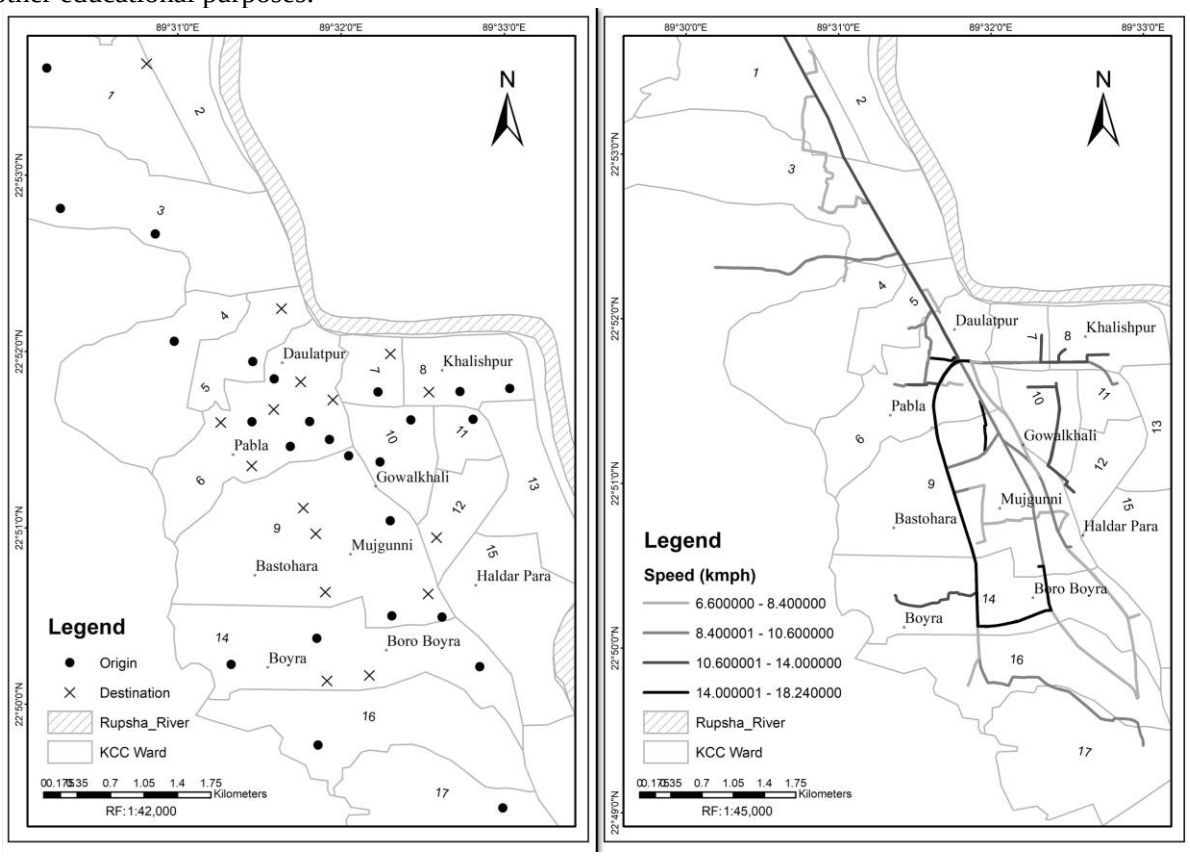

Figure 2: (a) Location of Origin-Destination and (b) speed variation in different routes

Again, in Figure 2 (b), speed variation in different route was shown. The speed of the cycle was more in the route between ward 14 to ward 06 via ward 09. Traffic volume was comparatively lower in that route. So, the cycle speed was more than 14 kmph on that route. Moreover, we saw that the speed varied with the main highway route to Khulna. The speed varied from 8.40-14 kmph in different section of the route. The reason was that the traffic volume was more on that route and high-speed

vehicle generally used that route. So, considering the safety and traffic issues, the speed in that section was moderate. But in between the different residential area, the speed was above the average speed that was in between 10.60-14.00 kmph. The speed in those routes were moderate that's because of the road type and condition.

3.3 Trip distributions

From the survey, it was found that the students generally gave 9 to 10 bicycle trips per week on an average and maximum student (36% of our surveyed respondents) gave 14 trips per week for their study and other purpose.

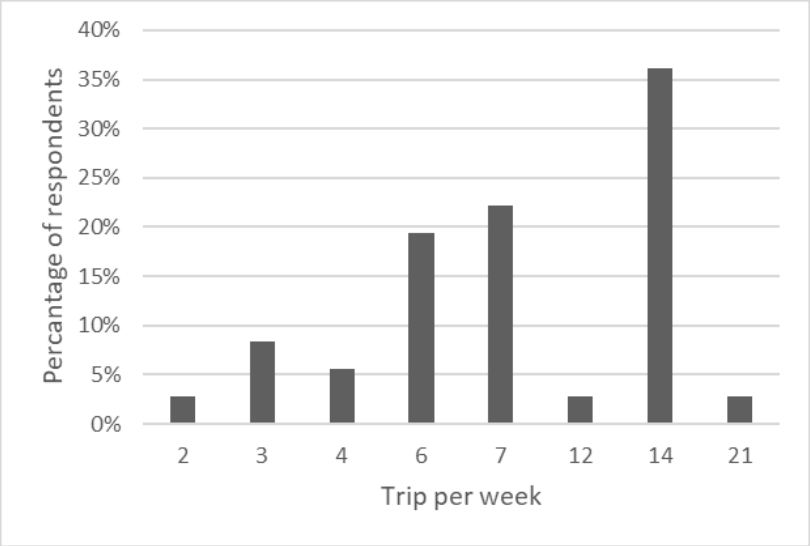

Figure 3: Number of trips per week of the respondents

The maintenance cost of bicycle was affected by the trip numbers. The correlation was 0.35 with 95 percent confidence interval. Average maintenance cost of bicycle was found BDT 115 per month.

Table 2: Trip distribution of bicycle user students according to their education institute and age

Institution	Age (Years)			Total (%)
	13-15	15-20	20-25	
College	0	36	8	44
School	20	25	0	45
University	0	0	11	11
Percentage	20	61	19	100

Around 80 percent of students using bicycles in Khulna city were school and college going and their age was between 13-18 years old (Table 2). So, their main purpose of using bicycle was going to school, college and coaching.

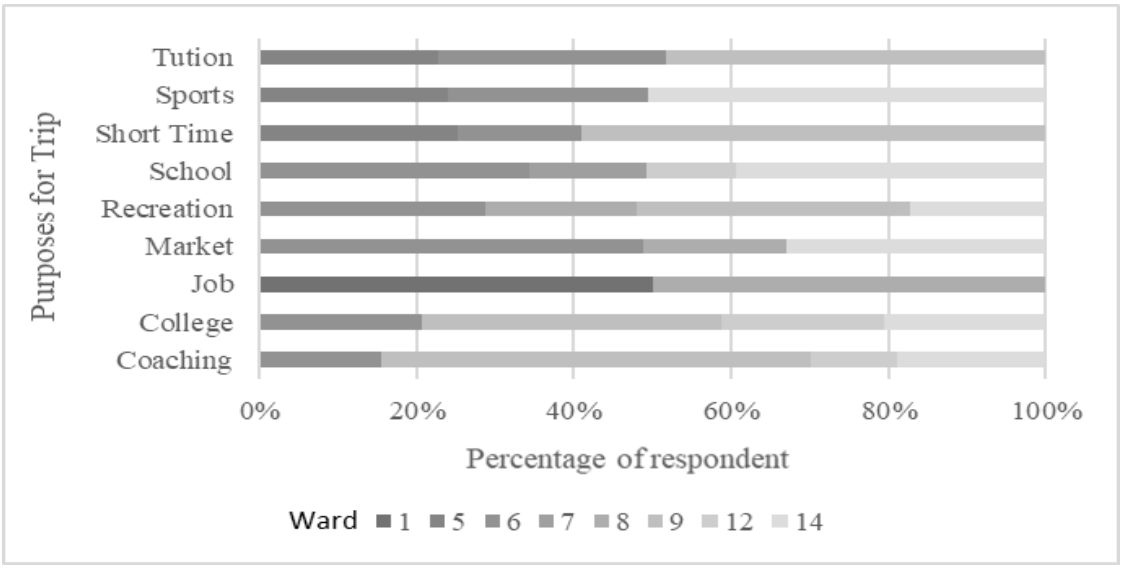

Figure 4: Trip distribution according to purpose

Rest of the respondents were university level students who generally used bicycle for going part-time job, tuition and coaching. Because of having advantage of taking shortcut bicycle was also popular to the students for their daily trip like for recreation, going to play ground, market and other purpose (Figure 4). There was no significance difference between the generated trips in the two-trip time considered in the study. But in morning it was comparatively generated more trip as almost 40 percent (Table 3) of the students went to school and college in the morning except the students who study in collage second year and University (National and Public). They usually did not go to college in the morning period.

Table 3: Trip distribution of the students in different time

Purpose	Percentage of trips in different time	
	Evening	Morning
Coaching	19	8
College	3	14
Job	0	6
Market	3	0
Recreation	6	0
School	3	25
Short Time	3	3
Sports	3	3
Tuition	3	0
Total	42	58

3.4 Speed Scenario

The value of correlation analysis of trip time and the speed of the bicycle was 0.147. Which indicates there was no relation between trip time and bicycle speed. That means speed was not affected by the time of the trip. From Table 4, it was found that the average speed of a bicycle in Khulna City was quite same in the morning and evening when the school and colleges start and close. At the evening students usually went to coaching center.

Table 4: Average speed of the student bicycle users

Trip time	Average speed (Kmph)
Evening	11.43
Morning	10.14
Average	10.68

Overall average speed was found 10.68 kilometers per hour. Where the usual average speed of a bicycle was 15-16 kmph (Eriksson, *et al.*, 2019). So, it seems that the average speed of the bicyclist was hampered due to bad condition of roads in Khulna City.

3.5 Accident Scenario

Table 5 showed that the students between age of 15-20 years, having an average speed of 11.15 kmph and rush speed 16.08 kmph and the age of 20-25 having a speed of 9.3 kmph and rush speed 14.37 kmph.

Table 5: Average speed of different age bicycle user students

Age (Years)	Speed (kmph)	Rush Speed (kmph)
13-15	10.79	19.61
15-20	11.15	16.08
20-25	9.30	14.37

On the other hand, the teenagers having almost the same average speed but have a high rush speed of 19.61 kmph, which indicated the teenagers ride was more rush compare to adult. So, the teenagers (13-19) faced more accident on the road while riding bicycle.

Around 45 percent of the bicycle rider students lost their control while riding rush and slipped on the road and get knee and elbow injury. And all this type of accident faced by the teenagers. But crash with other vehicles on major roads was faced by all age group students, which was almost 40 percent (Table 6). And this type of accident was faced by the other occupation bicycle riders as well. And this crash was happening due to heterogeneous traffic mode and absence of bicycle lanes.

Table 6: Accident faced by the students while riding bicycle in the study area

Types of accident	Age (Years)			Total (%)
	13-15	15-20	20-25	
Crash with Vehicle	17	11	11	39
Crashed with rickshaw	0	6	0	6
Lose control	17	28	0	45
Slide/Crash with Auto	0	6	0	6
Street Barrier	0	6	0	6
Percentage	33	56	11	100

3.6 Other Mode Choice Scenario

Students used other mode of transportation in bad weather condition and for mechanical problem of bicycle. They usually choose walking while the distance was short and can be reached within 15 minutes.

Table 7: Students preference according transport mode according to distance

Mode	Travel Distance (km)					
	Less than 2 km	2-4 km	4-6km	6-8 km	8-10 km	Total Trip
Walking	11%	4%	0%	0%	0%	14%
Rickshaw	7%	14%	0%	0%	0%	21%

Mode	Travel Distance (km)					
	Less than 2 km	2-4 km	4-6km	6-8 km	8-10 km	Total Trip
Auto	32%	18%	0%	4%	0%	54%
Mahindra	0%	0%	7%	0%	4%	11%
Percent	50%	36%	7%	4%	4%	100%

They also preferred auto when the travel distance was up to 4 km as it took low travel cost. Some portion of the student used Mahindra who traveled a long distance of more than 4 km in short time. And the students who traveled more than 6 km mostly did not travel in the bad weather (Table 7).

3.7 Relation with Trip Generation:

A linear regression model between the number of trips and other socio-economic parameters was established. Here we considered family income, other transport cost and travel distance as socio-economic parameters. In our regression model, number of trips per month was considered as the dependent variable. Travel distance (km), monthly family income and other transportation mode cost were taken as explanatory variables. The model showed that with the increasing of travel distance number of trips decreased. If the family income was increased the number of trips might increase and with the increasing of travel cost by other transport mode, the number of trips by bicycle might increase. And the explanatory variables were significantly correlated with the dependent variable (Table 8).

Table 7: Modeling results of trip number

Variable	Coef.	Std. Error	t	Sig.
Travel Distance (km)	-0.287	0.128	-2.234	0.037
Family Income	0.056	0.028	2.006	0.049
Other Transportation Mode Cost	0.450	0.081	5.568	0.002
Constant	0.177	0.225	0.788	0.440
Co-efficient of Determination $R^2 = 0.656$				

Logarithm was used for normalized the data of variable number of trips, travel distance and other transport mode cost for formulating the regression model. So, in the regression equation of this model would take $\log_{10}$ with the variables that were normalized. The coefficient of determination of this model was 0.656 which indicates the dependent variable number of trips was explained 65.6 percent by the explanatory variables. The regression model is following.

$$log\ Y = 0.177 - 0.287\ log\ X_1 + 0.056\ log\ X_2 + 0.45\ log\ X_3 \quad (2)$$

Here, Y = the number of trips per month, X_1 = travel distance in km, X_2 = family income per month and X_3 = the cost of another mode of transportation.

4. CONCLUSIONS

According to the result, the average speed and travel distance of the bicycle was found 10.68 kmph and 2.71 km respectively in the study area. In ward 09 and 14, the number of destinations were higher. Most of the students used bicycles for going to coaching centres and schools and their average trip number were 10 per week. Maintenance cost of a bicycle was found BDT 115 per month. Around 80 percent of bicycle user students were aged between 13-18 years. Other than bicycle, students preferred walking and auto for short distance travel. The regression model indicated that a total

number of trips were mostly affected by travel distance, here the distance travelled by the cyclist had a negative impact on the generated trips. Besides family income and other transport cost had a positive influence on the total number of the generated trips. Students face most accidents by losing control over the cycle for the bad condition of roads and crash with other type of vehicles for heterogeneous traffic composition and lack of different bicycle lane. The results of the research might help the concern authority in decision making for solving transport related problems. This research is conducted on the northern part of Khulna city and for only to explore the scenario of students using bicycle. Bicycle users of other occupation of Khulna city are not considered in the study. Further research would include the other part of Khulna city and the parameter which are not considered like relation between bicycling and influence of built environment of students and other occupations.

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A TYPOLOGICAL ANALYSIS ON THE STRATEGIES OF BUS PRIORITY LANES ON CITY STREETS: A RECOMMENDATION FOR BANGLADESH

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ABSTRACT

Recently public transport is not regarded as well reputed in consequence of poor service quality, traffic congestion, and impoverished vehicle condition. On the other hand, traffic congestion has turned into one of the significant problems in Dhaka, capital city of Bangladesh because of the increased number of private vehicles. "Bus priority lane" is a term which is an association of different approaches to enhance service and minimize delay for public transport. It could be introduced in a roadway in order to develope the transportation system as well as to reinforce the acceptance of public transport. Bus priority lane concepts began to become eminent in 20th century in Europe (UK and Paris). Traffic signal priority (TSP) is a technique to modernize the bus priority lanes to increase its effectiveness. The objective of this research is to carry out a typological analysis on the bus priority lane techniques which are being used in the various cities around the world, as well as to recommend the suitable and effective strategis for our country. In this study, a typological analysis was carried out on different types of bus priority lane system based on priority and alignment. In addition, a comprehensive review analysis of different cities' case study was also accomplished in order to have the better understanding about the various types of bus priority lane treatment available in those cities. Based on the scope of this study, this paper has concluded that before applying any of these bus priority lane techniques in Bangladesh, two points need to be confirmed beforehand: enough road width should be ensured to implement a bus priority lane, and the traffic volume should be within the roadway capacity.

Keywords: *Bus Priority Lane, Traffic Management, Public Transport, Congestion and Traffic Signal.*

1. INTRODUCTION

Dhaka is one of the major cities of South Asia with an area of 1383 square kilometres (BBS Report, 2008). It has a population of 8,906,039 and the population density is 29,392 per square kilometre (BBS Report, 2012b) in the city area. Everyday this vast population deals with many problems and the most common problem they have to face is the traffic congestion. Nevertheless, Dhaka is one of the least motorized cities in the world with a figure of only 2630 vehicles per 100,000 people. Among them 2195 are non-motorized vehicles (Islam & Hossain, 2001). As Dhaka is the capital of Bangladesh, it is containing the maximum facilities than the other cities of this country. Thus people are willing to come in this city for a better life and their livelihood. For this situation it becomes a huge problem to meet the basic needs of people. In this present time congestion becomes higher day by day because of the increase of private vehicles in the city streets. Eventually, people are losing their interest on public transport. Comparing with the population it can be said that the numbers of public transports are very few and the existing public transports are unable to provide people with enough comfort, rather consume their travelling time. It occurs due to poor traffic management and scarcity of adequate public transports. Nowadays, middle class people are also using private vehicle for consuming their valuable time and comfort as well. Consequently, it makes the congestion more, whereas, a bus carries twenty times as many passengers as a car, while it only adds three times to congestion (Bayen et al., 2015). However, it becomes a significant issue to promote people interested so that they would prefer public transport more than private vehicle.

Any arrangement which provides buses privileged treatment upon other traffic is termed as bus priority. Main aim motivating the application of bus priority lanes being to improve bus attraction and increase its attractiveness compared to other modes. The widespread bus preferential treatments are establishment of preserved bus lanes, exclusive median bus way, queue jump lanes, bus individual street, with flow interior bus lane, and exclusive bus lanes on main urban streets in order to ease quicker running of buses to render the mode more enviable (Vedagiri and Jain, 2012). Recently bus priority lanes are exercised wide-reaching in cities like London, UK; Paris, France; Sydney, Australia; Shizuoka, Japan, and Texas, USA.

Though several researches have been accomplished by many researchers in many countries across the world, but these studies were performed based on the situation of those respective countries. This research work was an attempt to carry out a comprehensive review analysis of different cities' case study as well as to conduct a survey in a metropolitan city street of Dhaka. A typological analysis on the different bus priority lane systems which are being used in different countries was also conducted to have a better insight about the bus priority lane treatment and thus the practicing transportation engineers can address the unexpected traffic problems and contribute to the sustainable development in our country. Even though, the authors have figured out some effective features of bus priority lane as a countermeasure for traffic congestion in our country, they also experienced some unusual features while carrying out the study as this research was only based on review analysis of different cities' case study. Consequently, it is imperative to carry out furthermore analysis in this regard.

2. LITERATURE REVIEW

The overall methodology of the study has been organized in three ways. In the first section, a preliminary follow-up case study analysis of several distinct significant cities including Sydney, London and Paris has been worked out. These cities have been chosen only because of having well-established bus priority lane networks running through congested, mixed-use urban districts as well as inter-cities. Thereafter, a typological analysis on the strategies of bus priority lane system has carried out, and finally types of bus priority lane which are suitable for Bangladesh have been proposed.

2.1 Review Analysis of Different Cities' Case Study

2.1.1 Review Analysis of Sydney Case Study

Bus lanes are the well-known strategies noticed in Sydney, Australia. Those lanes give priority for buses during particular periods. These lanes are in effect even during the hours, and they only permit constrained use by specific type of vehicles, for instance taxis or vehicles taking turn. Bus lanes only turn up in small portions of the city (i.e. at key intersections queue-jump lanes are observed). In the United States transit lanes are as analogous to high occupancy vehicle lanes. After meeting specified occupancy, a vehicle is eligible to make use of the lane. This kind of lanes are usually located beyond the Central Business District on the area's premeditated bus passageways, and able to offer a fewer constricting ways for easing bus service compared to other options. The section has some transit way or "T-way" strips that give bus with fast transit facilities. These lanes are more restraining compared to usual bus lanes and prohibit private vehicles to use those lanes. Those lanes comprise both selected lanes on street or highway amenities, or dedicated bus routes which do not flow together with diverse traffic. Nonetheless, this case study was mainly involved with bus lanes on Sydney Inner Region city streets. Bus priority lanes functioned on local streets is termed as bus lanes in this case study (Viegas & Lu, 2001).

Table 1: Metropolitan Profile of Sydney. (Sakamoto et al., 2007)

City population Metropolitan population	1.5 million 4.6 million	Sydney Inner Region Sydney Statistical Division
Annual unlinked urban transit trips Heavy/commuter rail (City Rail) Light rail, monorail Bus (Sydney Buses only) Ferry	326.3 million 111.9 million 8.0 million 191.9 million 14.5 million	34% of urban transit trips 2% of urban transit trips 59% of urban transit trips 4% of urban transit trips
Ratios calculated from data above a) Urban transit trips per city resident b) Urban bus trips per city resident c) Urban transit trips per metro resident d) Urban bus trips per metro resident	a) 225 annual trips per capita b) 132 annual trips per capita c) 71 annual trips per capita d) 42 annual trips per capita	

2.1.2 Review Analysis of London Case Study

London has established one of the best far reaching frameworks of effectively oversaw transport need paths across the world. Though its bus route-network has been existed over period of 40 years, London has significantly promoted and reinforced it during the past ten years, as part of a comprehensive redesign of its surface transport system. London's way to deal with the assignment and requirement of transport paths accentuates focal authority over a system of key arterials, yet nearby power over transport paths off this system.

In spite of London's varied public transport facilities which incorporates underpasses, commuter train, light rail etc., buses persist its utmost extensively employed travel pattern. Approximately 8,000 buses run alongside 700 bus lanes. This overall treatment fulfilled more than 2.2 billion commuter trips in 2010 (Table 2). Public transport use has enhanced since the city has undertaken a number of attempts to move private car users by implementation of cordon pricing scheme for motor vehicles incoming the city center. Passenger trip routes by bus have climbed about 62% between 1998 and 2008, while the population of London has risen by only 7.8% over the same decade (Sakamoto et al., 2007).

Table 2: Metropolitan Profile of London.

City population **Metropolitan population**	7.8 million 11.9 million	Greater London London Larger Urban Zone
Annual unlinked urban transit trips	3,944 million	
Heavy rail	1545 million	39% of urban transit trips
Light rail (Docklands & Tram ink)	106.2 million	3% of urban transit trips
Bus	2289 million	58% of urban transit trips
Ferry	4.1 million	0% of urban transit trips
Ratios calculated from data above		
Urban transit trips per city resident	504 annual trips per capita	504 annual trips per capita
Urban bus trips per city resident	293 annual trips per capita	293 annual trips per capita
Urban transit trips per metro resident	331 annual trips per capita	331 annual trips per capita
Urban bus trips per metro resident	192 annual trips per capita	192 annual trips per capita

2.1.3 Review Analysis of Paris Case Study

The city of Paris has established one of the most inclusive networks of bus lanes. Presently, development of new bus lanes is considered as a fragment of an extensive local agenda for improving bus service, which is known as "Mobilien" (Bayen et al. 2015). The City, Paris has a 190 km of bus lanes network as per 2008. Around 102 km of this total route are simultaneous movement for bus lanes entitled only by means of signs and markings, while 18 km are contra flow lanes and 69 km are secured lanes isolated from other lanes through obstacles varying from small curbs to wide-ranging planted medians. Significant characteristics of the existing Paris bus lane project have incorporated the allocation of a small curb barrier to insulate the bus lanes from conventional traffic lanes, along with the city's strategy to permit taxis and bicycles to share the lane with buses.

2.1.4 Corresponding Study for Bangladesh

As per authors concern any significant study was not done before on Bus Priority Lane in Bangladesh. Though some preliminary researches (Hoque, 1991 & Ahsan, 1991) had been done in Bangladesh for the issue of reducing congestion in the metro city Dhaka, those researches have only showed different aspects from different point of view. In this study, however, we made an attempt to conduct a survey along the route from Shahbag to Farmgate (around 5 km) in order to get understand the existing situation preciously, and also whether the feasibility of bus priority lane is applicable in this roadway or not.

3. TYPOLOGICAL ANALYSIS

There are several methods to give priority to the buses on a roadway. Besides accommodating the safe and efficient operation of buses, they are at variance in maintaining of traffic flow, the necessity for curbside access, the pedestrian- safety, cyclists and so on. Often specific conditions are provided when buses are given priority in a lane to fit the situation as well.

According to priority, there are four types of bus priority lane (Eichler and Daganzo, 2006), such as:

- Type A: Dedicated (or exclusive) bus priority lane (DBL)
- Type B: Intermittent bus priority lane (IBL)
- Type C: Bus lane with intermittent priority (BLIP)
- Type D: Multiple combinations of bus lane.

Type A which is "Dedicated bus priority lane" provides maximum bus frequency, Type B is "Intermittent bus priority lane" which operation system is relatively easier, where Type C (Bus lane

with intermittent priority) is suitable for high traffic volume and the Type D is "multiple combinations of bus lane" which has comparatively little adverse effects on overall traffic for continuous traffic lane. According to alignment, bus priority lanes are of three different types (Eichler and Daganzo, 2006): Type A is "Curb-side alignment" which is at the side of the curb, Type B is "Offset bus lane" which is parted from the curb by a single lane and Type C is "Median bus lane" that is near the median of the roadway.

3.1.1 Dedicated (or Exclusive) Bus Priority Lane (DBL)

It's a type of bus lane to be used by bus exclusively. No other types of vehicle are allowed in the same lane. When DBL is applied, it is expected that both bus and other modes of vehicles' speed will significantly increase as they will not further conflict with each other. Alternatively, as it takes up a lane completely for this purpose, it results in reducing vehicle capacity in the street. However, for controlling or reducing congestion, dedicated bus lane is proved to be a better policy rather than transit subsidization or congestion pricing.

By providing DBL, a major change in bus frequency (about 70%) is noticed. Moreover, in order to decrease total travel time, some buses should leave off at only main stopages and avoid certain less - essential ones. Furthermore, less bus stops might be constructed to enhance bus manoeuvres if the situation considers (Zhang, 2015). Eventually, DBL brings considerable changes in service levels,

though something subjected to mixed traffic conditions do not happen. These conditions may lead to higher demand of public bus transport under mixed traffic conditions (Leonardo & Basso, 2010).

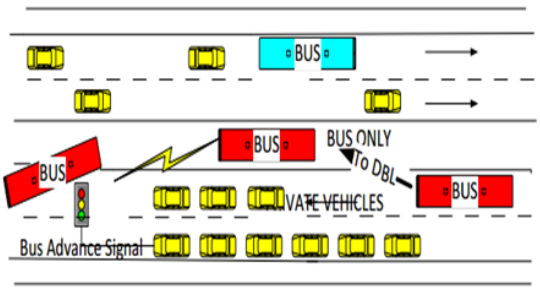

Figure 1: Single Dedicated Bus Lane (Type A) Scenario in the Middle of the Road only

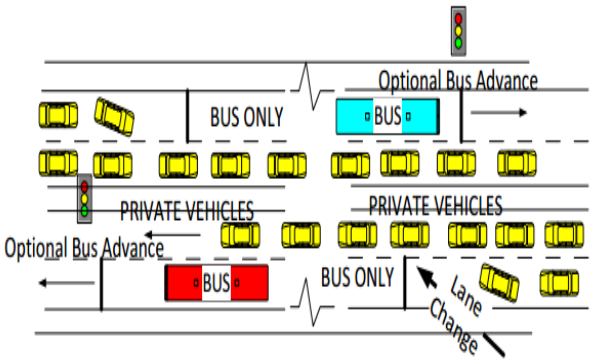

Figure 2: Two Dedicated Bus Lanes (Type B): one bus at each side of the Road

However, when a Dedicated or Exclusive bus priority lane is introduced, buses are still subject to traffic signal regulations, which are often governed by the overall traffic conditions, including buses and other private vehicles as well (Wang & Misook, 2013). DBL can be combined with traffic signal priority (TSP) to make the system more effective. Nevertheless, it has some drawbacks like dealing with pedestrian interference. In addition, an exclusive lane can be followed by a special lane of about 150m before intersection to facilitate left turning vehicles. Exclusive bus lanes implemented in the city of Dallas, Texas, USA was studied by (Cox, 1975) and he established that the additional special lane does not affect other vehicular traffic but helps increasing in speed of buses as well as reduces traffic time. Exclusive lanes are sometimes called with flow lanes and also accommodating bicycles and other emergency vehicles, such as ambulence, fire-services or even high occupancy vehicles can be allowed in it (National Capital Region Transportation Planning Board, 2011).

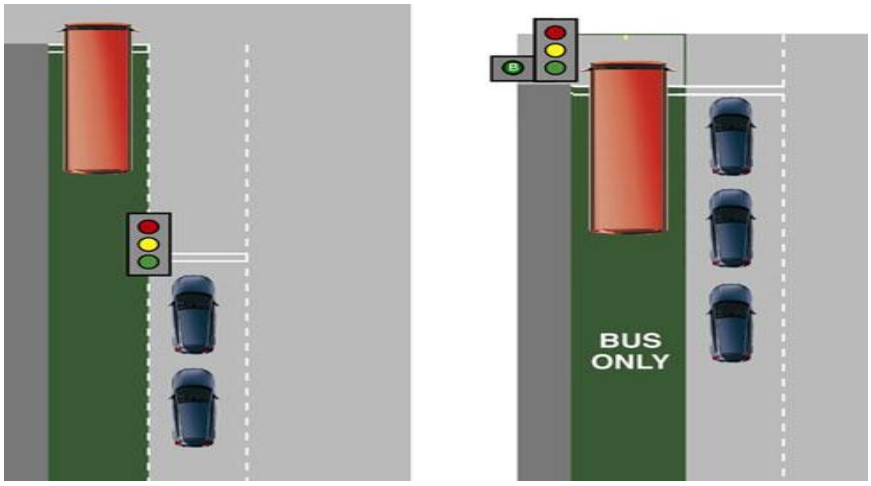

Figure 3: Exclusive bus lane (Type A) followed by special lane for left turning bus.

3.1.2 Intermittent Bus Priority Lane (IBL)

In this system, when a bus lane is not used by bus, it allows private vehicle to use the lane. It also never requests traffic to leave the lane to accommodate the bus. (Vegas, 2001 and 2004) first suggested the theory of IBL. Although, IBL restricts traffic from coming into the bus lane when it is occupied by bus, it does not interrupt in traffic as dedicated lane. Sometimes, traffic signal priority (TSP) is used in intermittent lane. Hence, IBL is much more efficient than dedicated bus lane. Structure of Intermittent Bus Lanes has been shown in Figure 4 below.

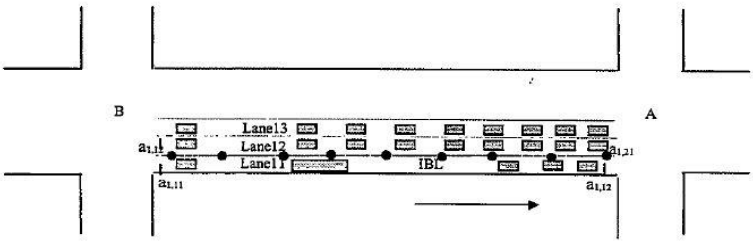

Figure 4: Structure of Intermittent Bus Priority Lane (Type B). (Eichler and Daganzo, 2006)

3.1.3 Bus Lane with Intermittent Priority (Eichler and Daganzo, 2006)

It is similar to the system of IBL except some specifics. It clears traffic out at the time when the lane to be used by bus, meaning when a bus approaches. However, it does not depend on TSP or any other kind of traffic signal. For that purpose, variable message sign (VMS) or dynamic signage is used to communicate with the users of BLIP. The evaluation and analysis to be made for establishing the system is comparatively less complex. Nevertheless, TSP is included in the system when it is highly required. BLIP can also be combined with in-pavement lights. For the reason that the lane needs to be cleared for approaching buses, it would be difficult to clear it many times a day. These types of lanes only benefits when traffic intensity is low and buses maintain a regular routine.

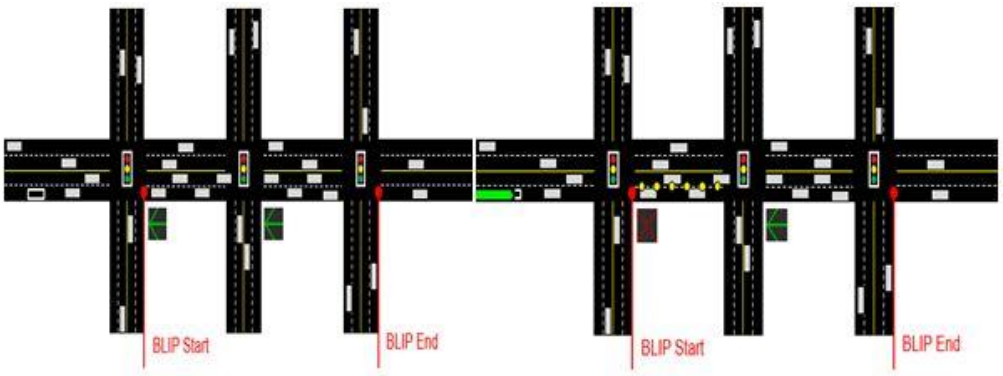

Figure 5: (a) Step 1: All Lanes Open; (b) Step 2: Bus Approaching & signals change.

Figure 6: (a) Step 3: General traffic leaving BLIP lane; (b) Step 4: Bus enters cleared BLIP lane (Eichler and Daganzo, 2006).

Table 3: Characteristics of (Type A, B, & C). (Eichler and Daganzo, 2006).

Type	**Lane**	**Priority Type**	**% of Reduced speed delay/Bus frequency**	**Advantages over other types**	**Drawbacks**
Type A	Dedicated Bus Lane (DBL)	Maximum no of Bus (no other traffic)	70% Bus frequency	Maximum bus frequency	• Interrupts traffic • Pedestrian interference
Type B	Intermittent Bus Lane (IBL)	Private vehicles allowed	Average 20-25%	Operation is easy	• Cannot force existing vehicles to move away
Type C	Bus Lane with Intermittent Priority (BLIP)	Private vehicles allowed (for a limited time)	5% reduced speed delay	High	• Disrupts traffic • Not recommended for low traffic

3.1.4 Multiple Combinations of Bus Lane

(Truong, et al., 2015) first attempted to understand the combined effect of multiple types of bus lanes through micro-simulation. Also, for observation, they considered that the bus lanes could be either continuous or discontinuous. And they figured out that series of continuous lanes have low negative impacts on general traffic rather than the identical number of intermittent bus lanes. They suggested that multiplier effects such as bus travel time advantages and ordinary traffic travel time demerits definitely exists for combined bus lanes. They also established that when upstream traffic volume outstrips the capacity of existing traffic lanes, it should never be recommended to turn the lanes into bus priority lanes as it promotes negative impacts significantly.

Moreover, according to alignment, there are four types of lane (Eichler and Daganzo, 2006), as mentioned below:

- Type A: Curb-Side Alignment.
- Type B: Offset (or interior) Bus Lane.
- Type C: Median Bus Lane.
- Type D: Far curb Lane.

3.1.4.1 Curb-Side Alignment

When a bus priority lane is established alongside the curb, it does not reduce the vehicle capacity of the street, rather it can be allocated for parking or dispatching in off peak hours. This type of lane can also be used by general traffic if it permits. But there are some drawbacks of this sort of lanes as well. For example, during the time it being used as a bus priority lane, the curbside cannot be used for delivering goods, passenger pick up, drop off or parking (Agrawal & Goldman, 2012). These bus lanes are sometimes called "Queue Jump Lanes" (QJL) as they make the buses 'jump' the queue of the traffic and do not make them wait on signals for a long time. Queue jump needs signal controlling to provide a phase specifically for the vehicles in it. This type of bus lane has significant effect that usually brings in 38 percent mean travel time reduction 103 to 44 seconds (Vedagiri & Jain, 2012).

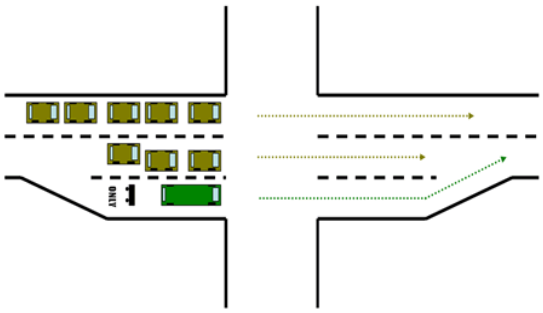

Figure 7: Queue Jump Lanes. (Bayen, et al., 2015)

3.1.4.2 Offset (or Interior) Bus Lane

Offset lane can be used as an alternative for curb-side lane. In this case, the lane is only detachted from the curb by a travel or parking lane. If not, it can be made large enough to share it with bus stops, parking spaces and other uses of the curb. These lanes are also known as "self-enforcing" for being separated from the curb and not being interrupted by the stopped vehicles.

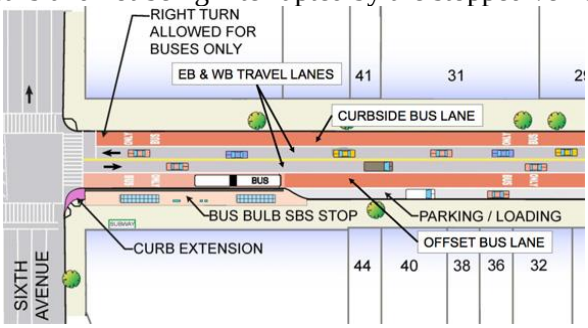

Figure 8: Offset or interior bus lane (Type B). (Bayen et al., 2015)

3.1.4.3 Median Bus Lane

Median bus lanes are provided along the median lanes in a two-way traffic. They are even further separated from the curbside and effective in long, large corridors that serve many bus routes. However, passenger platforms or loading areas will be needed in the middle of the road so that it will abate the vehicle capacity in the street and also might induce the safety issues.

3.1.4.4 Far Curb Lane (Agrawal & Goldman, 2012)

Far curb lanes have two options bus lane i.e. either concurrent with the flow or the opposite direction of traffic.

Table 4: Bus lanes according to alignment (Agrawal & Goldman, 2012)

Type	Lane	Position	Advantages	Drawbacks
Type A	Curbside Alignment	Alongside the curb	• Vehicle capacity remains same. • 38% mean travel time reduction.	• Curb cannot be used for other purposes.
Type B	Offset Bus Lane	Separated from curb by a single lane	• Curb can be used for other purposes.	No significant Drawbacks.
Type C	Median Bus lane	Along the Median	• Effective in Long, wide corridors.	• Require passenger platforms or loading areas. • Reduces vehicle capacity. • Safety Issues.

3.2 Review Analysis of Software Simulation (Tran et al., 2013)

Using "PARAMICS" simulation tool Tran et al., (2013) established a simulation-based analysis for the lane operation of bus and bus-signal priority also in city streets. PARAMICS can simulate exclusive bus lane and ordinary lane without any API (Application Programming Interface) development, but for bus priority lanes it is necessary to supersede the default core in PARAMICS by developing specific API for it. For the accuracy of the data simulated, some simple assumptions were also considered for lane changing behavior (Bayen et al, 2015).

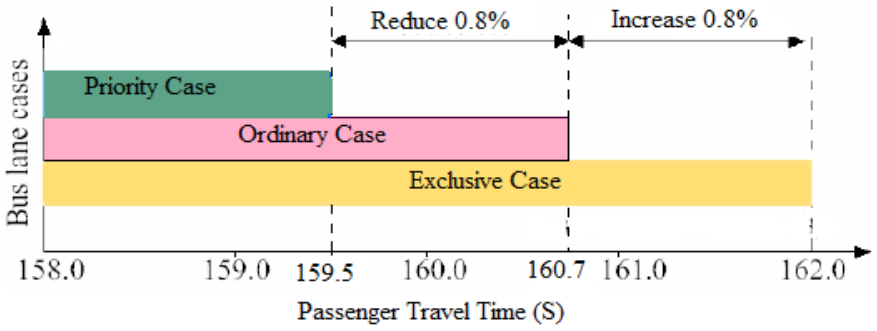

Figure 9: Comparison of passenger travel time (s). (Tran et al., 2013)

Comparative analysis of this research, however, made it evident that the bus priority lanes have had better contribution in minimizing passenger travel time in comparison between the bus priority lane and the regular lane. Accordingly, the bus priority lane system is capable to decrease travel time by 1.2 sec. (or 0.8%) per passenger compared to that in the current ordinary lane case (Figure 1), whereas, the exclusive bus lane treatment made the passenger travel time increase by 1.3 sec. (equivalent to 0.8%). Even though the exclusive bus lane can increase the bus travel time significantly, it has also the significant adverse impacts on non-bus operation in this case. Therefore, bus priority lane is the better strategy, which might enhance bus performance and decrease adverse effects on other vehicles (others than bus) concurrently.

4. DISCUSSION & RECOMMENDATION

Nowadays, it is a common scenario in our country that the metropolitan city streets are becoming less efficient with their high intensity of heterogeneous traffic. Besides, ordinary bus lane or bus priority lane is not yet a common policy to use against the congestion. In this study, on the scope of our survey (from Shahbag to Farmgate: around 5 km), it has been found that the ordinary bus lane in spite of having adequate width is not capable enough to minimize the traffic congestion. Moreover, due to the ample quantity of private vehicle, the ordinary bus lane is completely blanketed with them. Consequently, to order to reduce the pressure on the roads, increasing the demand of public transportation like bus is one of the crying needs on the city streets nowadays. However, based on the scope of the study and above discussion, the followings could be put forwarded to some extent. Among the discussed types in this study, almost each type of the bus priority lanes is applicable in the country, yet it is indispensible to analyze some more factors beforehand with a view to bring out the maximum benefit. In general, the dedicated lanes might not be the best option to consider for its significant drawbacks: it takes up a whole lane for its sole purpose and interferes with other traffic the most as well as pedestrians. The advantages that intermittent bus lane (IBL) has, makes it a better choice than DBL. BLIP also might not be a good preference all the time. Moreover, the Median bus lanes mostly require bus bulb with bus stoppage and other facilities in the middle of the road. Therefore, careful consideration is needed about the road width before choosing this type. Curbside alignment or off set lane can be a better option considering they allow the curb to be used for other purposes. Even though bus priority lane is not applicable in the roads, where traffic intensity is greater than the road capacity, nonetheless, if bus priority is given to some certain routes, it is possible that it will affect the alternate modes. Thus, the intensity of mixed heterogeneous traffic will decrease. For a bus priority lane, to be applied, the road width should be at least same as that there could be at least three lanes in each direction on the road, whilst it is not always necessary to take up a lane only to give priority to buses. Instead, it can be used by general traffic when not required by buses. Accordingly, a bus priority system should only be established in the priority lane. Moreover, it is very important to know the bus schedule or intensity at different times or days of a week. In addition, in order to maintain the bus priority lane system effectively, the TSP, VMS or other systems might be engaged as well. Moreover, traffic signal priority is highly recommended as it is inexpensive and has a great significant. To recapitulate, the bus priority lane system should be applied in a way so as to fulfill the objective of reducing congestion in an economical way and effectively as well, and thus by to promote public transport instead of private vehicle.

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FEASIBILITY STUDY OF MASS RAIL TRANSIT ON EXISTING RAIL LINES IN CHATTOGRAM CITY

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ABSTRACT

Chattogram is a major coastal city and the heart of economy of Bangladesh. The transportation network represents the flowing blood in the veins of economy. Due to exponential increase of population, the traffic pressure is heavy on roadway and this leads to traffic congestion. The Railway is another mode of transport which provides fast and congestion free movement of passengers and cargo. With the introduction of Mass Rail Transit in a form such as commuter train to city rail network, Chattogram has a real opportunity to become a tycoon in the industrial sector. Moreover, the circulation of traffic will be congestion free. But due to lack of proper transit system, this area is being ignored. Hence an initiative has been taken to study the feasibility of Mass Rail Transit on existing rail lines within Chattogram City.

The feasibility study has been done with subsequent physical investigation and detailing of all the existing permanent ways and several infrastructures of city rail network such as signals, level crossing, stations etc. The land use map of Chattogram City has been collected. Afterwards, the present area coverage with respect to land use has been checked. It has been found that present area coverage is not adequate for introducing Mass Rail Transit in existing rail network. Moreover, people from many outer periphery zones can't access to the network easily. Finally, few alternate routes have been proposed with their increased area coverage to improve the city rail network.

Keywords: *Traffic congestion, Mass Rail Transit, Area coverage.*

1. INTRODUCTION

From engineering aspects, a city should be free from traffic congestion, environmental pollution and must provide safety in traffic movement to all inhabitants. Chattogram is a significant littoral city and economic center of Bangladesh. The city is located at the intermediate portion of the Chattogram topographical Hill Tracts and the Bay of Bengal, having a global co-ordinate 22°22′N & 91°48′E. Almost 40% of Bangladesh's overall industrial outcome, 75% of its worldwide trade and 45% of its national revenue are achieved from Chattogram (Chittagong,2019).

The transportation system of Chittagong mainly consists of roadways, railway, waterway & airway. The roadway is the most common mode of transportation that is frequently used by people. Like other developed cities in the world, there is no mass transport system besides general road networks. With the extensive population growth, the highways have become saturated with traffic. As the inhabitants of the city have started to increase exponentially, the Chittagong Development Authority (CDA) has taken a few efficient transportation initiatives to lessen the traffic congestion in Chattogram (Chittagong Development Authority,2019). But the necessity of a properly planned transit system is still hunting the development of the city. Chattogram city, having about 59.45 km of rail-lines, utilizes almost less than half of its asset. This railway network may be used to facilitate the transportation system through mass transit to reduce the extensive pressure of congestion in highways.

Adopting "Mass Rail Transit" in the local railway lines can not only boost the economy but also shift the extra pressure of traffic from highway to rail transport. By using the transit system of the same, other cities of the country can also push a step forward to sustainable development. This study deals with the scope of mass transit system in existing local rail lines and recommends some improvement options.

2. OBJECTIVE & METHODOLOGY

This study follows three prime objectives.

- To survey the existing permanent way in city area & find out its present status.
- To check the feasibility of Mass Rail Transit regarding the improvement of the system.
- To propose alternate route regarding the feasibility of Mass Rail Transit on existing rail lines.

Initially the local rail lines of Chattogram city area was selected as the case study area. A railway map was collected, and the rail lines were divided into 12 splits under 5 routes to ease the work. A detail reconnaissance survey had been conducted to assess the present condition of the existing rail lines. After surveying each route, several characteristics of the existing signals, stations, level crossings and gauge of rail lines were observed with the classification of signals into active or inactive, stations into very good, good, fair and poor, level crossings into guarded / unguarded, double tracks / single track, Busy / Less busy, rail lines into broad gauge, meter gauge and narrow gauge.

After analysing data, it was found out how much area the existing rail lines will cover and how much people will be attracted towards the Mass Rail Transport on existing rail lines from the connecting highways. Some limitations were fixed during survey such as inactive signals, unguarded level crossings, insufficient number of stations, poor strengthening condition of rail lines. Based on land use and other necessary details, a final proposal was given for providing Mass Rail Transit.

3. PHYSICAL INVESTIGATION

The whole existing rail network has been surveyed and necessary data have been obtained through this survey along with some help from the corresponding authority. In order to ease the arrangement,

the whole network is divided into 5 sections which are further sub-divided into 12 splits. Five major sections are:

- Sholosohor-Oxygen-Chittagong University
- Ambagan-Sholosohor-Kalurghat
- North Halishohor-Port Colony-Marine Academy
- Middle Salimpur-Ambagan- Rail Station-Bander thana
- Bhatiari-Middle solimpur-north halishohor-Cement Klinker

All splits were investigated physically in details. The existing city rail network collected from Google Earth has been shown in Figure 1. The whole rail network within Chattogram City boundary which were divided into 5 routes, the details of the level crossings are showed in Table 1 along with their respective locations. It should be noted that all rail tracks within city area are metre gauge.

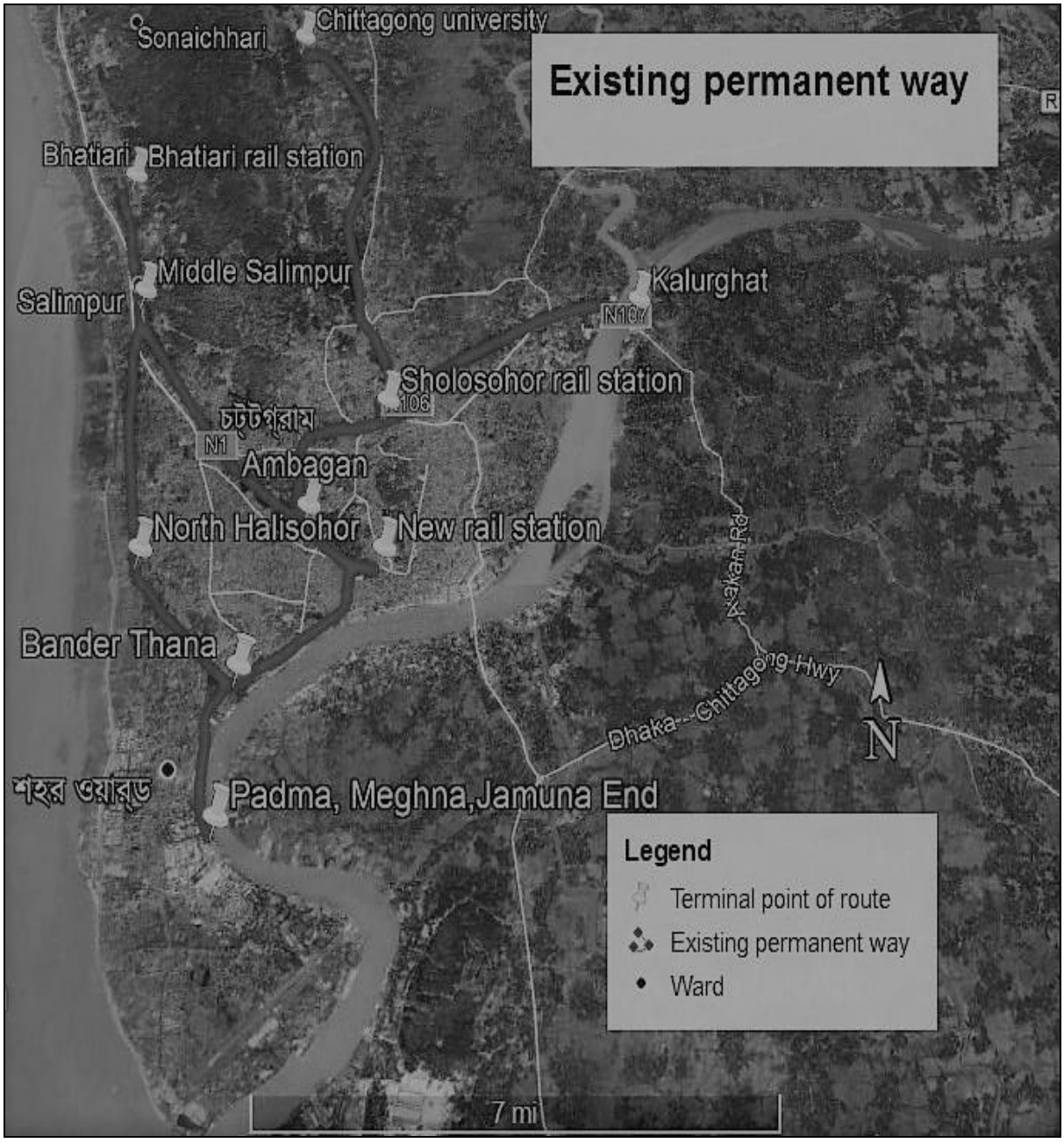


Figure 1:Existing permanent way

Table 1: Status of level crossings of existing rail lines within city area (Personal Field Survey,2019)

Route Name	Split Name	Location	Physical feature		
			G/U	D/S	B/L.B
Sholoshahar-Oxygen-Chittagong University	Sholoshahar-Oxygen	Oxygen	G	S	B
		Amin jute mill	G	S	L.B
		Raufobad	G	S	L.B
		Basher market	U	S	L.B
		Forest gate	G	D	L.B
	Oxygen-Chittagong University	Baluchora	G	S	L.B
		Notun para	G	S	L.B
		Borodigir par	U	S	L.B
		College road	U	S	L.B
		Fauzi flower mill	U	S	L.B
		Chowdhury hat	U	S	L.B
		Fathehabad	U	S	L.B
		Nondirhat	U	S	L.B
		CU	G	S	L.B
Ambagan-Sholoshahar-Kalurghat	Ambagan-Sholoshahar	2 no gate	G	D	B
		Khulsi	G	D	B
		Jhautola bazar	G	D	L.B
		Ambagan	G	D	B
	Sholoshahar- Kalurghat	Muradpur	G	S	B
		Sunnia madrasa	U	S	L. B
		Shyamoli residential	U	S	L. B
		Chand mia road	U	S	L. B
		Bahir signal	G	S	L. B
		Rastar matha	G	S	B
		A.K khan school Road,mohra	U	S	L.B
		Moulovi bajar	U	S	L.B
		Kalurghat	G	S	B
North halishahar-Port Colony-Marine Academy	North halishahar-Portcolony	Halishahar,boropul	G	S	L.B
	Portcolony-Marine Academy	Port colony	G	D	L.B
		Gasfill	G	S	B
		Port residential area	G	S	L.B
		Saltgola	U	S	B
		M.P.B gate	U	S	B
		Labour colony	U	S	B
		China mate	U	S	B
		Airport road 1 (TSP Complex)	U	S	L.B
		Airport road 2 (Eastern Refinary)	U	S	L.B
		Jamuna	U	S	L.B

Contd.

Route Name	Split Name	Location	Physical feature		
			G/U	D/S	B/L.B
		Megna	U	S	L.B
		Padma	U	S	L.B
Middle solimpur-Ambagan-Rail Station-Bander thana	Middle solimpur-Ambagan	Pahartoli	G	3 tracks	B
		Pahartoli Cda	G	D	B
		Ispahani	G	D	B
		Koibollodham	G	D	L.B
		Cda 1	G	D	L.B
		Fakirhat 1	U	D	L.B
		Fakirhat 2	U	D	L.B
	Ambagan-Rail station	Kodomtoli	G	5 tracks	B
	Rail station-Bander thana	Maderbari	U	S	B
		Rashid building	U	S	L.B
		Naval gate	G	S	B
		Barek building	U	S	B
		2 no gate bander	U	S	L.B
		3 no gate	U	S	B
Bhatiary-Middle solimpur-North halishahar-Cement clinker	Bhatiary-Middle solimpur	Kalushah Nogor, Overbridge	U	S	L.B
		Fauzdharhat Cadet College	G	3 tracks	L.B
		Jalil textile	G	4 tracks	L.B
		Jalil station	U	4 tracks	L.B
		BMA gate	G	D	L.B
		Port link	G	D	B
		Baneer bazar	G	D	
	Middle solimpur-North halishahar	Chowdhury Para	U	S	L.B
		Abbas Para (1)	U	S	L.B
		Abbas Para (2)	U	S	L.B
		Alisha majar	U	S	L.B
		Ful Chowdhury para	U	S	L.B
		Jella para,north cattoli	G	S	L.B
		Colonel road	U	S	L.B
		Ishan mohajon road	U	S	L.B
		Jella para,north cattoli	G	S	L.B
	North halishahar-Cement clinker	-	-	-	-

Here G/U means guarded/unguarded, D/S means double / single track, B/L. B means busy or less busy. It can also be observed clearly that there are no crossings in the Noth Halishahar- Cement Clinker split. The reason is that at present no permanent way exists there. The 12 splits are also tabulated along with their measurement and respective signal features in Table 2.

Table 2: Split length, Status of existing stations, signals within Chattogram City (Field Survey,2019)

Route Name	Split Name	Length (Km)	Station		Signal	
			Station name	Condition	Active	Inactive
Sholoshahar-Oxygen-Hathazari	Sholoshahar-Oxygen	3.50	Sholoshahar	Good	2	1
	Oxygen-Chittagong University	10.20	Notunpara	Good	6	0
			Chowdhury hat	Poor		
			Fatehabad	Good		
Ambagan-Sholoshahar-Kalurghat	Ambagan-Sholoshahar	4.05	Jhautola	Poor	9	0
	Sholoshahar-Kalurghat	7.80	Janali Hat	Good	9	0
North halishahar-Portcolony-Marine Academy	North halishahar-Portcolony	3.40	-	-	1	0
	Portcolony-Marine Academy	6.20	-	-	0	0
Middle Solimpur-Ambagan-Rail Station- Bander thana	Middle Solimpur-Ambagan	7.50	Pahartoli	Fair	19	0
	Ambagan-Rail Station	1.50	Chittagong rail junction	Good	33	0
	Rail station-Bander thana	4.30	Debar Par	Poor(off)	0	0
Bhatiary-Middle Solimpur-North halishahar-Cement clinker	Bhatiary Middle Solimpur	4.00	Bhatiary	Good	28	0
	Middle Solimpur-North halishahar	7.00	-	-	0	1
	North halishahar Cement clinker	-	-	-	-	-

4. FEASIBILITY OF MASS RAIL TRANSIT

After investigating the existing rail lines, they are analysed with respect to their present condition and effective area coverage to check the feasibility for providing mass rail transport along this network.

In the internal development the city is mainly based on 5 industrial areas. They are:

- Kalurghat Export Zone
- Nasirabad Sholosohor Export Zone

- Fouzdarhat Industrial Zone
- Export Processing Zone (EPZ)
- Patenga Industrial Area. (Land Use report,2005)

The overall development of this division is mainly on the North West and on the North East direction. The North East direction is blocked by Khagrachari hilly area. So, the overall possibility of the future growth of this city is North West region which heads towards the direction of Dhaka (Chowdhury, 2014). The details can be seen in the land use map given in Figure 2.

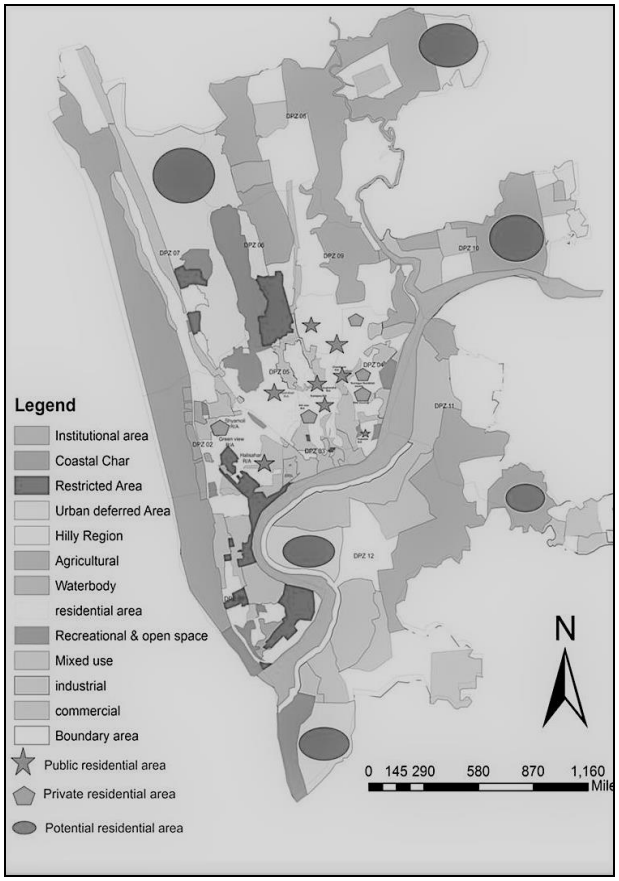


Figure 2: Land Use map (Chowdhury,2014)

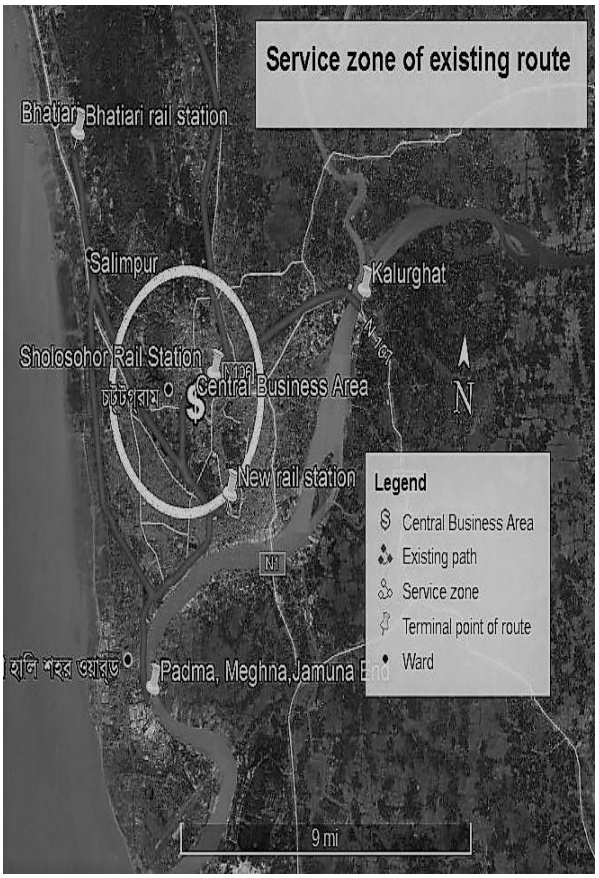


Figure 3: Service Zone of Existing Network

From Figure 3, an estimation of the area coverage of existing permanent way is almost 43.53 km sq. (calculated automatically from Google Earth). Chattogram city is about 168.1 km sq. So, the area coverage is almost 25% which is not enough for the Mass Rail Transport. Moreover, mainly New rail station to Dhaka, Sholosohor, and CU –these are the mostly used route which are centralized. Other routes are not efficient enough. Hence people on the periphery, can't access the rail network easily. As a result, main purpose of carrying mass traffic effectively and reducing congestion fails.

5. PROPOSED ROUTE IN THE CITY AREA

As the existing network is not enough to provide efficient service to the increased traffic, new route is needed to be introduced to overcome the shortcomings. So, conducting analysis on the topography to suggest probable route that may shift more amount of traffic from the congested area and outer perimeter. Considering mass traffic frequency 3 network can be suggested.

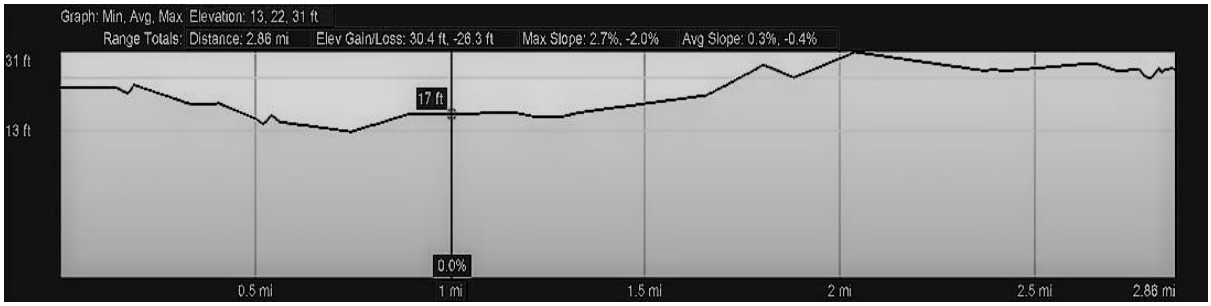
- Proposed route 01: Muslimabad to North Halishohor along outer coastal road.
  i) North Halishohor-CEPZ exit Road

ii) CEPZ exit Road-Muslimabad

- Proposed route 02: New Rail Station- East Bakalia –Janalihat Station-Fateabad rail station-Bhatiyari rail station.
  i) Rail station – Neyamot ali rd.
  ii) Neyamot ali rd.- Bhatiyari
- Proposed Route 3: East Bakalia-Sholosohor Rail Station

The topographical analysis has been shown here in Figure 4.

North Halishohor to CEPZ Exit Rd.

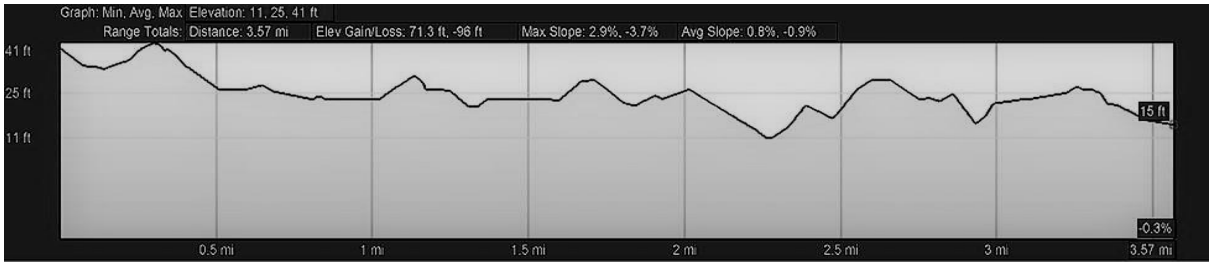


CEPZ Exit Rd. to Muslimabad

Rail Station to Neyamot Ali Rd.

Neyamot Ali Rd. to Bhatiyari

continued



East Bakalia to Sholosohor Rail station

Figure 4: Distance vs Elevation (mi vs ft)

The elevation and slope variations are shown in Table 3

Table 3: Elevation and slope details of proposed route

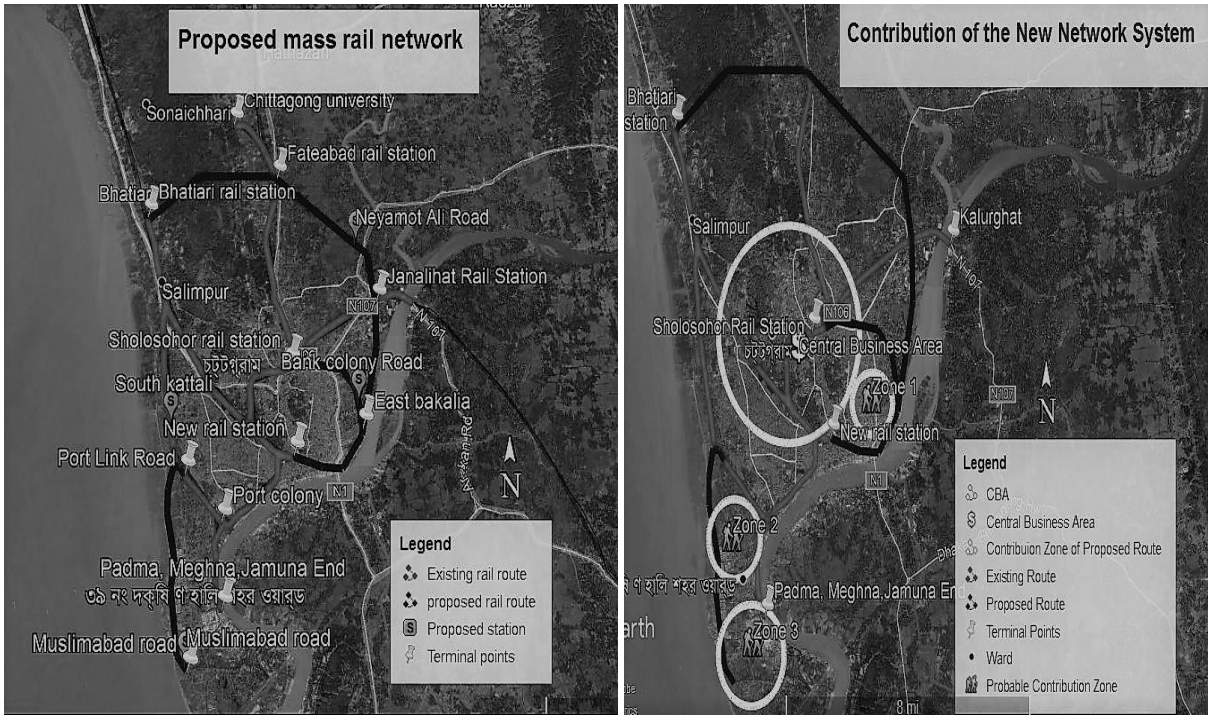
Route Name	Split	Max. Elevation(ft)	Min. Elevation(ft)	Avg. Elevation(ft)	Max Slope (%)	Avg. Slope (%)
Muslimabad-North halisohor	North halisohor-CEPZ exit rd	28	13	17	3.9	0.4
	CEPZ exit - Muslimabad	31	11	22	2.7	0.3
Newmarket rail station-Bhatiari	Rail station-Neyamot ali rd.	117	5	26	0.6	-2.9
	Neyamot ali rd. -Bhatiari	196	6	68	-19.9	1.5
East bakalia-sholosohor	East bakalia-sholosohor	41	11	25	-3.7	0.8

Calculating automatically from Google Earth, Chattogram City area is about 168.1 km square. Chattogram contains 178.15 km of rail line where the city has 59.45 km of rail lines. Providing 3 new routes we get 3 additional service zone which are shown in Figure 5 along with newly formed network. The area coverage of those also increases as in table 4.

Table 4: Area Coverage of New Network

Zone no.	1	2	3
Area (km square)	3.55	5.81	9.38

Net area coverage =3.55+5.81+9.38+43.53=62.27 km sq. which is 40% of city area. Previous area coverage was 25%. So new network increases the area coverage by 15%, making it feasible for carrying mass traffic.



New Network Extra service zones

Figure 5: New network with extra service zone

6. CONCLUSIONS

Traffic congestion is a serious problem that needs immediate attention and sustainable solution. A Mass Rail Transit system can reduce traffic congestion and enhance economic growth. Existing network carry passenger only centrally. So, people from outer periphery and distant places can't access the rail Network. It has been found unsuitable for less area coverage and all routes not being used effectively. Hence new routes have been introduced which increase the area coverage about 15%. New network can provide traffic circulation along outer periphery of major residential zone and provide easy access from any places within city area.

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EXPLORING PUBLIC PERCEPTION ON RAIL TRANSIT SERVICE OF BANGLADESH

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ABSTRACT

Public transportation system is one of the most essential components required for the development of any country. It provides the most effective and efficient way for transporting a significant amount of people, particularly in areas where rapid urbanization has resulted in an increased number of populations. With the growing rate of population, public transport demand is also increasing. Consequently railway transportation has to play a vital role to meet this increasing demand of transport in Bangladesh. Traveling by train is cheaper and convenient compared to other available modes of transport in Bangladesh. This paper aims to explore public perception on rail transit service quality (SQ) of Bangladesh. A broad face to face questionnaire survey was conducted at Kamalapur Railway Station in Dhaka city to 1037 respondents. The questionnaire was well structured which included 25 service attributes regarding train service quality. Findings from the survey indicates that passengers are moderately satisfied with security inside train, air ventilation inside train, waiting place condition of railway station, food facilities in train, toilet facility for commuters, behavior of train's staff, compartment condition of train, compartment arrangement of train and cleanliness of train. From the survey report it has been found that most (67%) of the respondents' are moderately satisfied with the overall train service quality in Bangladesh. Outcomes of this study can be utilized by Bangladesh Railway (BR) to improve the overall service quality of rail transit service of Bangladesh.

Keywords: *Public perception, rail transit service, service quality*

1. INTRODUCTION

Public transport is a vital component of any developing city which offers several facilities to individuals, societies and local economy playing a crucial role for the growth and development of a city by meeting the increased number of mobility demand due to rapid urbanization. Effective and efficient public transportation system improves living condition in a city by increasing mobility, reducing pollution and benefiting the community financially. Several types of public transport are available according to capacity and mobility in different countries. Among the available different modes of public transport, train is the popular choice for developing and developed countries. Because train as a mode of transport not only carries great amount of passengers and goods but also it causes less environmental damage compared to motorized road traffic. Thus train can play a vital role in reducing pollution, congestion, and fatalities.

For a densely populated country like Bangladesh, rail service as a means of transport is very effective. Compared to other available services, rail service is considerably faster. It is also very reliable as it is least influenced by weather conditions and traffic jam. In case of capacity and time, railway transport can carry larger volume of goods and passengers over greater distance in much quicker time which is making it more economical compared to motorized road traffic. So, rail has to play a potential role in mass transit for Bangladesh which is experiencing a rapid increase in motorized traffic.

Rail transit service is a popular mode of public transport in Bangladesh as it is affordable and cheaper compared to other available modes of transport. It is operated and run by the government of Bangladesh which is commonly known as Bangladesh Railway (BR). BR has a total route of 2,877.10 km where 1,648.24 km is meter gauge, 659.33 km is broad gauge and 569.53 km is dual gauge. Covering 458 stations spreading all over the country, BR is providing facilities to freight services and passengers (Length contents, 2014). BR provides train service around the country by dividing it into two zones; namely East Zone (EZ) and West Zone (WZ). BR currently operates 86 intercity trains, 135 Local/Mixed/P&V trains, 4 International trains and other 64 trains comprising of Commuter, Mail Express and DEMU (Passenger Trains in BR, 2017). Over the last few years the participation of private sector in railway operations has gradually increased which includes the leasing out of commercial functions for passenger trains. For the development, maintenance, operation, expansion and provision of telecommunication services in railway, BR signed private sector contracts. The involvement of private sector has been found greatly successful resulting in improved service and increased revenue. Currently, railways play an important role in case of connectivity across and within regions of the country.

Compared to the expansion and improvement of road network, rail network has not received any significant consideration and attention. Due to lack of sufficient funds for maintenance of rail tracks and supporting infrastructures, the rail sector is in a dreadful condition, resulting in poor performance of Bangladesh Railway (Abdullah, 2012). The quality of service reduces with the increase of age of public transport organizations and the public is compelled to accept what is offered to them as they don't have any alternative (Andreassen, 1994). Therefore, such a situation arises when it becomes necessary to introduce or reintroduce the concept of quality back into public transportation to meet the quality expectations of the public (Ancarani & Capaldo, 2001).

In spite of service quality being a crucial aspect in the field of public transport, inadequate research has been done to study this concern, especially in government run rail service in Bangladesh. To fulfil public demand and attract more passengers, public transport must ensure high service quality (Stradling, Anable & Carreno, 2007). It is important to find out satisfaction and dissatisfaction level of customer about public transport, so that the system can be made further attractive and demandable. As rail is a popular mode of public transport, it requires regular assessment to improve its service quality and satisfy its users.

2. LITERATURE REVIEW

Public Transport (PT) serves a significant role as a medium of movement of users' from one place to another, especially in urban areas. Several types of public transports are used worldwide, such as bus, taxi, light rail transit (LRT), monorail, paratransit, commuter rail, tram, subway, mass rapid transit (MRT) etc. PT increases the quality of life having a direct effect on the national economy of a country (Henry & Litman, 2006). PT provides a cheap, convenient and rapid mobility service to function for the society (Das, Ladin, Ismail & Rahmat, 2013). The service that is provided by public transport was found to be affordable and highly reliable due to long term experience over decades (Stelzer, Englert, Hörold & Mayas, 2006). Public transport is also a better solution to reduce air pollution, traffic congestion and limited parking problems (Das, Ladin, Ismail & Rahmat, 2013). On the other hand, PT can pay to the three scopes of sustainable development, namely social, environmental and economic (Morton, Caulfield & Anable, 2016). Public transport users' in developed countries have flexibility to change their travel schedule including route and mode if they are dissatisfied with the existing service quality (Joewono, Tarigan & Susilo, 2016). People in the developing countries, such as Bangladesh, are less enthusiastic to use public transport since it provides poor quality service (Borhan, Ibrahim, Syamsunur, & Rahmat, 2019). Existing service condition provides an impression of uncertainty among users to change to more accessible and reliable modes of transport (e.g bicycle, motorcycle).

In general, service quality is defined as the overall assessment by customer toward performance of service provider (Lien, Wu, Chen & Wang, 2014). Service quality is a measurement of how well the service is provided according to consumer needs (Lai & Chen, 2011). Consequently, the service quality of public transport reflects the overall satisfaction level of public transport users respecting to the overall service provided by public transport authority. Many authors have supported the theory that 'customers are the sole judges of service quality' (Berry, Zeithaml & Parasuraman, 1990). Customer satisfaction refers to the overall evaluation of service quality in terms of the provided service met or exceeds their expectation or not (Lee, Lee, & Feick, 2001). Affording a high quality public transportation service that meets passengers' expectation and travel needs is important in creating a reliable, safe, attractive and comprehensive urban transport system. Hence, nowadays the importance of public transport service quality has been widely assessed by researchers or experts in the field of public transport. For example, Users' perception on public transport service quality was assessed by qualitative method (Beirão & Cabral, 2007). In addition, some researchers also focused on identification of the most significant elements of travel satisfaction of users' with public transport service quality (Abenoza, Cats & Susilo, 2017). Besides, Stradling, Anable & Carreno (2007) focused on service quality of public transport in their studies. The aim of this study is to explore public perception on rail transit service of Bangladesh.

In the past few years, several studies regarding the users' satisfaction and ways to improve service quality have been conducted worldwide. Several researchers suggested that strong efforts should be taken to improve comfort level and cleanliness (Dell'Olio, Ibeas & Cecin, 2011). Service quality could be significantly improved by performing combined management strategies of rail transit (Diab and El-Geneidy, 2012). The important criteria that influence the service quality of high-speed rail transit are the comfortable air conditioning, cleanliness of vehicles, employees' neat outlook, employees' service attitude and punctuality (Chou, Lu & Chang, 2014). Aydin, Celik & Gumus (2015) have used hierarchical framework to explore passenger satisfaction of rail transit service. The organizational forms do have an impact on the passenger satisfaction of public transport service (Zhang, Juan, Lu & Xiao, 2016). A systematic information integration method was used to improve the service quality of high speed rail stations by maximizing the capacity utilization of waiting room and minimizing the walking distance of passengers, which are closely related to achieving passenger satisfaction (Lai & Chen, 2011). Xiaoqiang, Lang & Jin (2017) found that attractive price is useful to improve customer satisfaction and expand ridership of rail transit service. Thus, a dynamic pricing method was proposed for passenger groups to appreciate passengers, thereby increasing the revenue. Farajpour, Kisomi & Bagheri (2017) used SERVQUAL and KANO methods to investigate the crucial factors that affect service quality and passenger satisfaction of rail transit. The study showed that

travel passes for passengers, modern fittings inside the train, on-time service, and staff's willingness are important to achieve the passenger satisfaction level and improve service quality.

3. METHODOLOGY

3.1 Data Collection

A comprehensive questionnaire survey was conducted face to face among the passengers at Kamalapur Railway Station situated in Dhaka which is the largest railway station in the country. It is one of the most important terminals for Dhaka and other parts of Bangladesh. The survey was conducted from 10th to 20th March 2017. The respondents were asked about 25 service attributes regarding their overall satisfaction on present condition of train service. To evaluate the rail service quality the passengers were asked to rate the service attributes according to their perception on a five point likert scale ranging from 1 to 5 (1, 2, 3, 4, 5 represents "Very Bad", "Bad", "Moderate", "Good", and "Very Good" respectively). Total 1037 respondents were interviewed by seven surveyors.

Table 1: General characteristics of respondents

Charateristics	Statistics
Gender	Male (74%), Female (26%)
Age	11~20 Years old (22%), 21~30 Years old (53%), 31~40 Years old (17%), 41~50 Years old (7%), 51~60 Years old (1%), >60 Years old (0%)
Occupation	Student (26%), Service Holder (29%), House Wife (7%), Worker (17%), Businessman (21%)
Reason of using intercity train	Captive rider (4%), Economical (11%), Comfortable (25%), Safer (57%), Others (3%)
Will choose alternative mode due to delay time	More than 1 hour (6%), More than 2 hours (22%), More than 3 hours (46%), More than 4 hours (18%), More than 5 hours (8%)

3.2 Data Analysis

Majority (34%) of the respondents said that they travel by train 1-2 times per 3-4 month while 30% respondents travel 1-2 times per six month and 18% respondents travel 2-4 times per month. Only 4% users travel 2 times per week as shown in Figure 1. About 31% trains delay 10-15 minutes while 11% trains delay15-20 minutes and only 19% trains provide service without any delay as shown in Figure 2.

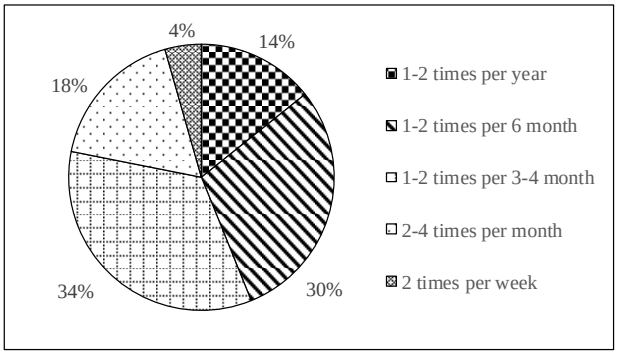

Figure 1: Frequency of travel

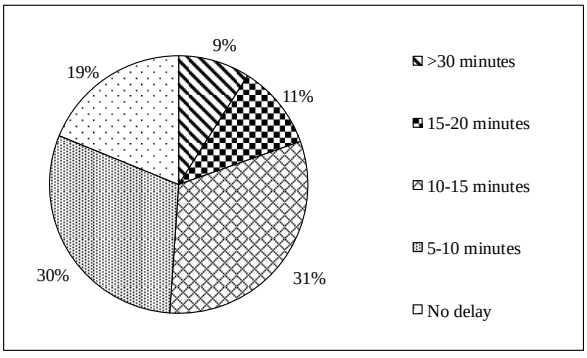

Figure 2: Delay occurred by train

Figure 3 shows a comparison between online ticketing system and counter ticketing system. More than half (56%) of the commuters said that online ticketing system is moderately preferable while 32% users replied that online ticketing system is preferable. Only 2% users answered that online ticketing system is not preferable. Majority (65%) of the respondents said that counter ticketing

system is moderately preferable while 17% users replied that it is preferable but not satisfactory. Only 4% users have found counter ticketing system as preferable and satisfactory.

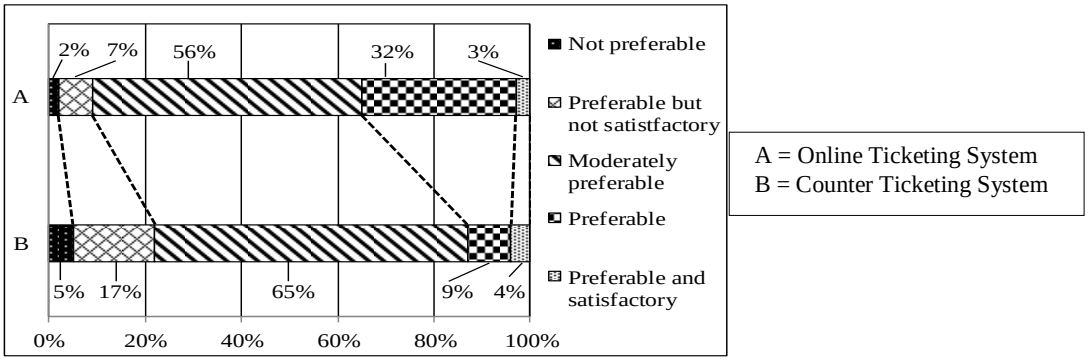

Figure 3: Comparison between online ticketing system and counter ticketing system

In case of ticket cost, majority (79%) of the passengers replied that ticket cost is fair while 16% users said that it is costly and 5% users said that it is cheap as shown in Figure 4. Figure 5 shows that 53% of the respondents have found first class ticket of train available to purchase in chair coach only. Among respondents, only 5% passenger didn't get any first-class ticket available to purchase at anywhere.

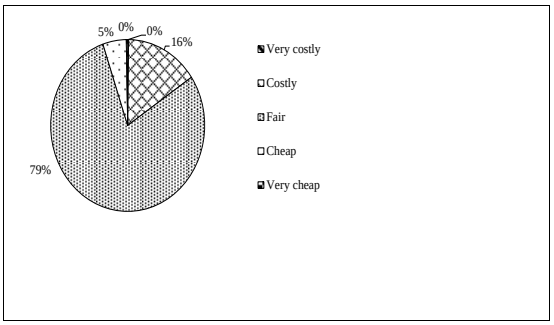

Figure 4: Ticket cost of train

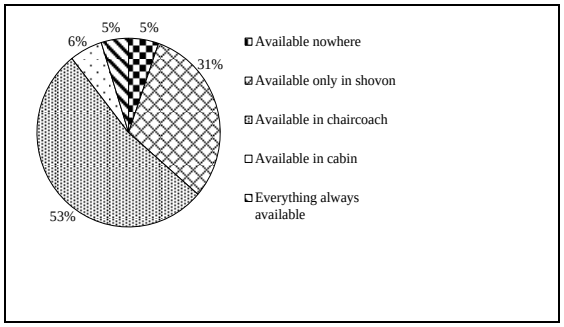

Figure 5: First class ticket availability of train

For 44% users, it takes 6-8 hours to reach their destination while 37% users reach their destination within 4-6 hours. In case of 4% users only, the travel time is 10-12 hours as shown in Figure 6. If trains' ticket is unavailable, majority (81%) of the passengers travel by bus as an alternative to train while 7% passengers travel by taxi or rent a car and another 7% travel by plane. Surprisingly 5% of the passengers cancel their trip which means they don't travel if trains' ticket is unavailable as shown in Figure 7.

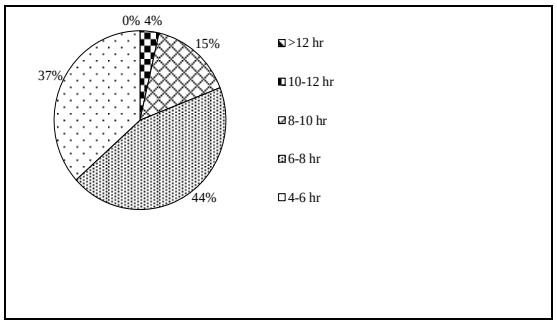

Figure 6: Time required to reach destination

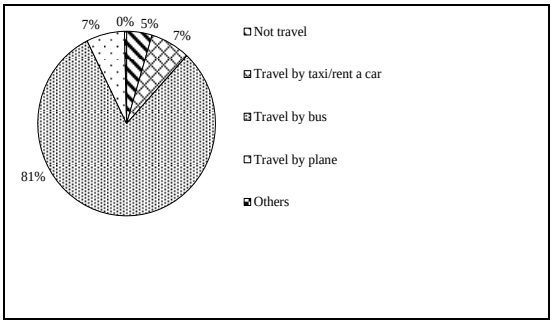

Figure 7: Alternative mode of transport if trains' ticket is unavailable

71% of the respondents said that compartment arrangement of train is moderate as it takes a little time to find out their desired compartment while 22% of the respondents said that it is good as they found compartments to be serially arranged as shown in Figure 8. Majority (73%) of the respondents replied that conditions of compartments are moderate while 19% said that it is good. Only 6% of the respondents experienced old and broken compartments; so they rated it as bad as shown in Figure 9.

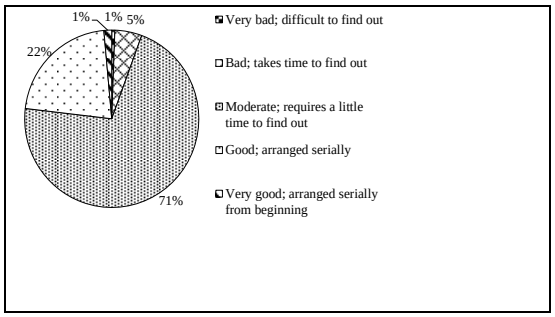

Figure 8: Compartment arrangement of train

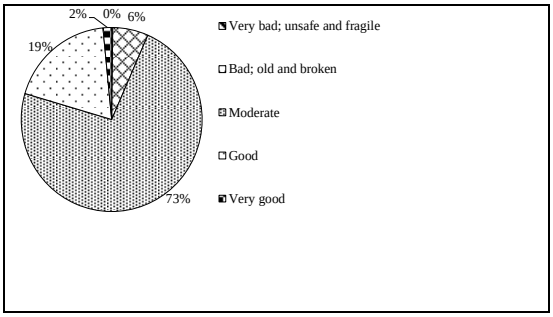

Figure 9: Condition of compartments

In case of comfort level in journey by train, majority (60%) of the respondents said that it is comfortable in chair coach while 16% said that it is comfortable in shovon. Only 1% replied that it is not comfortable to travel by train as shown in Figure 10. For 51% of the respondents, the noise level of train was tolerable. 14% of the respondents said that it was intolerable whereas 26% found less noise on train as shown in Figure 11.

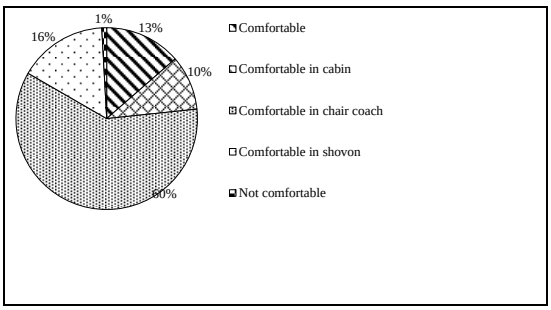

Figure 10: Comfort level in journey by train

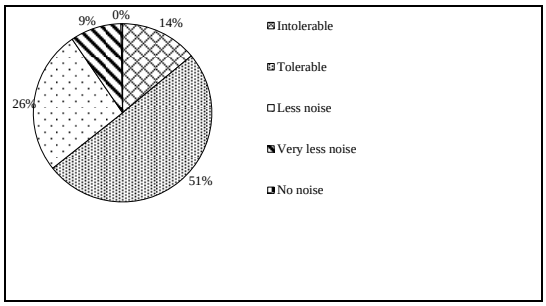

Figure 11: Noise level of train

Figure 12 shows that respondents are moderately satisfied with almost all of the service attributes. Respondents perceived that security inside the train (68%), air ventilation inside the train (60%), waiting place condition of railway station (61%), food facilities in train (67%), toilet facility for commuters (56%), behaviour of train's staff (58%) and cleanliness of train (66%) were moderate.

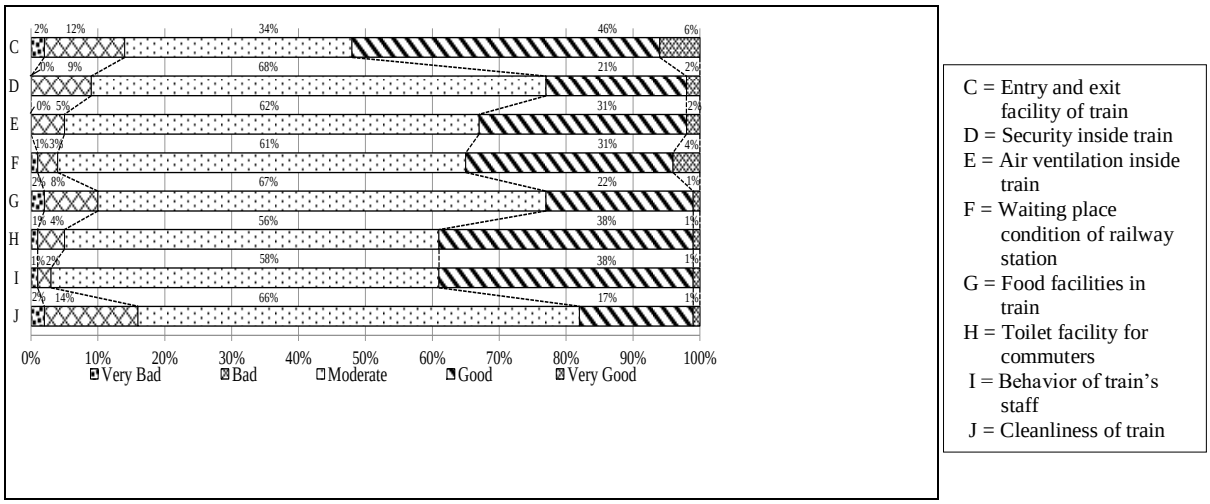

Figure 12: Users' perception about different service attributes

Entry and exit facility of train is the only attribute which has mostly been rated as "Good (46%)" among the service attributes shown in Figure 12. It reveals that respondents are much satisfied with the entry and exit facility of train. Also 38% respondents rated toilet facility for commuters and behaviour of train's staff as "Good".

More than half (56%) of the respondents said that sometimes people travel on trains' roof while 25% said that people travel once in a while as shown in Figure 13. Majority (60%) of the commuters said that females are harassed sometimes while only 4% said that females are regularly harassed and 9% commuters said that female harassment never occurs inside train as shown in Figure 14.

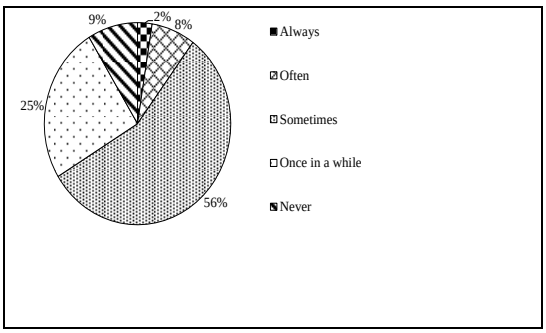

Figure 13: Frequency of traveling on trains' roof

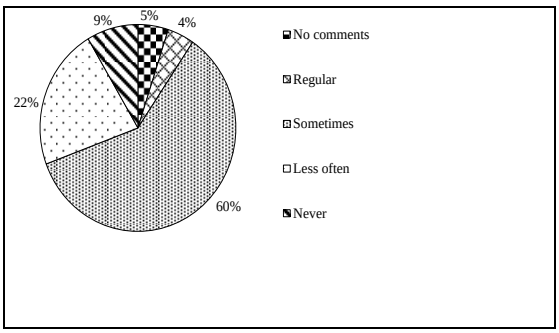

Figure 14: Female harassment inside train

Majority (71%) of the users expressed that necessary steps taken by government are not sufficient while 5% passengers said that no necessary step has been taken by government and 5% passengers had no idea about it. 16% passengers said that steps taken to improve service equality are sufficient but there is no implementation of these steps taken as shown in Figure 15. About 40% respondents agreed to pay (+100 BDT) extra money for quality development. Only 1% commuters agreed to pay more than (+500 BDT) for quality development as shown in Figure 16.

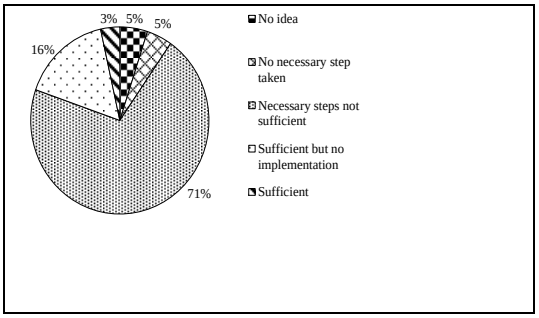

Figure 15: Adequacy of steps taken by government to improve service quality

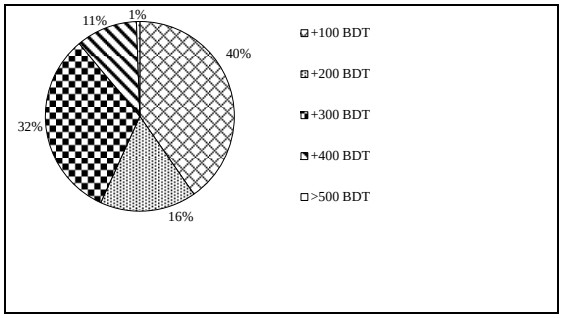

Figure 16: Willing to pay extra cost for quality developmentsufficient

Majority (67%) of the respondents are moderately satisfied with overall service quality of train in Bangladesh. 26% respondents said that the overall service quality is good and only 5% respondents said that overall service quality is bad as shown in Figure 17.

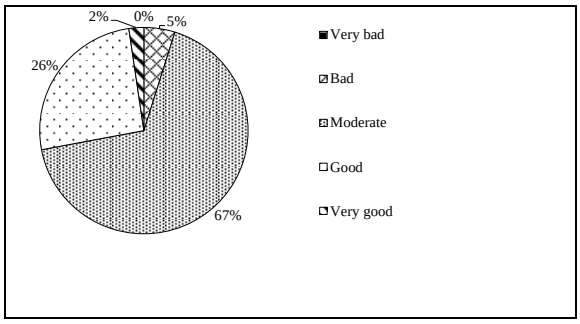

Figure 17: Overall service quality of train in Bangladesh

4. RESULTS

This study evaluates the overall service quality of train as a mode of transport in Bangladesh where 25 service attributes regarding train service quality were considered. Respondents from Kamalapur Railway Station were asked to give their opinion on these service attributes according to their perception of service. About 34% users travel 1-2 times per 3-4 month and 30% users travel 1-2 times per six month. Survey result indicates that about 31% train delay 10-15 minutes from the assigned time of departure. For 44% users it takes 6-8 hours and for 37% users it takes 4-6 hours to reach their destination respectively. 56% of the respondents said that online ticketing system is moderately preferable whereas 65% users said that counter ticketing system is moderately preferable for purchasing ticket. Majority (79%) of the users said that ticket cost of train is fair and 16% users said it is costly. 71% of the respondents said that compartment arrangement of train is moderate as it takes a little time to find their desired compartment. Majority (73%) of the respondents said that conditions of compartments are moderate. 60% users said it is comfortable to journey by train in chair coach. About 46% of users said entry and exit system of the train is good and 12% commuters said it is bad. Majority (68%) of the passengers said that security inside the train is moderate and 21% users said it is good. Majority (61%) of the users said that waiting place condition of railway station is moderate. 51% of the respondents said that noise level of train is tolerable. Majority (66%) of the users said that the cleanliness of train is moderate. So, overall research indicates that majority (67%) of the respondents are moderately satisfied with the service provided by train.

5. CONCLUSIONS

For a densely populated country like Bangladesh, train service can play a significant role in the field of transport by meeting increased mobility demand which will improve the overall transportation system of the country. Moreover, improved transportation system will contribute for overall development of the country. So, a transport system like train which is full of possibilities requires observation and improvement in service quality. This study explores passengers' perception on different service attributes as well as overall service quality of rail transit service of Bangladesh. The research result shows that, passengers are moderately satisfied with rail transit service of Bangladesh. The outcomes of this study offer significant comprehension for improving the train service quality currently being offered by BR and the aspects where greater attention is required. It is expected that the outcome of this research work will be beneficial for further improvement of rail transit service of Bangladesh. Moreover, this study can be utilized by BR to improve train's overall service quality. Though findings of this study offer prompting direction in assessing train service quality, some limitations are also acknowledged. Only one railway station (Kamalapur) in Bangladesh was selected to collect data for this research. More locations should be included in future for better result. The data has a gender bias. Only 26% of the participants were female as they were less enthusiastic in answering the questionnaire. So, more participation from women should be ensured in future. Further variation in samples as adding more variables and increasing the number of data may help to obtain better result.

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ASSESSING PEDESTRIAN SAFETY IN CONSIDERATION OF EXISTING PEDESTRIAN FACILITIES

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ABSTRACT

The population is growing at a fast rate in Dhaka city. To fulfill various purpose everyday a great number of trips are made by this continuously growing population. Generally every trip starts and ends up with a walk trip. So, the roads of Dhaka city are daily used by a considerable number of pedestrians along with vehicles. But pedestrians are among the most vulnerable of all the road users. In fact majority of the road accidents involve pedestrians. Hence ensuring safety of pedestrians and to improve the facilities has become a major concern. This paper aims to explore the existing pedestrian facilities and evaluate pedestrians' safety. An indistinct questionnaire survey was conducted at four major pedestrian generation locations in Dhaka city to 210 pedestrians. The questionnaire was divide in three major parts which represents the existing pedestrian facilities and pedestrians' safety. Findings from the survey indicate that existing pedestrian facilities are poor and safety measures for pedestrians are inadequate. According to 78% of the respondents the roads are unsafe for pedestrians. Also, people are unlikely to use pedestrian facilities due to presence of hawkers, inadequate facilities, vehicle parking on road and so on. The study also reveals that for ensuring pedestrian safety improvement of traffic rule is required alongside with the improvement of footpath. The outcomes of this study can be utilized by the city officials to ensure safety of pedestrians through improving the existing pedestrian facilities.

Keywords: *Dhaka city, pedestrian safety, existing facility*

1. INTRODUCTION

Dhaka, the capital of Bangladesh has turned into a megacity due to rapid growth of population and urbanization. Because of being the economical centre of the country and continuous development, it has now become one of the most densely populated cities in the world having a population of 41000 per square kilometer (Demographia, 2019). Moreover, Dhaka is one of the busiest cities in the world. Current road capacity of Dhaka is failing to support the increased number of vehicles. Therefore, the city is heavily suffering from traffic congestion which is spoiling passengers' valuable time. So, in purpose of saving both time and money, people tend to walk to nearby destination. But the existing pedestrian facilities are inadequate and unsatisfactory. Although Dhaka is developing day by day but the facilities for pedestrians are not improving up to that extent. In fact, the facilities for pedestrians are overlooked here. Pedestrian safety is a major concern in Dhaka city due to poor facilities provided to pedestrians. Due to poor safety, pedestrians are at considerable risk compared to all other road users. Usually pedestrians face great risk of road accident. The fatality rate in Bangladesh due to road accident is very high compared to other developed countries. Every year 85 deaths occur against per ten thousand registered motor vehicles in Bangladesh whereas in other developed countries the number of registered motor vehicles is much higher but the death rate is below 5. Among the total road accidents, 50% of the accident involves pedestrians (NRSSAP, 2011). In order to avoid accident risks, adequate safety should be provided to pedestrians through improving pedestrian facilities.

For a long time, transportation planners and engineers haven't paid concern to the non-motorized transportation system. Even in present time, the motorized transportation system is getting enormous importance compared to the systems that serve the needs of non-motorized users likewise pedestrians and bicyclists. Due to increase in motor vehicle growth, most attention is given for traffic regulation of motor vehicles only and the pedestrian regulation is totally neglected. But the accident rate of pedestrians shows that it is necessary to give importance to non-motorized transportation system. An important consideration is required for non-motorized modes of transportation by provision of suitably designed walkways, crosswalks, sidewalks and so on (Kadali and Vedagiri, 2016). Requirements of all users should be considered by planners, designers, and policy makers so that it can be used by pedestrians and those with disabilities to move along or cross a roadway.

In spite of being an important issue pedestrian facility have always been neglected. It is urgently required to asses and improve existing pedestrian facilities in Dhaka to make the city pedestrian friendly and livable.

2. LITERATURE REVIEW

Walking is regarded as one of the ancient non-motorized mode of transport. Prior to the invention of any means of transport people used to travel by walking. According to Leong (2011), a pedestrian is someone who travels by walking and each pedestrian is an integrated part of road space. The likelihood of walking greatly depends upon the quality of the walkway (Jaskiewicz, 2000; Southworth, 2005; Xi and Son, 2012). Therefore, quality of pedestrian facilities directly influences pedestrians.

Safety is a great concern for pedestrians as they are usually vulnerable to accident risks, difficult weathers, thieves and others which discourage pedestrians to travel a considerable distance by walking. Unsafe facility causes conflict between the vehicles on the runway and the pedestrians, between pedestrians on footpath or roadway and between roadside development and parked vehicles (Laxman, Rastogi & Chandra, 2010). Therefore, unsafe facility is resulting in accidents. All over the world traffic accidents that involve cyclist and pedestrians have become a serious safety issue (Mei, Xiaobao & Bin, 2013). A developing country having a large population often faces problem associated with pedestrians as they often become a cause of traffic congestion and traffic accidents. In order to avoid these pedestrian emerged problems several facilities are offered to assist pedestrian to

cross road safely. People tend to use pedestrian facilities more frequently if adequate facilities are provided to them. Proper facilities like crossing, sidewalk etc. ensures pedestrian safety by separating pedestrians from motor vehicles temporally.

Sidewalk is one of the useful facilities offered to pedestrians as it ensures comfortable movement of pedestrians parallel to the vehicle traffic. According to Asadi-Shekari, Moeinaddini, & Zaly Shah (2012), sidewalks should be designed in order to serve all type of users like children, adolescent, adult, elderly people and people with disabilities. Sidewalks need to serve different type of users according to their needs with an appropriate environment which guarantees safety and comfort regardless of users' physical restriction (Khisty, 1994; Rakesh, 2010). Therefore, considering all types of pedestrians, assessment of existing pedestrian facilities should be done.

A guideline for pedestrian facilities (Indian Roads Congress, IRC: 103-1988) specifies the importance of crosswalk for pedestrian at all essential intersections and at places where possibility of conflict exists between vehicles and pedestrians. It shows that footpaths should be at right angles to the runway wherever possible and should be properly marked so that the risk of accidents involving pedestrians can be minimized. Also, sidewalks or crosswalks should not increase walking distance for pedestrians. Adequately visible roadway, obstruction free and adequate waiting space are important prerequisites for determining the position of crosswalks according to IRC.

Pedestrians' road crossing behaviour is correlated to human behaviour factors. If adequate requirements are not met pedestrians may illegally cross road rather than utilizing crossing facilities. Environmental designs and urban forms can easily influence the complicated behaviour of pedestrians of different purpose. A proper design of facility can influence walking without damaging safety and convenience (Gue et al., 2014; Elvik, Sørensen & Nævestad, 2013). The main external factor that leads to unsafe crossing is waiting time and crossing distance. According to Kadali and Vedagiri (2013), lack of time forces pedestrians to cross the road without considering safety. Due to urgency people try to keep moving along the shortcut which is unethical. Further, the deficiency of implementation of traffic rules influences pedestrians and affects the quality of facilities offered to pedestrians in developing countries. Moreover, roadway characteristics such as road width, ramps, continuity, height, curb, median height, median width, median opening width, barricades at sidewalks and marks of zebra crossing at crosswalk locations are not designed considering the necessities of the minority having physical disabilities which is another reason behind not using offered facilities by pedestrians (Kadali and Vedagiri, 2016).

Different studies have been done by different researchers all around the world related to pedestrian. A study be Muraleetharan, Adachi, Hagiwara & Kagaya (2005) defined the factors which affects pedestrian level of service at intersections. The study also proposed an estimation method for measuring pedestrian level of service at intersections. The study concluded that turning vehicle has larger influence on pedestrian level of service than other factors. Also, factor like waiting at signals has been found to be significant factor in determining pedestrian level of service at intersections. In order to find factors influencing pedestrians' road crossing behaviour, several models has been developed by researchers. Yannis, Papadimitriou & Theofilatos (2013) developed a binary logit model and a log normal regression for mid-block street crossings in urban areas. The study examined pedestrian gap acceptance and making of decision process to cross the street. In a divided mid-block crossing Kadali et al. (2014) examined the pedestrian gap acceptance behaviour using an artificial neural network model to understand the process of decision making. The results from the study were pedestrian speed condition, pedestrian rolling gap, vehicular gap size, frequency of attempt and vehicle speed had major role in pedestrian gap acceptance. A study by Pervaz and Newaz (2016) showed that illegally occupied footpath by hawkers, illegal on-street parking, garbage stock on road side, lack of authorized bus stops, violation of crosswalk rule by vehicles are hampering pedestrian facilities greatly. Also, ineffective pedestrian crossing control devices, competition among drivers, absence of footpath barrier are raising safety concern among pedestrians.

According to Nelson & Zaly Shah (2010), pedestrian facilities are greatly neglected in urban transportation planning though it is undoubtedly important for pedestrians. For ensuring pedestrian safety it is required to pay attention to pedestrian facilities to improve and provide adequate facilities.

3. METHODOLOGY

3.1 Data Collection

A distinctive face to face questionnaire survey was conducted at four major parts of Dhaka city for data collection. The survey locations were Farmgate, New-market/ Science laboratory, Mirpur-10 and Gulistan. Locations were selected on the basis of number of pedestrian generations. Due to high pedestrian generation these locations were suitable to identify the existing condition of pedestrian facilities and safety measures. Data collection was conducted by 4 surveyors at two peak period during a day from 8:00 to 10:00 and 16:30 to 18:30 hours from August 11 to August 12, 2016. The questionnaire was prepared based on pedestrians' facility and safety. It consisted of three main parts where first part was about personal information of the respondent; second part was about existing facilities for pedestrians and the final part was about probable improvement areas for improving pedestrian facilities. Among total collected 210 samples, 200 samples have been considered for analysis. Rest of the samples have been ruled out due to incompleteness.

3.2 Data Analysis

Figure 1 shows that majority (42%) of the respondents are student while 22% respondents are office workers. 14% of the respondents are from various profession rather than the defined occupation here. Respectively 9%, 8% and 5% respondents are labours, housewife and garments employee. Respondents from all these professions shown in figure 1 have provided their opinion about the road safety for pedestrians as shown in figure 2. Majority (78%) of the respondents said that the roads are unsafe for pedestrians where 19% of the respondents found the roads sometimes safe and sometimes unsafe. Only 3% of the respondents said that the roads are safe for pedestrians.

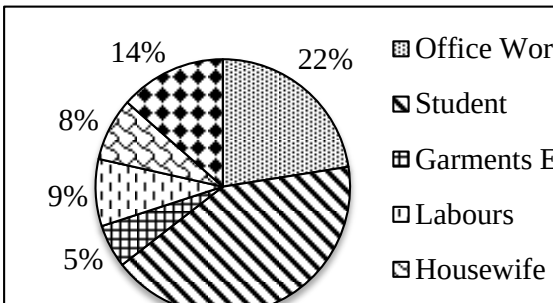

Figure 1: Occupation

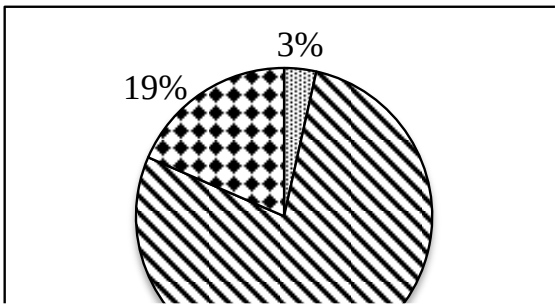

Figure 2: Road safety for pedestrians

Respondents who claimed that the roads are unsafe for pedestrians have mentioned same reasons due to which the roads seemed unsafe to them. Majority (39%) of the respondents have said that lack of pedestrian safety makes the road unsafe for pedestrians. Also, 32% and 22% of the respondents have accused "no application of traffic rules" and "uncontrolled traffic system" as the main reason behind the roads being not safe for pedestrians as shown in figure 3. Among the respondents only one-fourth (25%) uses footpath where 28% of the respondents uses footpath irregularly. Almost half (47%) of the respondents don't use footpath as shown in figure 4.

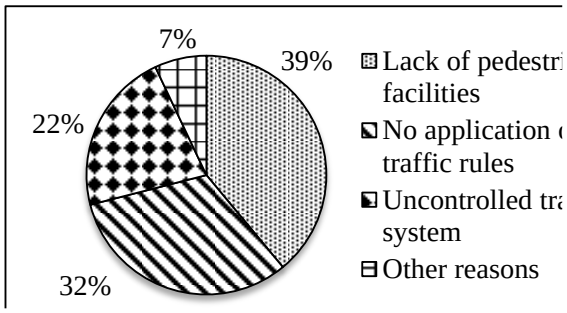

Figure 3: Reasons of roads being unsafe

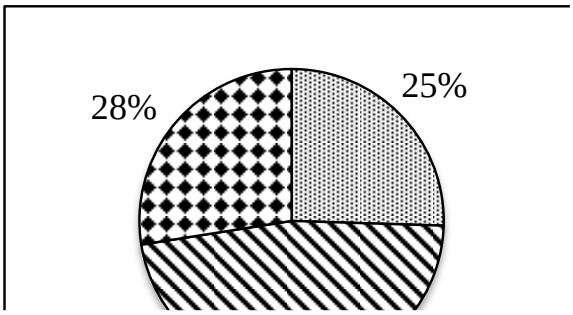

Figure 4: Users' response on using footpath

Majority (38%) of the respondents have said that they don't use footpath because of hawkers which makes walking in the footpath difficult. Also, 15% of the respondents don't use footpath due to its discontinuity where another 15% of the respondents are reluctant to use footpath due to insufficient space for walking as shown in figure 5. Figure 6 shows that more than half (67%) of the respondents don't use zebra crossing. Only 12% of the respondents abide by the law as they use zebra crossing for crossing the road.

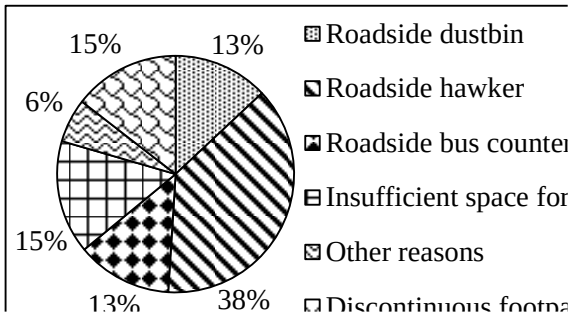

Figure 5: Reasons of not using footpath

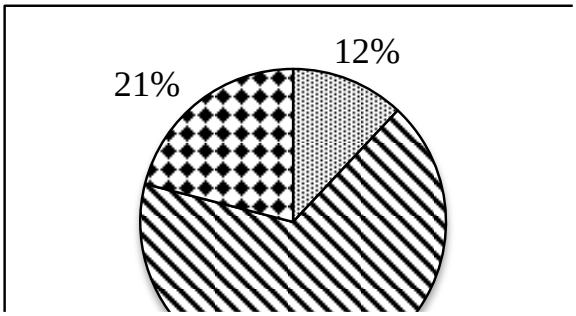

Figure 6: Users' response on using zebra crossing

Majority (35%) of the respondents claimed that it is difficult to understand the position of zebra crossing due to its faded colour while 22% of the respondents said that vehicles do not abide by the rules of zebra crossing which influences them to not use zebra crossing as shown in figure 7. Among different facilities provided for pedestrians, foot over bridge is the mostly used one. 37% of the respondents use foot over bridge to cross roads but majority (44%) of the respondents don't use foot over bridge. Yet, 19% of the respondents use foot over bridge sometimes as shown in figure 8.

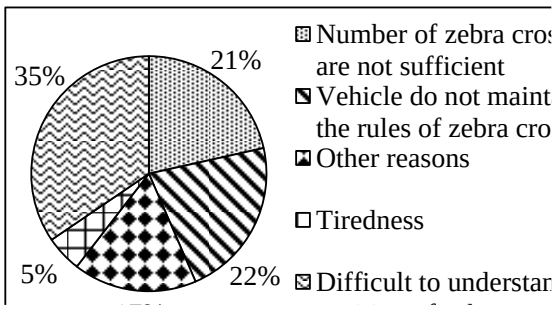

Figure 7: Reasons of not using zebra crossing

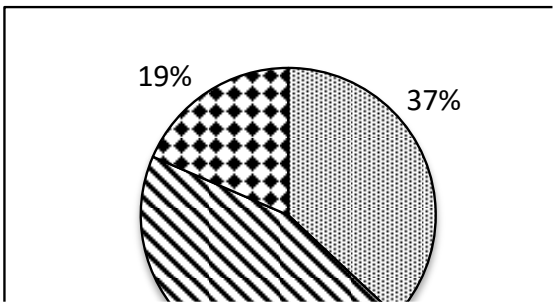

Figure 8: Users' response on using foot over bridge

More than half (51%) of the respondents avoid foot over bridge as climbing the stairs of foot over bridge makes them tired. Also, 8% of the respondents have claimed that due to lack of time they avoid foot over bridge as shown in figure 9. Roadside parking is another fact that is hampering pedestrian facilities. Majority (97%) of the respondents agreed that road side parking hampers pedestrian facilities while 2% of the respondents said that road side parking don't create problem for pedestrians.

Only 1% of the respondents said that sometimes road side parking hampers pedestrian facilities as shown in figure 10.

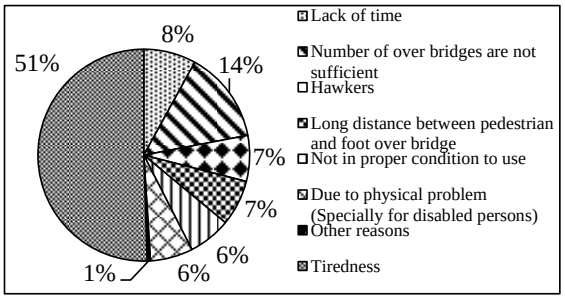

Figure 9: Reasons of not using foot over bridge

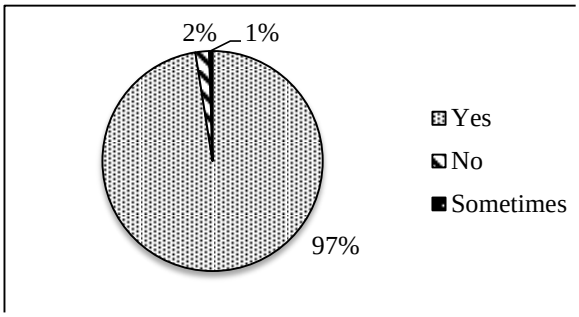

Figure 10: Road side parking hampering pedestrian facilities

But the thing that mostly annoys people and disturbs normal movement of pedestrians is motor bike riding on footpath. Figure 11 show that almost all of the respondents (99%) agreed that riding of motor bike on footpath disturbs pedestrians' normal movement. Only 1% said that motor bike rides on footpath and disturbs normal movement of pedestrians sometimes but none was found to deny this fact. 78% of the respondents said that unplanned water drainage system is causing pedestrians' movement problem as shown in figure 12. 22% of the respondents said it causes problem to pedestrians' sometimes. Also, none was found to decline this reason as a problem creator for pedestrians.

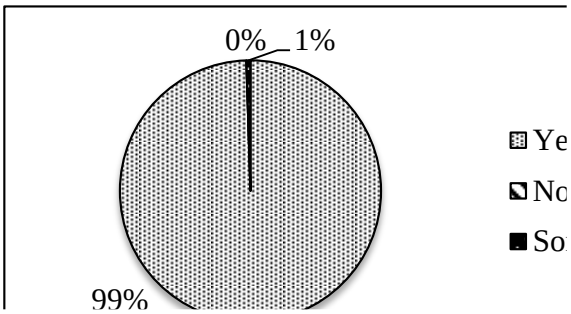

Figure 11: Motor bike riding on footpath disturbing pedestrians' normal movement

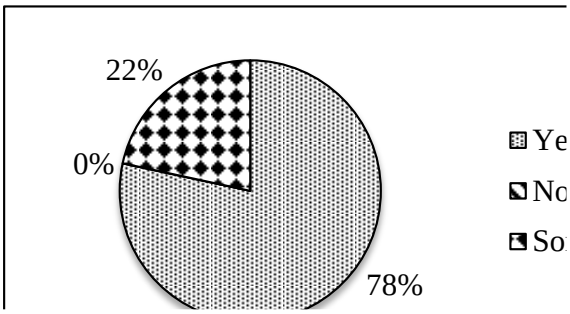

Figure 12: Unplanned water drainage system causing problem for pedestrians

Cutting and filling process on road is a common scenario in Dhaka. This process of cutting and filling greatly hampers pedestrian facilities. Majority (74%) of the respondents agreed that cutting and filling process on road disturbs pedestrian facilities where 25% respondents said that it hampers pedestrian facilities sometimes as shown in figure 13. Only 1% respondents said that it doesn't create trouble for pedestrians. Speed hump, a traffic calming device used to slow down the speed of motorized vehicle is available in the roads of Dhaka city. In reply asking of how much effective it is in case of providing safety to the pedestrians, majority (67%) of the respondents said that it is effective. In the meantime, 9% of the respondents said it doesn't ensure safety to pedestrians therefore it is ineffective. Also, 24% of the respondents said it works well sometimes as shown in figure 14.

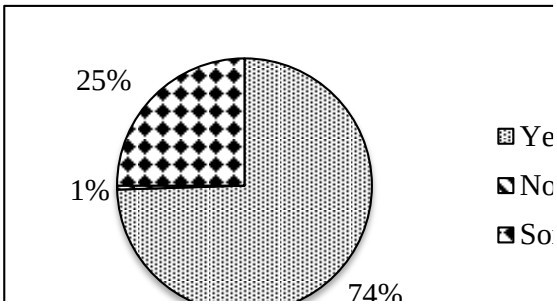

Figure 13: Cutting and filling process on road hampering pedestrian facilities

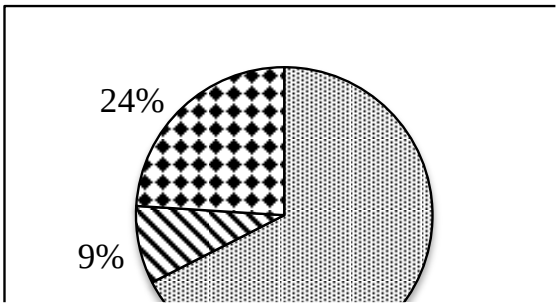

Figure 14: Effectiveness of speed hump on road for pedestrians' safety

Based on respondent's perception the level of existing pedestrian facilities has been shown in figure 15. Majority of the respondents (65%) rated existing pedestrian facilities as "Poor" while 16% of the respondents rated it as "Very Poor". 14% of the respondents rated the facilities as "Satisfactory" and only 5% respondents said the facilities are "Good". None rated the level of pedestrian facilities as "Very Good". Figure 16 shows the willingness of the respondents to use pedestrian facilities if the facilities are improved. Majority (98%) of the respondents agreed that they will use the facilities but 2% of the respondents said that they won't use the facilities yet the facilities are improved.

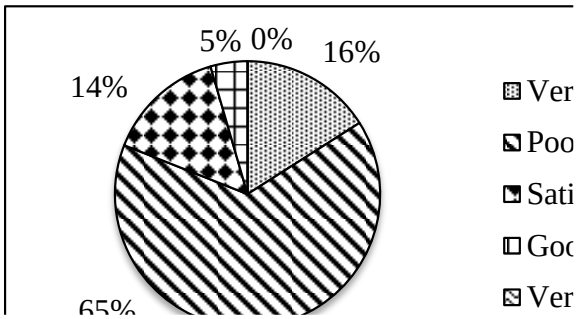

Figure 15: Level of existing pedestrian facilities

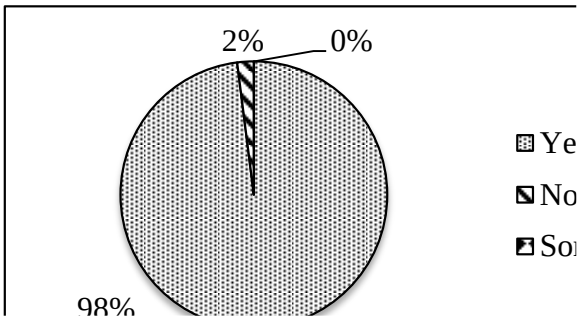

Figure 16: Willingness to use pedestrian facilities if improved

To ensure pedestrians' safety respondents were asked to provide their opinion at where they want improvements. Figure 17 shows that majority (31%) of the respondents want improvement of traffic rules where 25% of the respondents' first demand is proper footpath. Also, 19% respondents said that properly controlling traffic will improve pedestrian facilities and ensure pedestrian safety.

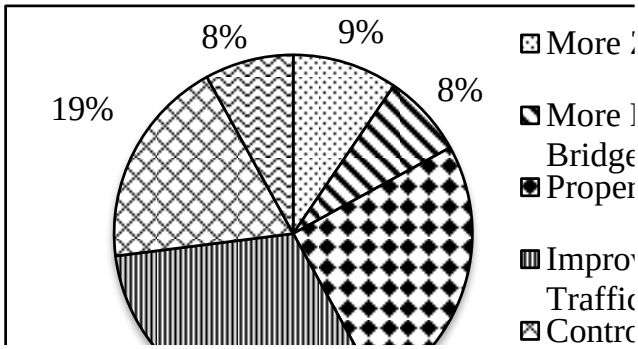

Figure 17: Required improvements or facilities to ensure pedestrian safety

4. RESULTS

This study evaluates pedestrians' safety considering available pedestrian facilities in Dhaka city. By occupation, majority (42%) of the respondents are student and office worker (22%). It indicates more

than half of the total pedestrian number consists of students and office workers together. Considering road safety 78% of the respondents have said that the roads in Dhaka are unsafe where only 3% respondents found the roads to be safe. 39% of the respondents said that lack of pedestrian facilities is making the roads unsafe for pedestrians. Mainly inadequate and inefficient foot over bridge, zebra crossing and footpath is resulting in poor pedestrian facilities. Respondents' are unlikely to use the existing poor pedestrian facilities as 67% of the respondents don't use zebra crossing; 44% respondents don't use foot over bridge and 47% respondents don't use footpath. Major reasons behind not using footpaths are presence of hawkers on footpath; insufficient space and discontinuous footpath which influence people to avoid using footpaths. Non-appearance of zebra crossing due to faded colour, not maintaining the rules of zebra crossing by vehicles and inadequate numbers of zebra crossing are the major problems associated with the use of zebra crossing which are driving people to avoid using it regularly. People tend to avoid using foot over bridge due tiredness of climbing foot over bridge, outnumbered foot over bridges compared to demand and lack of time. Also, pedestrian facilities are greatly hampered by some unexpected and illegal incidents such as road side parking, motor bike riding on footpath and so on. 97% respondents agreed that illegal road side parking hampers pedestrian facilities. Also, almost all (99%) of the respondents agreed that motor bike riding on footpath greatly disturbs pedestrians' normal movement. Not only these illegal and unexpected incidents are hampering pedestrian facilities but also some activities done by the city officials are disturbing normal movement of pedestrians. Cutting and filling process on road is a common scenario in Dhaka city which is greatly disturbing the pedestrian facilities as 74% of the respondents have said that it is creating trouble for pedestrians. Also, 78% of the respondents have said that unplanned water drainage system is causing problem for pedestrians. Considering pedestrians safety, many speed humps have been installed throughout the roads in Dhaka city. 67% of the respondents agreed that speed humps are effective in ensuring pedestrian safety where 9% of the respondents have said that speed humps are ineffective in this case. Considering all the existing facilities for pedestrians, majority (65%) of the respondents have rated the level of existing pedestrian facilities as "Poor" while 16% of the respondents have rated it as "Very Poor". Due to poor facilities provided to pedestrians, people are unwilling to use the existing facilities. But 98% of the respondents have agreed that they are willing to use these facilities if they are improved. For ensuring pedestrian safety majority (31%) of the respondents have said that they want the traffic rules to be improved first. Also, 25% of the respondents demanded proper footpath while 19% of the respondents demanded controlled traffic system to ensure pedestrian safety.

5. CONCLUSIONS

Poor pedestrian facilities are the main reasons behind not using the facilities by pedestrians. Therefore, it is important to improve the existing facilities to ensure pedestrians safety. Proper footpath should be designed and constructed to improve pedestrian facilities. Also, it should be assured that the footpaths are hawker free so people get enough space to use it comfortably. At the same time traffic rules should be improved and strictly enforced which will certainly improve the traffic condition on road and will facilitate the movement of pedestrians. Road side parking and motor bike riding on footpath should be strictly handled as it hampers pedestrian facilities. City officials should pay attention to improve pedestrian facilities by properly planning an effective and long-lasting drainage system. Not only in drainage system but also at every possible aspect the city officials should come up with proper planning to reduce harassing the pedestrians as continuous unplanned cutting and filling process on road disturbs pedestrian facilities. Also, awareness should be raised among pedestrians to use pedestrian facilities and abide by the traffic law.

Findings from this study may help the city officials on understanding the existing pedestrian facilities and decide the improvement sectors. Improving pedestrian facilities will not only ensure pedestrian safety but also will encourage people to use pedestrian facilities regularly. For further study, including more variables, increasing the number of samples and adding more survey locations may help to achieve better and precise result which will help the city officials in taking future decisions.

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PERFORMANCE EVALUATION OF WASTE TILES IN FLEXIBLE PAVEMENT CONSTRUCTION

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ABSTRACT

Huge vloume of tiles dust are produced from building construction and ceramic industries. Basically Waste Tiles Aggregates (WTA) are being produced by crushing ceramic tiles during the process of transport and installation of roof, wall and floor. Present society are progressively moving forward to be more environment friendly. To meet up this purposes, recycling and reuse of this waste material can be the best alternatives than landfill disposal in respect of environment conservation and economy. To increase the usage of wastes tiles in pavement construction, different percentage of wastes tiles can be used with the natural aggreegate. The technical feasibility of using waste tiles aggregates as partial replacement of natural aggregates in bituminous mixes can be evaluated. This research work presents some of the laboratory investigation on the possible application of waste tiles aggregates in bituminous mixes. The physical properties of coarse aggregates, fine aggregates, filler and bitumen are determined according to standard test. Marshall test specimens are prepared for testing to measuere the Marshall properties. Three specimens are prepared with bitumen content 4.5%. For Mix Type A, black stone chips, coarse sand and stone dust filler are used. Mix Type B is preared by black stone chips with some percentage of WTA, coarse sand and stone dust filler and Mix Type C is prepared by black stone chips with some percentage of WTA, fine waste tiles and stone dust filler. Five bitumen content are used with increment of 0.5% for Mix Type A, B and C. The strength properties are measuered for both coarse and fine aggregates produced from waste tiles. Marshall stability value 13.0 kN, 12.9 kN and 13.4 kN at optimum bitumen content 5.65%, 5.70% and 5.80% for Mix Type A, B and C respectively are determined. Acording to AASHTO, Marshall stability test properties of mixes of waste tiles aggregates are satisfactory. The required bitumen content is higher for mix type C and it is 1.02 times of mix type A. Mix type B needs comparitively less amount of bitumen than mix type C and it is 1.04 times of mix type A. The investigated results indicate that the bituminous mixes with waste tiles aggregates give satisfactory results for construction of medium traffic road.

Keywords: *Waste Tiles Aggregates, Marshall Mix Design, Flexible Pavement Construction.*

1. INTRODUCTION

The recycling of waste aggregates has long been recognized to have the potential to conserve the natural resources and to reduce energy used in production. It is a standard alternative for both construction and maintenance, practically where there is a shortage of aggregate. Generally, the term 'waste aggregate' refers to aggregates that have been used previously in construction which comprise construction and demolition waste, deteriorated asphalt pavement material, used railway ballast and so on. Ceramic materials, which include ceramic tiles and other ceramic products, contribute one of the highest content of wastes in the construction and demolition wastes. Actually, ceramic tile, being one of the most widely used construction materials, having its consumption rising with the growth of population and urbanization in many countries. Not only for walls and flooring in the buildings but also in many kinds of industrial and commercial structures, we use them in decoration, protection, or other improvement applications. During the process of wide range of manufacturing, transport and installation, a large number of tiles wastes are generated in an increasing amount day by day. However, with the large number of wastes comprising ceramic tiles and assured increase of it in the future, land filling has also become a major problem, particularly in countries where land is scarce. So apart from putting more effort in minimizing its generation and the setting up of temporary fill banks, recycle is one of the most effective means to alleviate the growing problem. On the other hand, many highway agencies, service providers, private organizations and individuals have completed or are in the process of completing a wide variety of studies and research projects concerning the feasibility, environmental suitability and performance of using recycled products in highway construction. The ever-increasing economic cost and lack of availability of natural material have opened the opportunity to explore locally available waste materials like waste tiles. Thus, recycling has been gaining wider attention as a variable option for the handling of waste tiles. As per the studies, recycled aggregate utilization from the ceramic industry wastes was largely considered in road construction as: landfills, sub-base courses on low volume roads, concrete blocks and manufacture of concrete (Koyuncu H. *et al.*, 2004, Huang B. *et al.*, 2009). Krüger and Solas., (2008) investigated the use of sanitary ceramic wastes as recycled aggregates for road surface courses. High whiteness and hardness of recycled aggregates from sanitary ceramic wastes improved sunlight reflection, avoiding heating during summer months and increased pavement stability, further improving the visual contrast in the roadway. Silvestre *et. al.*, (2013) reclaimed that recycled ceramic wastes are considered technically feasible to be incorporated as aggregates into asphalt concrete mixtures for open graded wearing courses. The mixture with 30% of recycled ceramic aggregates by aggregates weight meet most of the mechanical and superficial characteristics to be used as road surface layer for medium–low traffic volumes, with exception of water sensibility. In this study, investigation and experiments were performed to attain and compare the physical properties of stone aggregates and waste tiles aggregates primarily. Thus, the behaviour of bituminous mixes with respect to stone aggregates and waste tiles aggregate was evaluated to suggest a design criterion for the construction of flexible pavements with waste tiles aggregate.

2. MATERIALS AND METHODOLOGY

Two types of coarse aggregates were used in this study which consist of black stone chips to the size of 19 mm and less were collected from the construction site of Architecture Building of Rajshahi University of Engineering and Technology (RUET), Rajshahi, Bangladesh. Waste tiles were obtained from different waste disposal sites of Rajshahi, Bangladesh. Tiles pieces were crushed manually to bring the size of 12.5 mm and down grade as coarse aggregates.

Figure 1 and Figure 2 indicate the appearances of these two types of coarse aggregates respectively.

Figure 1: Appearance of Stone Aggregate

Figure 2: Appearance of Waste Tiles Aggregate

Coarse sand, collected from Domar, Panchagar, passing through 2.36 mm sieve and retained on 0.075 mm sieve was used as fine aggregate. Particles of waste tiles were obtained after collection of tiles pieces from different waste disposal sites of Rajshahi, Bangladesh. They were crushed manually to bring the size of 2.36 mm and retained on 0.075 mm sieve as fine aggregate. Stone dust finer than 0.075 mm (No.200) was used as filler in all bituminous mixes. The appearances of two types of fine aggregates are shown in Figure 3 and Figure 4 respectively.

Figure 3: Appearance of Coarse Sand

Figure 4: Appearance of Fine Aggregate from Waste Tiles

Bitumen used in this study was of 60-80 penetration grade asphalt collected from Eastern refinery, Chittagong. This was used for all the mixes so that the type and grade of binder would be constant.
The engineering properties of materials were determined according to the procedure specified by AASHTO, ASTM and BS standards. In order to study the effect of aggregates on the behavior of bituminous mixes, Marshall Test specimens were prepared for three types of aggregate mixes with 50 blows for medium traffic road according to the standard procedure specified by AASHTO.

2.1 Physical Properties of Aggregates

Table 1: Properties of Coarse Aggregates

Properties	Methods (AASHTO/BS)	Coarse Aggregates	
		Crushed Stone	Waste Tiles
Unit weight(loose), kg/m^3	T19	1520	1230
Unit weight(dense), kg/m^3	T19	1610	1240
Bulk specific gravity	T85	2.63	2.35
Apparent specific gravity	T85	2.78	2.43
Absorption of water, percent	T85	0.7	1.20
Abrasion(Grade-B),percent	T96	12	19
Soundness(Na_2SO_4),percent	T104	3	7
AIV, percent	BS812	8	16
ACV, percent	BS812	11	23
Ten percent fines value, kN	BS812	300	120
Flakiness Index, percent	BS812	12	15

Table 2: Properties of Fine Aggregates and Filler

Properties	Methods (AASHTO)	Fine Aggregates		Filler	
		Coarse sand	Waste Tiles	Stones Dust	Tiles Dust
Unit weight(loose),kg/m^3	T19	1440	1230	1160	1170
Unit weight(dense),kg/m^3	T19	1570	1350	1300	1347
Bulk specific gravity	T85	2.461	2.530	--	--
Apparent specific gravity	T85	2.647	2.960	2.513	2.642
Absorption of water	T85	3.125	2.327	--	--

2.2 Bituminous Mix Design

In order to study the effect of aggregates on the behavior of bituminous mixes, Marshall Test specimens were prepared with 50 blows for medium traffic road according to the standard procedure specified by AASHTO. Three types of mixes were studied and these were designated as mix types A, B and C.

Mix Type A : consists of black stone chips as CA, coarse sand as FA and stone dust filler
Mix Type B : consists of black stone chips, partially replaced by 35% WTA(9.5mm down grade) as CA,coarse sand as FA and stone dust filler
Mix Type C : consists of black stone chips, partially replaced by with 35% WTA(9.5mm down grade) as CA, fine waste tiles as FA and stone dust filler

2.3 Marshall Mix Properties

The maximum load carried by a compacted specimen at a standard test temperature of 60°C can be defined as Marshall Stability of a mix. The deformation of the Marshall Test specimen that undergoes during the loading upto the maximum load in 0.25 mm units is called the flow value. Marshall properties like stability, flow value, unit weight, total voids in a mix, voids in mineral aggregates and voids filled with bitumen were determined for three mix types. The graphs were plotted for bitumen content with respect to Marshall Stability, unit weight and air voids. The bitumen content corresponding to maximum stability, maximum unit weight and 4% air voids were obtained from these graphs. The average value of bitumen content obtained from the 3 plotted graphs is treated as the optimum bitumen content (OBC). The graphical representations of Marshall Test Properties are illustrated as follows.

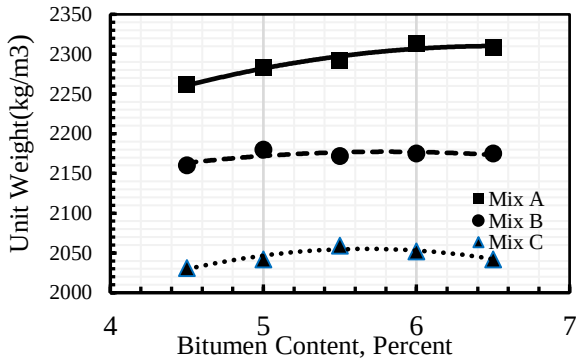

Figure 5: Relationship between Unit Weight and Bitumen Content for Mix Type A, B and C

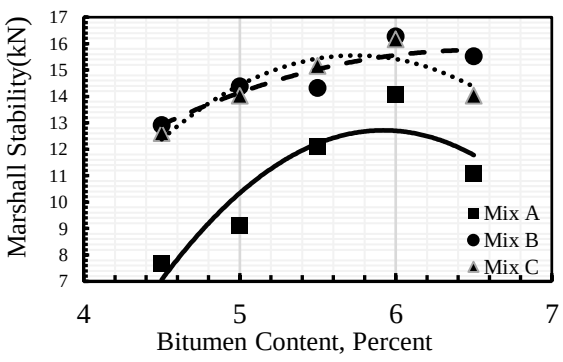

Figure 6: Relationship between Marshall Stability and Bitumen Content for Mix Type A, B and C

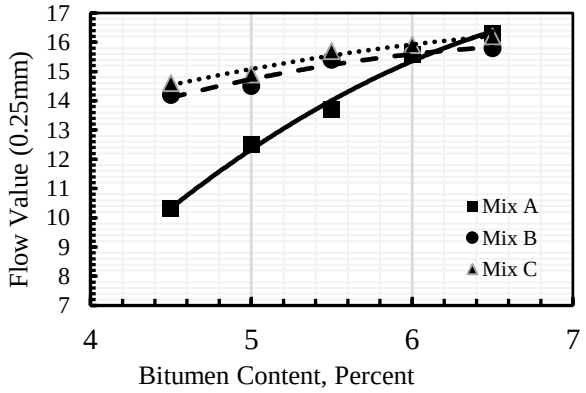

Figure 7: Relationship between Flow Value with and Bitumen Content for Mix Type A, B and C

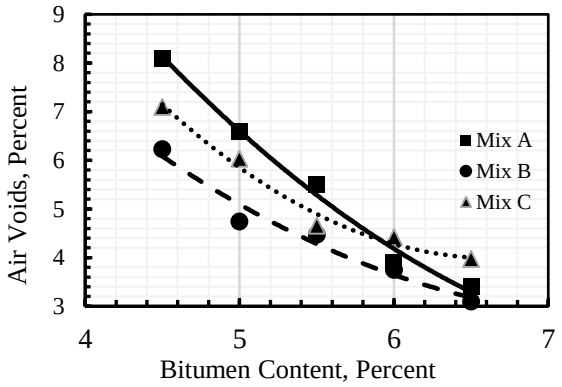

Figure 8: Relationship between Air Voids and Bitumen Content for Mix Type A, B and C

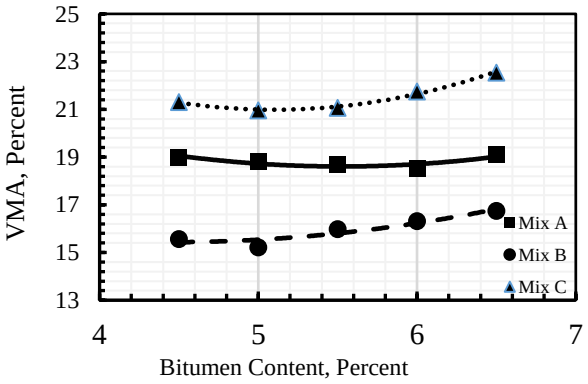

Figure 9: Relationship between VMA with and Bitumen Content for Mix Type A, B and C

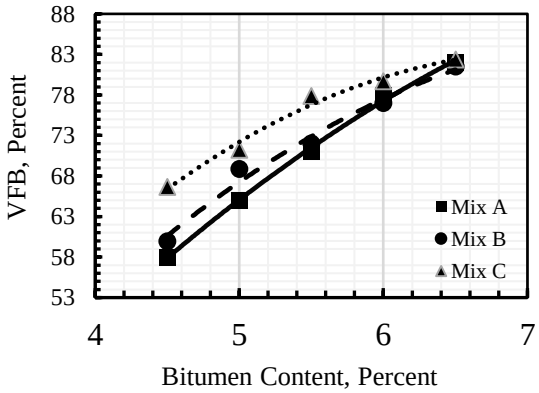

Figure 10: Relationship between VFB with and Bitumen Content for Mix Type A, B and C

Table 3: Characteristics of Bituminous Mixes for Mix type A, B and C

Aggregate Types	O.B.C (%)	Unit weight (kg/m^3)	Marshall Stability (kN)	Flow (0.25 mm)	Air voids (%)	VMA (%)	VFB (%)
A	5.65	2305	13.0	12.5	4.1	18.75	76
B	5.70	2178	12.9	12.8	4.1	15.80	74
C	5.80	2219	13.4	12.6	4.0	15.20	76

3. ANALYSIS OF RESULTS

As determination and comparison of the physical properties of natural aggregates and waste tiles aggregates are one of the main objectives of this study, Table 1 and Table 2 represents the experimental test results of physical properties of both types of aggregates. The experimental result shows that both types of aggregates satisfied the respective limiting value. Though tiles dust were not used in this study, we can use this as an alternative of stone dust filler regarding comparison of physical properties of both. Marshall Stability at optimum bitumen content for Mix types A, B and C are 13.0, 12.9 and 13.4 kN respectively. These three stability values satisfy the limiting value (3.336 kN) specified by The Asphalt Institute. The flow values are 12.5, 12.8 and 12.6 respectively. These values satisfy the limiting value 8-16 according to design criteria for medium traffic. From Table 3 it is found that at optimum bitumen content, %Va for mix type A, B and C are 4.1%, 4.1% and 4.0% respectively. These values satisfy the

limiting value 3-5% specified by The Asphalt Institute. Table 5 shows that the %VMA at optimum bitumen content for mix types A, B and C are 18.75%, 15.80% and 15.20% respectively. These values are greater than the minimum value 12%. Table 4.5 shows that the %VFB at optimum bitumen content for mix types A, B and C are 76%, 74% and 76% respectively. These values satisfy the limiting value 65%- 78% specified by The Asphalt Institute. Marshall Stiffness value of Mix type A, B and C at optimum bitumen content are 4.16, 4.03 and 4.25 kN/mm respectively. All these values are above the required value of 2.1 kN/mm.

4. CONCLUSIONS

On the basis of experimental results of this study, the following conclusions are drawn:

a. Aggregates which are obtained by crushing waste tiles are suitable for the bituminous mixes from the consideration of aggregate strength properties.
b. Waste tiles aggregates as a partial replacement of black stone chips, coarse sand-bitumen mix with filler satisfies all the requirements of bituminous mixes for medium traffic road.
c. Waste tiles aggregates as a partial replacement of black stone chips, waste tiles fines-bitumen mix with filler satisfies all the requirements of bituminous mixes for medium traffic.
d. Marshall Test properties of mixes with waste tiles aggregates are satisfactory but required bitumen are 1.02 times and 1.04 times more for mix type B and C respectively than that of mix type A. Though the required amount of bitumen is more for mixes with WTA, it is considerable in the sense of utilization of a waste material.
e. The investigated results indicate that the bituminous mixes with waste tiles aggregates give satisfactory results when they are constructed using dense grading, good compaction and optimum bitumen content for medium traffic.

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OVERVIEW OF THE HIGHWAY CRASHES IN BANGLADESH

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ABSTRACT

Each year around 3000 police reported road crashes resulting in equivalent number of deaths occur on our roads in Bangladesh. Actual annual road fatalities are estimated to be over 20,000. Around 61% of the road crashes occurred in national and regional highways of Bangladesh which resulted 66% of the total road fatalities. Of those 50% of road traffic fatalities are attributed to Vulnerable Road Users (VRUs) - pedestrians, bicyclists, motor cyclists and users of informal and unsafe motorized and non-motorized transport. Among these VRUs fatalities, pedestrian fatalities emerges as the most common type amounting upto 77%. Heavy vehicles, especially buses and trucks are mostly involved in these crashes. The road environmental factors are particularly prevalent with major roadway defects in design and layout, shoulders, road sides, bridge and its approaches, delineation devices and lack of access controls and others. Unregulated private/business access to national and regional highways leads to endless linear settlements resulting in high risks for pedestrians and other vulnerable road users. Improving safety of these highways and road environment is now a great concern which emphasizes on wider application of proven road engineering measure at the locations identified by systematic crash investigation and research.

This paper presents a brief overview of current road crash and fatality statistics in national and regional highways of Bangladesh for the period from 2006-2015. This study specially assesses the contributory factors and striking characteristics including aspects of road infrastructure safety improvements.

Keywords: *Road safety, national and regional highways, pedestrian, countermeasures.*

1. INTRODUCTION

Road transportation is the major mode of transport in Bangladesh and is playing enormous role in enabling economic development, promoting prosperity and poverty reduction. There is no doubt that road transportation is vitally important to our economic and social welfare and must be so maintained and continually improved with due consideration for safety, minimizing crash hazards and risks. However, each year thousands of people are killed and injured on our roads. These terrible losses of lives and injuries affect us personally, socially and economically. Crashes on national and regional highway are taking lion's share of road causalities with frequent occurrence of major fatal crashes. Improving safety of these highways and road environment is now a great concern which emphasizes on wider application of proven road engineering measure at the locations identified by systematic crash investigation and research. This paper present striking characteristics of crashes on the two classes of highways including crash factors and aspects of road infrastructure safety improvements

2. TRENDS OF TOTAL ROAD CRASHES AND FATALITIES IN BANGLADESH

The number of police reported crashes and fatalities during the period of 2006 to 2015 are 25,556 and 24,462 respectively (Accident Reseacrh Institute [ARI], 2016). Figure 1 shows the trend of crashes and fatalities during this period. It is clearly seen that the number of crashes and fatalities are in decreasing trend. Adoption and improvements of safety measures and increasing awarness among road users played great role behind this decreasing trend. However, the high figures of crashes and fatalities estimated by some national private sources, international agencies and organizations always create debate about the actual figures and reported figures. But it is obvious that, underreporting of crashes and fatalities data mislead researchers and road safety engineers about the actual trend.

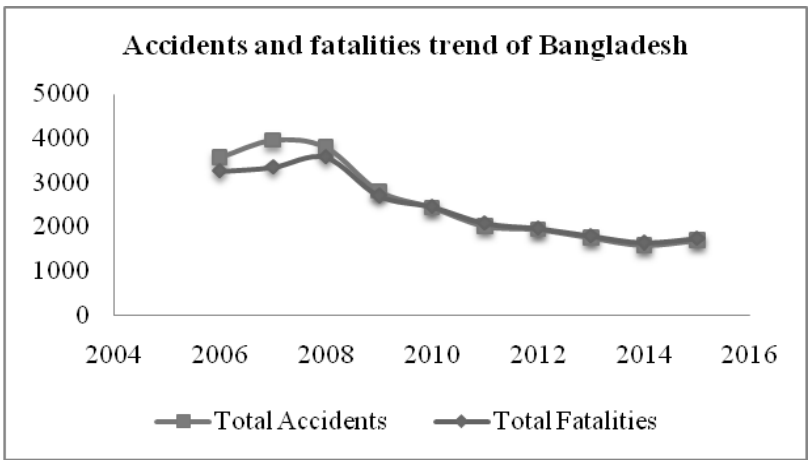

Figure 1: Trend of crashes and fatalities in Bangladesh

3. CRASHES AND FATALITIES BY LOCATION TYPE

Percentage of crashes and fatalities by location type in Bangladesh confirms significant fluctuations in between 2006 to 2015. Figure 2 shows that urban crashes and fatalities increased significantly upto the year 2011 (upto 47% and 41% respectively) and decreased during 2013 (36% and 31% respectively) and then again increasing very recently in 2015 (46% and 38%). Trend of rural crashes and fatalities shows opposite scenary. This may be the result of the intervention of some speed enforning measures in rural highways. Study also shows that, percentage of urban fatalities are less with respect to urban crashes. This is the effect of lower speed of the vehicles in urban areas. High speed rural areas shows reverse result.

4. CRASHES AND FATALITIES BY ROAD CLASS

The distributions of total crashes and fatalities according to road class are national highways 47% and 51%, city roads 18% and 14%, regional roads 14% and 15%, feeder roads 12% and 11% and rural roads 9% and 9% respectively. Table 1 presents the comparative distribution of crashes, fatalities by road class.

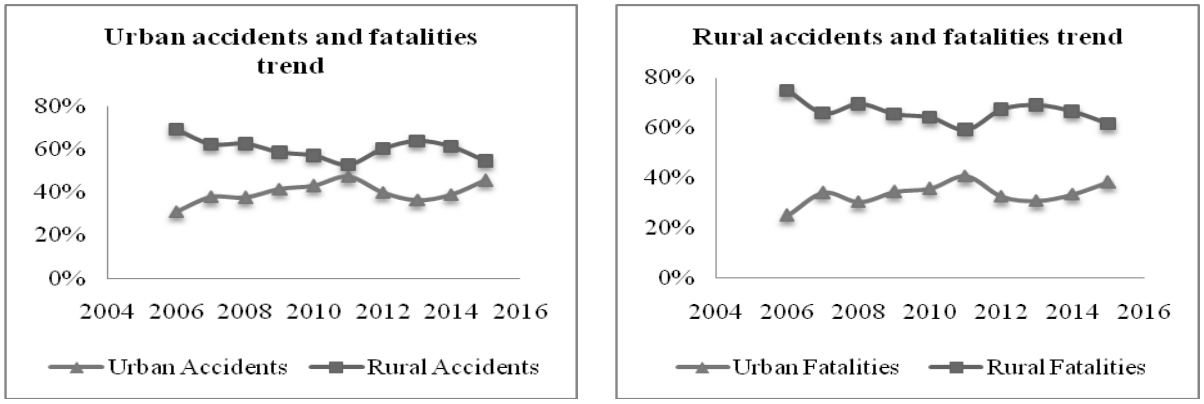

Figure 2: Crashes and fatalities by location type in Bangladesh

Table 1: Road crashes and fatalities by road class

Road Class	Crash	fatality
National Highways (NHs)	47%	51%
Regional Highways (RHs)	14%	15%
Feeder Roads (FRs)	12%	11%
Rural Roads (RRs)	9%	9%
City Roads (CRs)	18%	14%

Furthermore, crashes and fatalities in national and regional highways have shown upward trend recently (as shown in Figure 3). Thus, it is clear that crashes on the national and regional highways are of primary concern to improve the road safety situation in Bangladesh. The incidence of aggressive speeding is also evident on these highways.

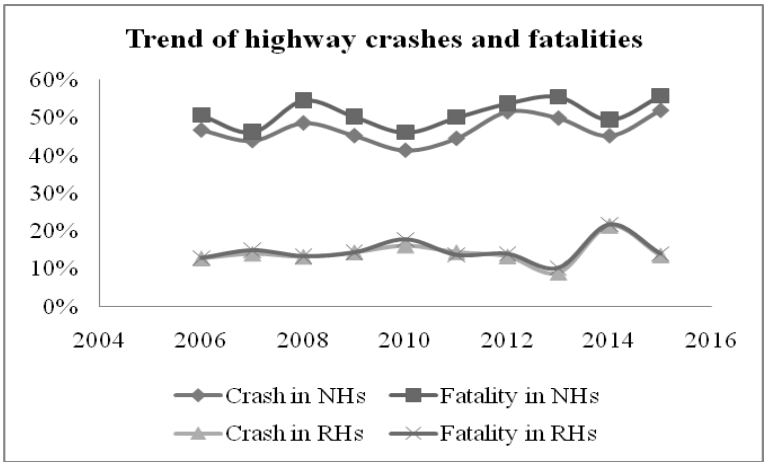

Figure 3: Road crash and fatality trend in national and regional highways

5. CRASHES AND FATALITIES IN HIGHWAYS BY COLLISION TYPES

More frequent collision types have been identified in this study. Of the total reported crashes and fatalities hit pedestrian emerges as the most common type of collisions in national and regional highways amounting upto 43% and 38% respectively (Figure 4). This is followed by the head on (21% and 28%), rear end (13% and 12%) and overturn (7% and 9% respectively). This four types of collision comprises upto 84% and 87% of crashes and fatalities in these highways respectively. The figure also indicates that pedestrian safety issues must be considered as an urgent basis. Again the greater incidence of head-on type collision highly justifies the necessity of separating opposing traffic stream.

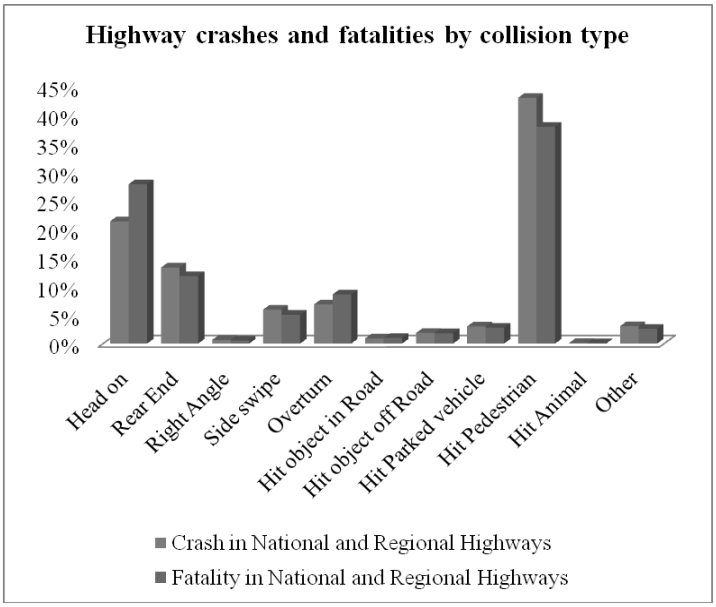

Figure 4: Highway crashes and fatalities by collision type

6. CRASHES AND FATALITIES IN HIGHWAYS BY ROAD GEOMETRY

It is found that, nearly 91% of crashes and 90% of the fatalities in national and regional highways occur at straight section of the highways. This result also substantiates the over speeding of these highways.

Table 2: Highway crashes and fatalities by road geometry

Road geometry	Crash in highways	Fatality in highways
Straight	92%	91%
Curve	6%	7%
Slope	1%	1%
Others	1%	1%
Total	100%	100%

7. CRASHES AND FATALITIES IN HIGHWAYS TIME OF THE DAY

The frequency distribution of crashes and fatalities of highways for the various times of the day depict that the peak time of crash occurrence for major crashes and fatalities is 12:00 pm-2:00 pm (13% crashes and 13% fatalities) as shown in Figure 5.

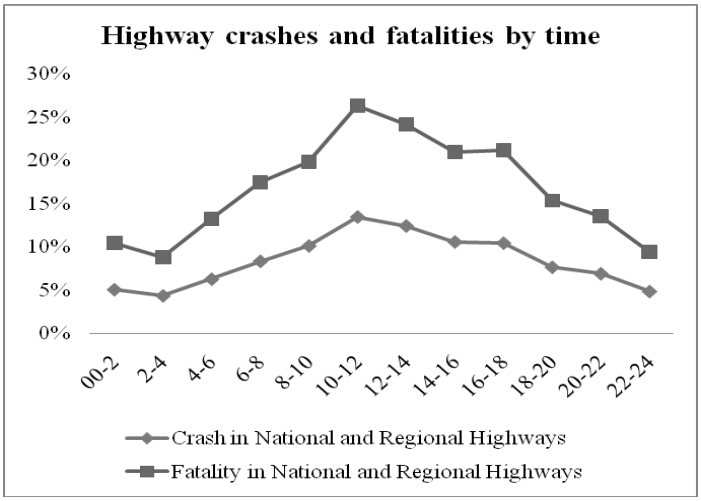

Figure 5: Highway crashes and fatalities by time of the day

Nearly 57% crashes and 55% fatalities occur between 8:00 am- 6.00 pm. Other time periods in which relatively high numbers of crashes and fatalities occur are 6:00-8.00 am (8% and 9% respectively) and 6:00 pm-8:00 pm (8% and 8% respectively.

8. CRASHES AND FATALITIES IN HIGHWAYS FATALITY BY AGE

The age distributions of fatalities among various road user groups are shown in Figure 6. The study observes that most economically active and productive people (26-45 years age groups) are the main victims of road fatalities which are 46% of all road deaths in the highways. The other significant road death groups are 21-25 years group (12%) and 16-20 years group (7%). Children who are aged under 15 represent a significant proportion (14%) of road highway fatalities.

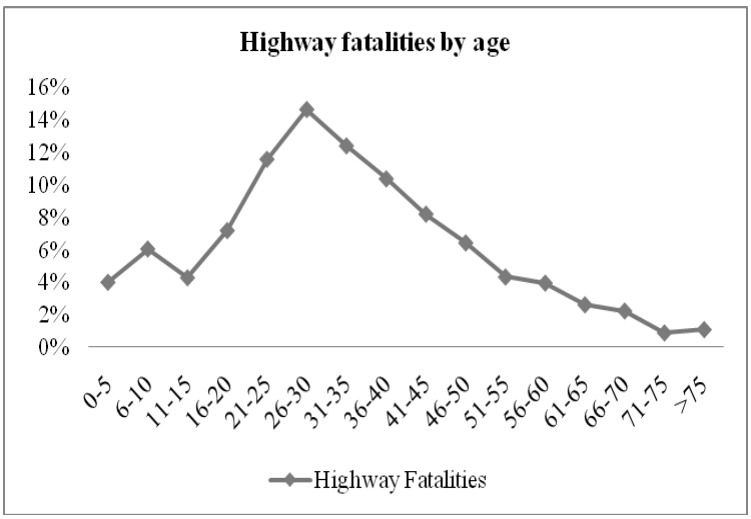

Figure 6: Highway crashes and fatalities by age group

9. VRUS CRASHES AND FATALITIES IN HIGHWAYS

In highways, nearly 50% of the road traffic fatalities are attributed to VRUs (viz. pedestrian, bicycles, cycle rickshaws and motor cycles). Of these VRUs, 77% fatalities are attributed to pedestrian fatalities followed by motorcyclists 13%, rickshaws 5% and bicyclists 5%. These VRUs are in general slow-moving and exposed and at higher risk of injury when their travel path conflicts with those for

the high speed motorized vehicles (Hoque, Mahmud & Qazi, 2008). The lack of external protection is the most fundamental features of VRUs which cause them to be fatally injured even when the collision speed is not that high. The irony is that most of the VRUs of the highways have little choice but to travel along roads in close proximity to fast vehicles. As a consequence, they found themselves in a high risk situation, which inevitably leads to large numbers of crashes. Due to absence of proper regulation and dedicated facilities for this vast group of road users they consequently become the worst sufferer of road crashes in this country. Therefore, it is crucially important to realize that facilitating VRUs and ensuring their safety is the key to ensure a sustainable transportation system under mixed traffic condition in the foreseeable future.

10. PEDESTRIAN CRASHES AND FATALITIES IN HIGHWAYS

Pedestrian-vehicle conflicts are clearly the greatest safety problem and show almost steady trends in Bangladesh. In recent years, pedestrian crashes and fatalities showed increasing trend. In 2012, nearly 33% crashes were hit pedestrian type which were responsible for almost 29% of toal fatalities in highways (Figure 7).

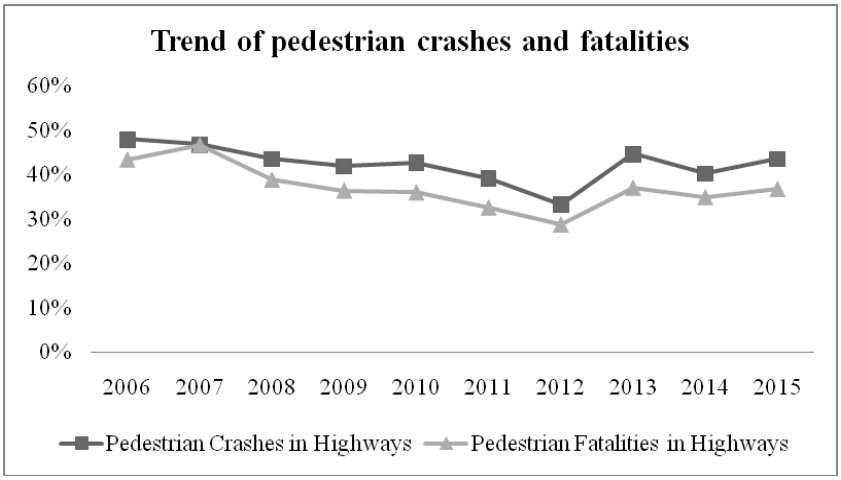

Figure 7: Pedestrian crashes and fatalities trend

In 2015, the percentage of pedestrian crashes increase to 44% and fatalities to 37%. It clearly indicates that these type of crashes should be mitigate urgently. In highways, 37% crashes and 40% fatalities occur while crossing the roads followed by 28% crashes and 29% fatalities during walking through edge of the road or shoulder (Table 3).

Table 3: Pedestrian fatalities by pedestrian actions

Pedestrian Actions	Crash in National and Regional Highways	Fatality in National and Regional Highways
None	20%	21%
Crossing	37%	40%
Walking on the Road	7%	8%
Walking through Edge of the Road	28%	29%
Working/Playing on the Road	7%	2%

11. VEHICLE INVOLVEMENT IN HIGHWAY CRASHES AND FATALITIES

Studies of road crashes revealed that heavy vehicles such as buses and minibuses (32%) and trucks (24%) are major contributors to road crashes in highways. This group of vehicles is particularly over involved in pedestrian. Informal vehicles like Nosimon, Korimon, etc. contribute 9% of the vehicles

involved in highway crashes. Besides, motorcycle (8%) plays a great role in road crashes in Bangladesh. Low level of awareness of the safety problems, inadequate and unsatisfactory education, safety rules and regulations and traffic law enforcement and sanctions of the drivers play significant role behind this crashes.

Yearly trend analysis of the involved vehicles in highway crashes shows that trucks and informal vehicles involvements are increasing alarmingly. In 2006 the involvement of informal vehicles was 4% which has increased up to 15% in 2015. Often these low speed informal vehicles involve in collisions with heavy and higher speed vehicles and results greater death rates.

12. MAJOR ROAD CRASH CAUSATIONS IN HIGHWAYS

The principle contributory factors behind road traffic crashes and fatalities in highways of Bangladesh have been identified in this study. The analysis shows that overspeeding and careless driving contributed almost 85% and 85% of crashes and fatalities in highways respectively. Besides this, pedestrian action also mentionably contributed to 8% and 7% crashes and fatalities in highways of Bangladesh.

13. ROLE OF ENGINEERS IN ROAD SAFETY

Road crashes are considered a "public health" problem, which confronts society generally. Engineers must, therefore, work closely with experts in other scientific disciplines such as educators, health and enforcement agencies to effectively tackle the problem. Engineering improvements to road safety can be conveniently subdivided into three categories: road and roadway environemnt improvement; vehicles improvement; and improvements aimed at assisting other scientific disciplines. Road and vehicle engineering measures have been well proven effective in reducing crashes. Road safety is more appreciated in developed countries and their crash rates are decreasing. In comparison, the problem may appear of little concern in developing countries and their crash and casualty rates are higher than developed countries. It is unlikely that much progress can be made in substantially reducing crash cost unless a comprehensive strategy is adopted with due regard to the latest advances, principles and measures. A multi-directional approach should be considered along with collaboration between, traffic police, health, law, and transport authorities in developing countries.

14. THE SAFE SYSTEM APPROACH AND ROAD INFRASTRUCTURE SAFETY IMPROVEMENTS

One of the most recent advances in tackling road safety is the concept of safe system approach (Hoque and Salehin, 2013). It deals with more forgiving approach (Figure 8) and considers that public make mistakes and they are vulnerable. This approach puts particular emphasis on safe roads along with the mutual importance of safe road users, vehicles and speeds. The approach is very effective in preventing road deaths and serious injuries on large scale and its potential in less motorized countries like Bangladesh is enormous. Given the road environmental situation and hazards associated with VRUs, as discussed in the preceding sections, the systematic implementation of safe system approach can significantly enhance the safety of the VRUs in Bangladesh.

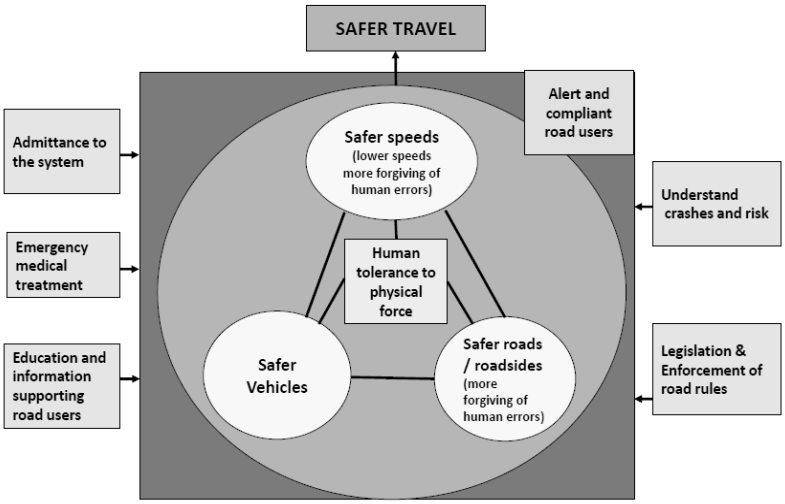

Figure 8: Safe system (Source: Australian Transport Council, 2004)

15. HIGHWAY INFRASTRUCTURE SAFETY IMPROVEMENTS IN BANGLADESH

In Bangladesh, extensive studies of police reported crash data as well as on-scene in-depth investigation of selected crashes have been conducted for understanding of the characteristics and identifying effective safety improvement options with particular regard to road infrastructure improvements. The following promising actions of road infrastructure safety are of prime importance for road safety in Bangladesh. The treatments and approaches would help road infrastructure required to deliver safe system outcomes (Hoque, Salehin & Smith, 2012).

15.1 Hazardous Road Location Treatments

Spot safety programs which seek to identify, prioritize and treat crash locations have been very successful. There is urgent need and scope for road environmental improvements aimed at correcting the most common deficiencies in hazardous road locations in Bangladesh. Hazardous road location treatments have shown high economic benefits and demand priority consideration in Bangladesh. Desirably, emphasis should be placed initially on introducing low cost improvement schemes which proved to be highly effective. Typical safety measures are incorporation and treatments of road shoulders, pedestrian facilities (segregated footways, crossings), junction improvements, treatment of hazards, speed control devices, median barriers, access control, channelization, traffic islands, skid resistance treatment, improved delineation devices, safety zones etc. including provision of divided roads.

15.2 Road Safety Audits

Alongside crash reduction work, crash and injury prevention work must also be pursued through road safety audit as an important process in road safety engineering. An effective road safety audit process has great potential for improving road safety. Road safety audit being a systematic examination of roadway elements for safety would focus on explicit safety implications and recommend desirable changes or modifications in highway design and operational aspects appropriate to the local safety needs. Road safety auditing or checking is a very essential and systematic step that needs to be introduced to document such widespread safety deficiencies for appropriate corrections. Proactive identification and treatment of hazardous road locations through road safety audit is considered to be highly beneficial to Bangladesh context.

15.3 Road Inspection and Assessment

This approach has now emerged as a new tool for systematic analysis of road infrastructure deficiencies and provides targeted countermeasures programs to improve road safety across an entire

road network. The International Road Assessment Programme (iRAP) tools particularly address the safety of vulnerable road users and asses each stretch of roads for its safety for pedestrians, bicyclists, motor cyclists and car occupants separately (International Road Assessment Programme [iRAP], 2008). The iRAP methodology offers 'vaccines for roads' and therefore demands priority consideration for application in Bangladesh with support from the international road safety community. The iRAP targets high-risk roads where affordable programs of safety engineering can reduce large number of deaths and serious injuries on the basis of strong partnership for key local stakeholders.

16.FURTHER HIGHWAY SAFETY MEASURES FOR BANGLADESH

Other promising road infrastructure safety measures that demand increased attention includes the following.

16.1 Walking Facilities

Nearly 28% of highway pedestrian crashes and 29% of fatalities occur while walking along the edge of the highways. Adequate shoulder and separate walking facilities are importance to separate the pedestrians away from the main traffic stream which will ultimately reduce the this type of crash in the highways (Mahmud, Hossain, Hoque, & Hoque, 2006).

16.2 Crossing Facilities

About 37% pedestrian crashes and 40% pedestrian fatalities occur while crossing the highways in Bangladesh. So it is very important to provide crossing facilities, such as, overpass and underpass at right place to separate the pedestrian and main traffic. In addition, for school-goers of young ages pedestrian flag facilities can be applied.

16.3 Service Roads

Bicyclists, motor cyclists and pedal rickshaws are legal road users and have the right to use the roadway. Service roads are wished to be used to decrease fatalities of such road users in highways.

16.4 Treatment of Roadway Shoulder

It is well established that the safety benefits of shoulders improvement are evident with benefit-cost ratio of 29:1 (Hoque et al., 2006). Major two type of collision such as run-off and head on collision can be significantly reduced by shoulder widening. Moreover, wide paved shoulder provides shelter for slow moving vehicles.

16.5 High Roadside Slope Protection and Treatments

Exposed roadside steep-slope, particularly at bends is a potential hazard. Installation of roadside safety barriers is the best option to encounter this hazard. When such places are not properly delineated or guided, there is always chance of crash at night time. Installing guide post or even placing wire-rope barrier can increase safety tremendously. Setting of guide post with reflector or reflective paint can be very useful at night.

16.6 Enforcement Measures

Advanced warning which could be as VMS (Variable Message Sign), traffic signs, and advanced road markings can be efficient for speedy road users like motorcyclist. Here new Intelligent Transportation System (ITS) can be major tools for enforcing safety of the road which are proven to be effective in developed countries..

16.7 Policy Measures

Land use policy need to be applied for regulating to construct new infrastructure in city areas. Additionally, all safe infrastructures should follow manual of roads and highway department and related departments

17. CONCLUSIONS

This paper has mainly highlighted the characteristics of highway crashes and fatalities in Bangladesh by identifying most common types of crashes and the causal factors. It is found that VRUs are the main victim of these fatalities, accounted for over 50% of the total highway fatalities. Hit pedestrians represented by far the largest share of the highway fatalities with nearly 77% of the total VRUs fatalities. Thus, the pedestrian safety should be considered as a priority group in taking any roadway safety improvement schemes and measures. Infrastructural safety improvement of roads, roadside hazards treatment, roadway environmental safety, standard design principles and frequent safety inspections are highly needed to address other types of crashes in highways of Bangladesh. Detailed analysis of the most recent crash statistics revealed that effective road safety countermeasures in accordance with crash patterns are necessary and have been identified in this paper. The role of road safety engineers are particularly significant in this context with a view to apply effective countermeasures within the context of safe system principles.

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