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ANALYSIS OF ACCIDENTS TREND DUE TO DRIVING PROBLEMS IN BANGLADESH

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ABSTRACT

In world nearly 1.3 million people die in road accident each year, on average 3,287 deaths a day. Bangladesh has one of the highest fatality rate in road accidents in the world which causes untold suffering and misery to the members of the victim's family. Many studies have shown that drivers are responsible for most of the accidents. The aim of this paper is to identify the causes of road accidents and accidents trend due to driving related problems in Bangladesh. For this study 15 years (1998-2013) accident data have been collected from Accident Research Center(ARC), BUET and detail diagnosis have been done on these available data. In this analysis driver's characteristics and some factors that affect safe driving & causes accidents were identified so that adequate procedures can be taken to reduce such as fatal accidents. The current condition of existing facilities of safe driving and some suggestion to reduce accidents rate is also discussed in this research. From this paper it is found that by proper licensing & training of drivers, improving existing road facilities, regularly checking fitness of the vehicles, introducing traffic islands at intersections, introducing enforcement to control traffic and preventing alcohol use of driver's will reduce accidents rate.

Keywords: *Road accident, driver behaviour, traffic, alcohol, licence*

1. INTRODUCTION

In Bangladesh, road accidents and injuries are now a growing and serious problem. It has about 1.6 million motorized and could be over 3 million non-motorized vehicles(Hoque,2004) This situation is very severe by international standard. Each year, half million people die and 10-15 million people are injured in road accidents worldwide (Odgen,1996) Yet among all transportation accidents road accidents are paid less attention than air plane crush to the policy makers and general people, as a result more road accidents occurs (Odgen,1996). Even lesser attention is given to the accident caused by driving problems. Although driving problem is one of the major problem that causes road accidents, particularly in developing countries like Bangladesh.

According to a study conducted by the Accident Research Centre(ARC) of BUET, road accidents claim on average 12,000 lives annually and lead to about 35,000 injuries in Bangladesh . According to World Bank statistics, annual fatality rates from road accidents is found to be 85.6 fatalities per 10,000 vehicles (World Bank Report, 2009). Also, 77% of traffic accident fatalities are pedestrians and 50% of these fatalities involve buses (Hoque, M. M., 2004) The majority of the people including media pundits tend to hold the drivers responsible for all sorts of traffic accidents. There is no doubt that the greater number of road accidents and resultant fatalities are caused by irresponsible and inexperienced drivers. Drivers are hampering road safety agenda.

The objectives of this paper is to provide a broad overview of characteristics features of drivers and factors that causes road accidents and which are related to safety problems in Bangladesh.

2. METHODOLOGY

In Bangladesh, police is the core organization for road accident data collection and storage. For each accident the Accident Research Center(ARC) is completed by a sub inspector of police after visiting the accident spot. The ARF is then dispatched to the respective Accident Data Units(ADU) where the information from ARF and location of the accident is incorporated into Microcomputer Accident Analysis Package (MAAP). Ten regional ADUs were established during early 1998. These units are responsible for processing and analysis of accident data of their jurisdiction. Additionally, an ADU was established at police Headquarters' (HQ) to assemble the national accident database and to analyze accident data at national level. Data is sent from the regional ADUs to the police HQ in soft form. The MAAP system is used to analyzed accident data and it provides the pattern of accidents in the country.

The Accident Research Center (ARC) at BUET essentially uses the MAAP database. This database was transferred to the center to the institutional collaboration of the Road Safety Cell (RSC) of the BRTA and the police department. The current road safety research and investigation works have been based on this database. The MAAP data has now been included as part of the official First Information Report (FIR) form, so it is expected that the system will improve more in the future years.

Data in this research were collected from accident records database maintained at the Accident Research Center (ARC) of BUET for the 15 years (1998-2013) and PPRC report-2012. The data included accident date, time location and other relevant information. For convenient, the whole study was divided into two categories. After that the collected data was analyzed and related graph was prepared using the Polygon Analysis Procedure of Micro Computer Accident Analysis Package(MAAP).

2.1 Background of the problems

Bangladesh is one of the densely populated country. It having an area of 1,47,570 sq.km and a population of 160 million. The number of population is increasing day by day. A rapid urbanization has been taken place around the country in the last few decades. So people needs vehicles to travel from one place to another. For travelling purpose the number of vehicles is increasing day by day. Due to rapid increasing of vehicles the number of drivers are increasing as well as accident rates. As a results the number of casualty rate is increasing which is very alarming.

Mainly accidents are occured due to bad driving or driving related problems. Now a days drivers are given license without appropriate training by authoraty and some drivers drive their vehicles even without having any license. For this reason, road accidents are becoming common senerio in Bangladesh. From literature review, it has been found that causal factors fall within four major clusters: i) driving habits ii) road-related factors iii) vehicle-related factors iv) socio-economic environmental factors. Beside these, drivers are not tring to maintain traffic rules and regulation. Adverse roadway, roadside environment, poor detailed design of junctions and road sections, overloading, dangerous overtaking, reckless driving, carelessness of road users, failure to obey mandatory traffic regulations, variety of vehicle characteristics and defect of vehicles etc are common reason for accident. factors affect safe driving which causes fatality accidents. The 2013 WHO global report on road safety highlights five causal factors of drivers that causes road accidents are- i) excessive speed ii) drunk driving iii) non-use of motorcycle helmets iv)non-use of seat belts v)non-use of child constrains.

Bangladesh has one of the highest fatality rate in road accidents. Whereas many other developed countries the accident rate is relatively low. From figure-1 it is seen that number of casualty is decreased from the year 2011 to 2013. In the year 2003 it is maximum.

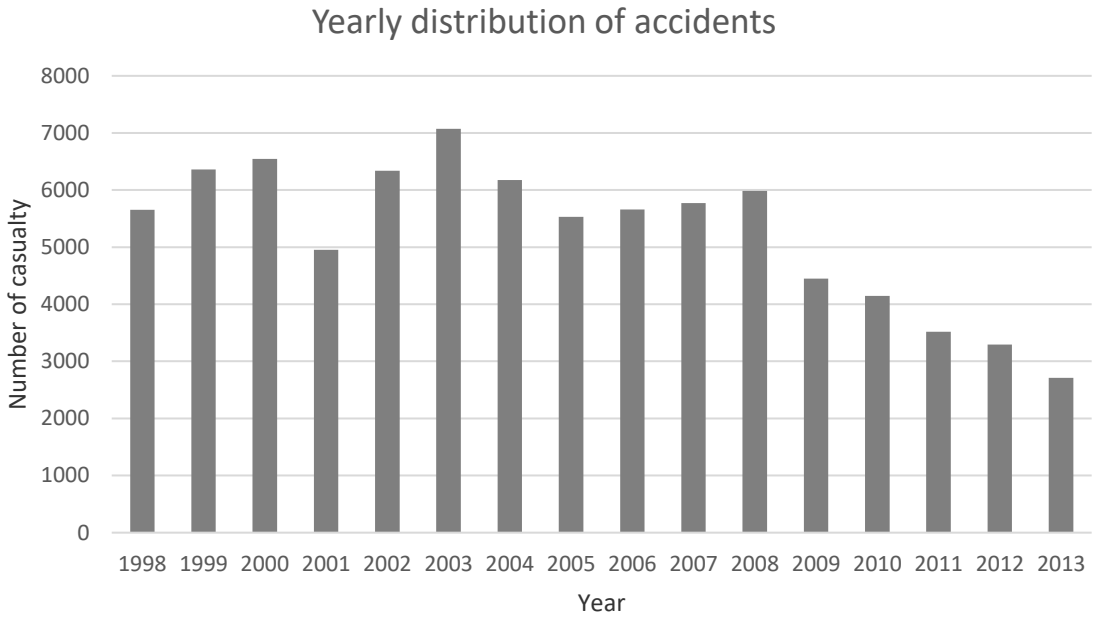

Figure-1: yearly trend of accidents; Source: Accident Research Center(ARC), BUET

3.CHARACTERISTICS OF ACCIDENT DATA

The analysis of accident data involved the determination of accidents severities rate due to bad driving on the basis of

i) Driver's characteristics.
ii)The different factors that affect drivers.

3.1 Driver's characteristics

3.1.1 According to driver's age

Figure-2 shows the age distribution of drivers according to their casualty rates. Variation of ages are presented as abscissa with respect to the percentage of casualties involved in accident which is presented as ordinate. According to figure-2 the age of driver below 10 years and above 60 years are less vulnerable to road accidents. The age of drivers between 21-40 years are more involved in road accidents and causes more casualty. The accident rates are decreasing above the age of 40. So young people are more involving accidents due to inadequate educational background. Though below 18 age is not accepted for driving license but from analysis it is seen that below 18 age peoples are also driving vehicles.

Figure 2: Casualty rates of driver on the basis of age (1998-2013)

3.1.2 According to alcohol use of driver

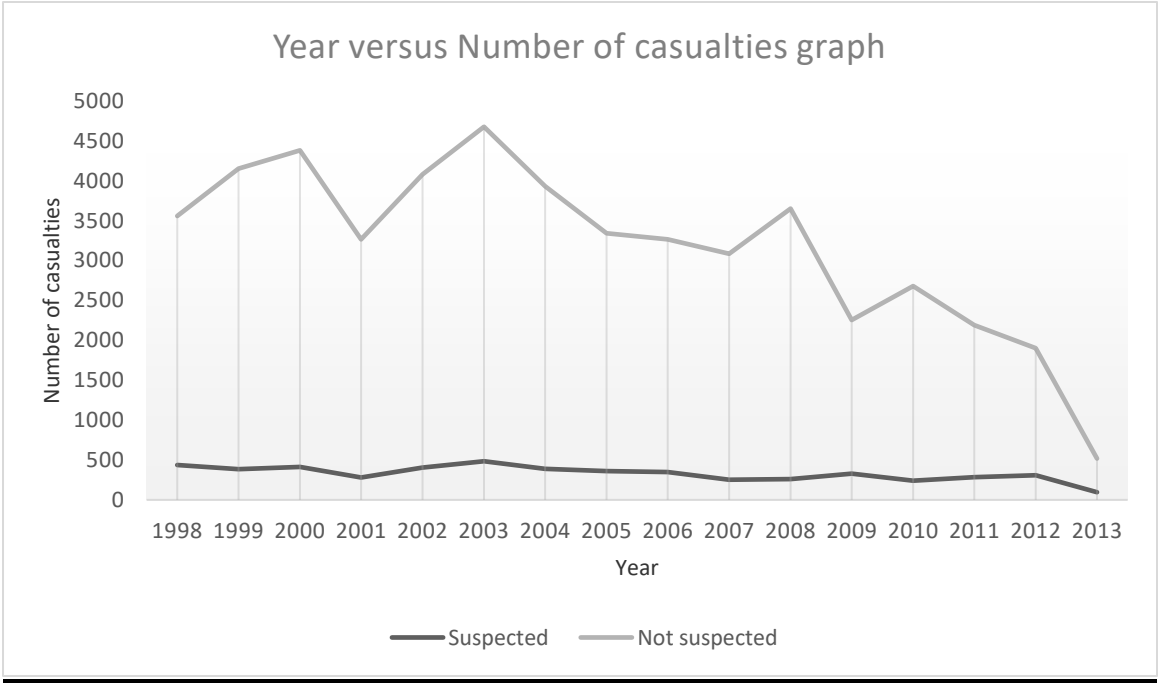

Figure 3: Yearly trend of number of casualties according to driver alcohol use (1998-2013)

Figure 3 shows the graphical representation of yearly distribution of casualty rates of drivers which depends on driver's alcohol use.(ARC, BUET)) From figure-3 it is seen that number of casualties due to suspected alcohol use of drivers are more from the year 2002 to 2004. In year 2003 it is maximum. From the year 2005 suspected casualty rates due to driver alcohol use are started to decrease and in the year 2013 it is minimum. So number of casualty rates are decreased due to alcohol use in recent decades. In the case of non-suspected alcohol use of drivers the same results are found. It is maximum in the year 2003

and started to decrease from the year 2005 and it is minimum in 2013.So proper checking of driver's medical condition is required.

3.2 Different factors that affect drivers

3.2.1 According to time periods

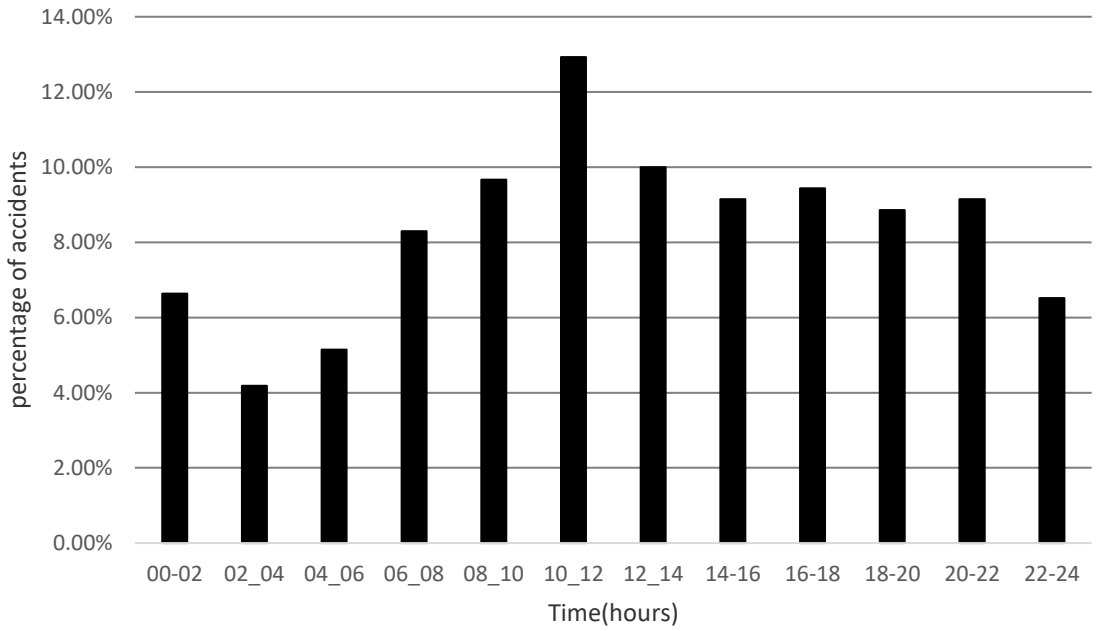

Figure 4: Percentage of accidents by time of day. (2013)

Figure-4 shows, hourly distribution of accidents which represents hour of accidents as abscissa and percentage of accidents as ordinate. From figure-4 it is seen that, from 10a.m. to 12p.m. the percentage of accidents is 13% which is maximum and it is the peak value of accidents. It also observed that, from 12a.m. to 6a.m. the accident rate is minimum. In day time from 6a.m. to 6p.m. the percentage of accidents is more than night time. So day time is peak time for accidents. Time was represented as local time. Mainly people leaves their home during day time to fulfill their needs that's why accidents rate is more in day time.

3.2.2 According to road surface type

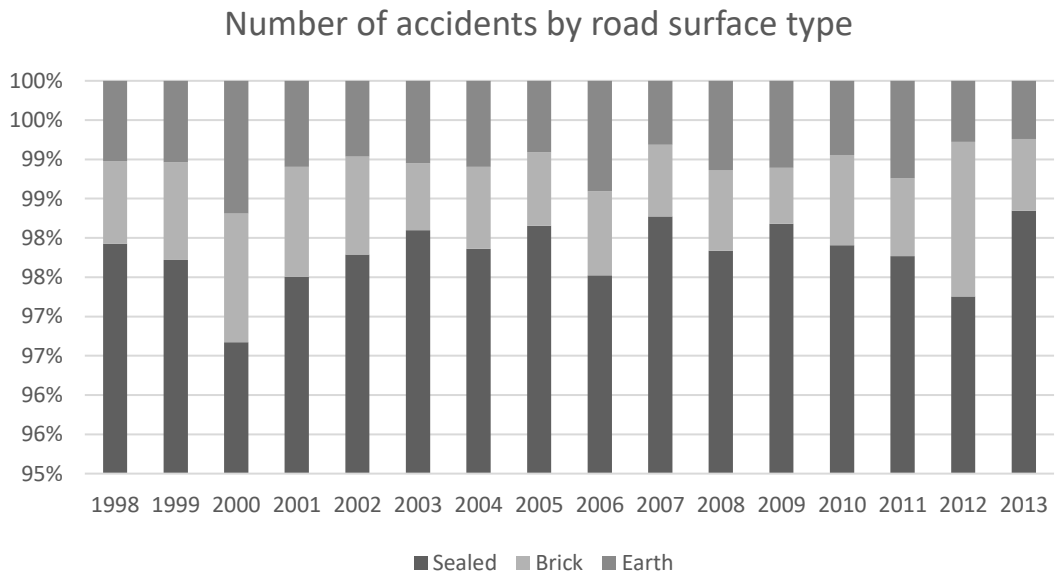

Figure 5: Accidents trend analysis according to road surface type.

Figure 5 shows, yearly distribution of accidents according to road surface type, year of accidents as abscissa and percentage of accident as ordinate. From figure-5 it is observed that, from the year 1998-2013 the accidents rates is more in bituminus road than brick road and earth type road surface. So drivers are involved in more road accidents in sealed roads. In year 2013, the percentage of accidents is maximum in sealed roads and minimum in year 2000. From figure-5 it also seen that, the accidents rates in earth surface roads are decreased in last few decades and increased in brick surface roads. From “Roads and Highway Department of Bangladesh” it is found that total length of the paved road in Bangladesh is 17353.69km whereas total length of earth road is only 684.51km and unpaved road is 636.06km. The vehicle operation is easy in bituminus road than brick and earth road. So vehicle speed is found more in sealed road than brick road & earth road. So it is seen that because of more length & ease of vehicle operation the accident rate is more in sealed road than brick & earth road.

3.2.3. According to Traffic control system

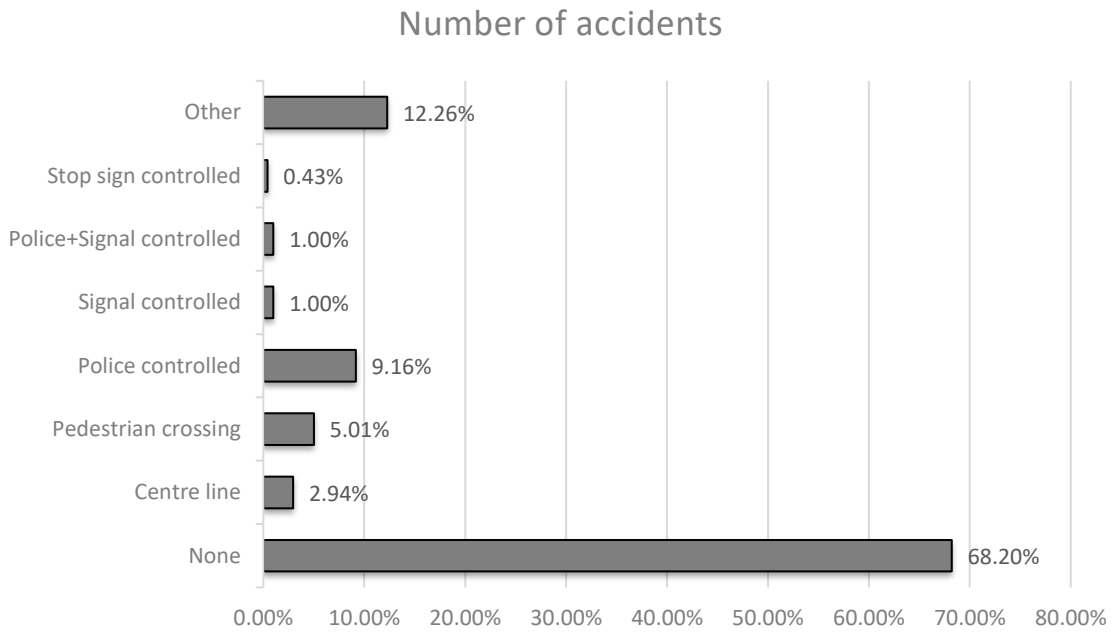

Figure 6: Accidents rate according to traffic control system (2013)

From figure-6, the bar diagram of accidents rate in year 2013 according to traffic control system, it is observed that, 68.20% accidents were occurred due to the absence of traffic control system. Rest of 31.80% accidents were occurred at the present of traffic control systems. According to modal analysis, 5.10% accidents were occurred at pedestrian crossing and 9.16% accidents were occurred in spite of presence of police control system. 2.94% accidents occurred at center line, 1% at signal controlled, 1% at police and signal controlled, 0.43% at stop sign controlled and 12.26% accidents occurred at other control systems.

3.2.4. According to Junction type

Figure-7 shows a bar diagram of number of accidents by junction type. From the analysis from collected data it is seen that 73% accidents were taken place in the absence of junctions. Rest of 27% accidents were taken place in the presence of junctions. 5.28% accidents were taken place at cross junction, 8.18% accidents were taken place at T-junction, 1.15% at staggered, 1.23% at roundabout, 0.27% at rail crossing and 11.33% accidents were taken place at other junction types. So minimum accidents rate is at rail crossing.

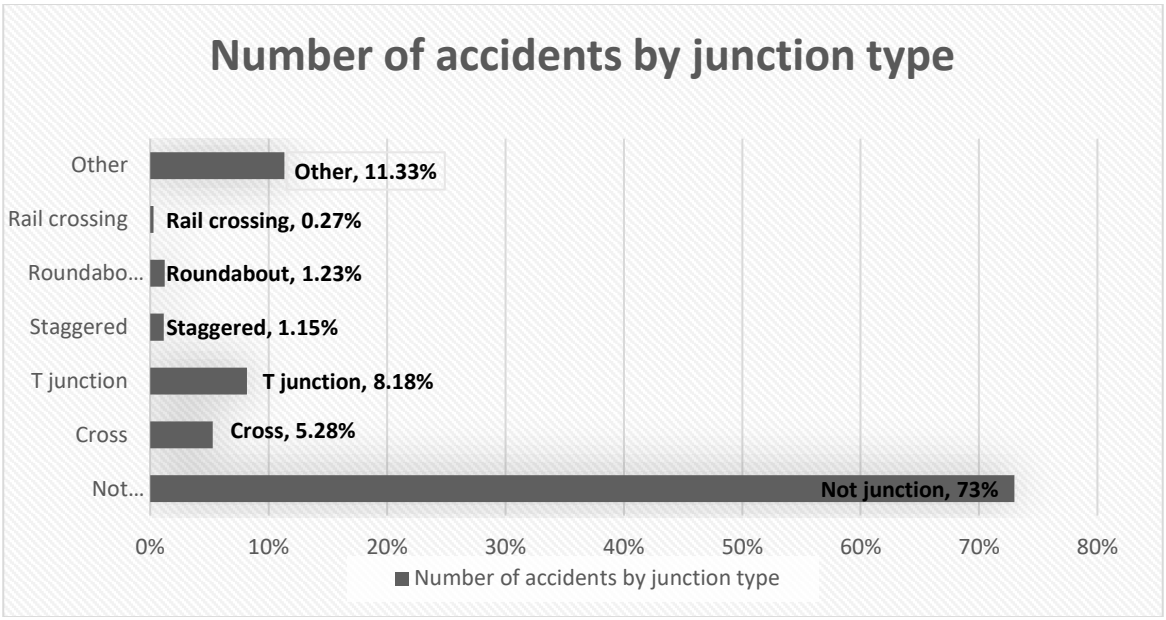

Figure 7: Accidents analysis according to junction type (1998-2013); Source: ARC(BUET)

3.2.5. According to contributory factor

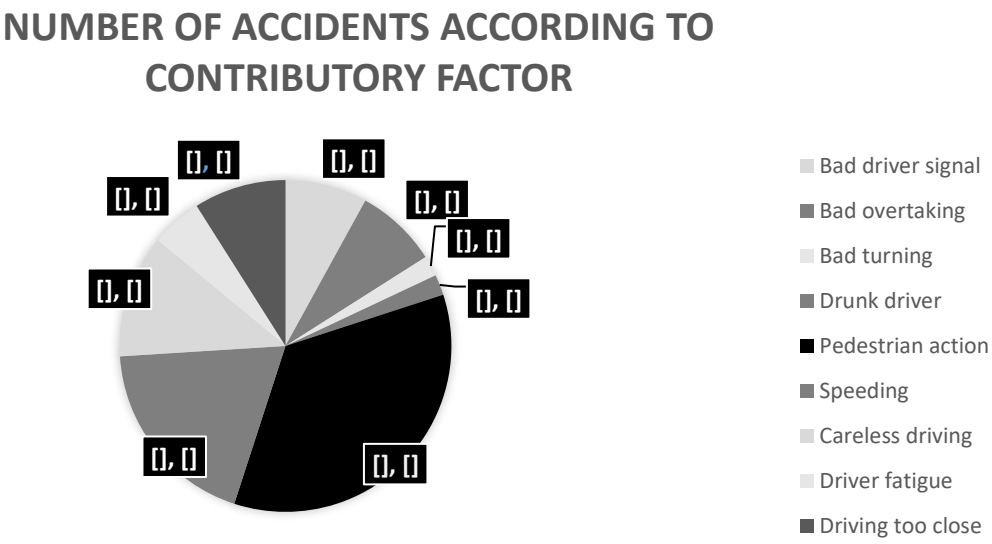

Figure 8:Rate of accidents according to contributory factor (1998-2013)

Figure 8 shows modal distribution of number of accidents according to contributory factors. From the analysis it is seen that, 35% accidents were taken place because of pedestrian action which is huge number. 19% accidents were occurred due to over speeding of drivers. Beside these 12% accidents were occurred due to careless driving, 5% due to driver fatigue, 9% due to driving too close, 8% due to bad driver signal, 8% due to bad overtaking, 2% due to bad turning and 2% due to drunk driver. So accidents mainly occurs due to careless movement of pedestrians. The analysis was done from collected accidents data from 1998 to 2013.

3.2.6. According to vehicle type

Figure-9 shows a graph of casualty class as abscissa and number of casualties as ordinate. From Figure-9 it is observed that pedestrians are involved in maximum number of accidents. Among motorized vehicles mainly motorcycles and buses are involved in maximum number of accidents. Cars, jeeps, micro buses and cycles are less responsible for accidents. From the figure-9 it also seen that, fatality rate is more than grievous rate in accidents occurred by all type of casualty class.

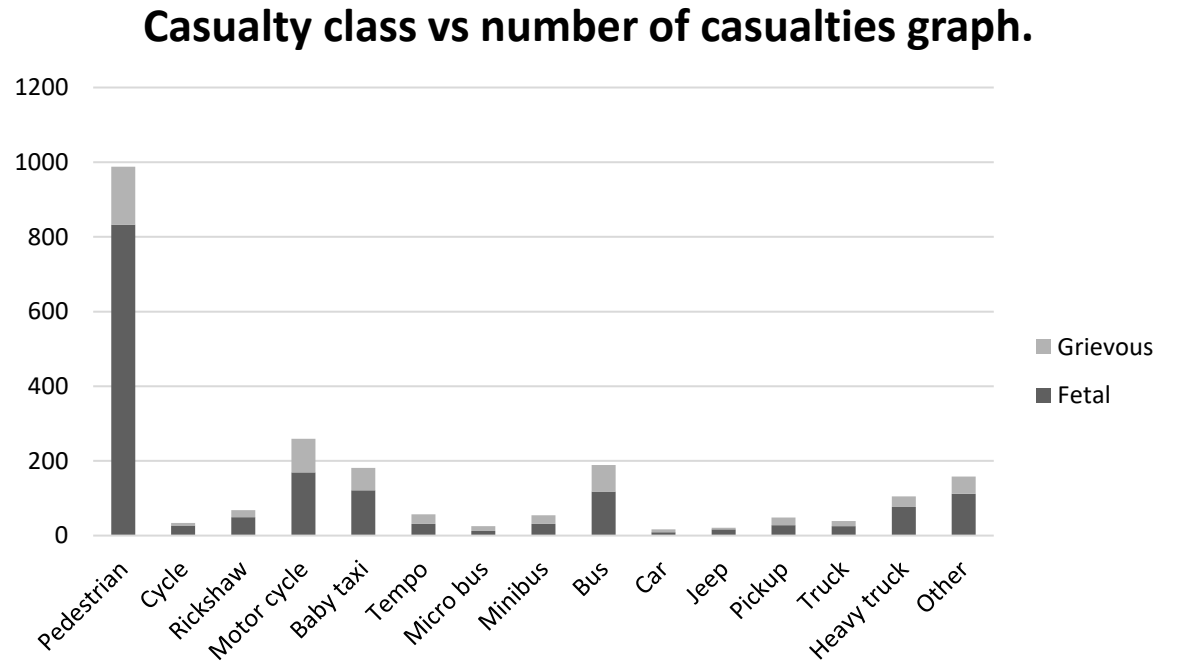

Figure 9: Number of casualties according to casualty class (2013)

3.2.7. According to training of driver

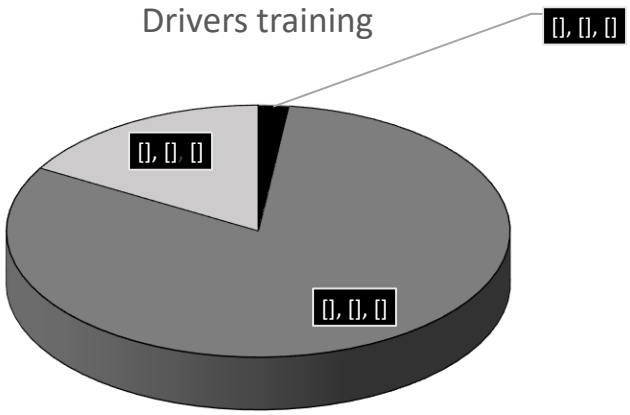

Figure 10: percentage of driving training of drivers

Figure-10 shows a modal analysis of present situation of driver's driving knowledge. It is seen that 81.40% drivers in Bangladesh does not have any formal learning about driving.

Only 2% has formal training of driving and proper knowledge about driving. Rest of 16.70% drivers have both formal training and informal learning. So this 16.70% does not complete their proper training. So the numbers of non-trained drivers are more.

4. RESULTS & DISCUSSION

Results obtained from the study can be summarized as follows:

- From the available data it has been observed that the ages of drivers' ranges between 21 to 40 are mainly involved in accidents.
- The number of accidents due to alcohol use of driver's both suspected and not suspected is maximum in year 2003 and it is decreased in last few years.
- Accidents mainly take place in sealed surface roads because its length is more than other types of road & high speed of vehicles.
- It is observed from the study that 68.20% accidents take place in the absence of control systems.
- From the analysis it is observed that 73% accidents occurred due to absence of junctions.
- Pedestrian action (35%) is the main contributory factor which causes maximum number of accidents.
- It is also observed from the study that motor cycles and buses are involved more accidents than other type of casualty classes.
- From the available data it is observed that 81.40% drivers in Bangladesh does not have any formal learning of driving. These drivers are mainly responsible for accidents.

CONCLUSIONS

From the above analysis it is observed that accident is mainly occurs due to age of drivers, alcohol use of drivers, not wearing helmet & seatbelt, high speed in sealed surface road, absence of vehicle control system, absence of junctions, lack of driver's proper licensing & formal training. It is also observed that motor cycles & buses are the main culprit for accidents. The accidents rate can be decreased by proper licensing & training of driver, adequate control system & presence of junction, strict law to regulate traffic rules, controlling pedestrian movements.

ACKNOWLEDGEMENTS

I want to give thank to Accident Research Center ARC(BUET) to help me collect data.

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APPLICABILITY OF LOW DENSITY WASTE POLYTHENE (LDPE) WITH BITUMEN IN TERMS OF ROAD CONSTRUCTION

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ABSTRACT

Significant amount of waste polythene is increasing day by day either by getting mixed with MSW (Municipal Solid Waste) or thrown over habitable land area causing environmental pollution. To confront this trend, molten polythene has been used as a modifier of bitumen as it possesses the binding property that can be used for road construction. To investigate the effect of waste polythene on the properties of bitumen, routine tests were performed on bitumen and modified bitumen as per AASHTO. The value of penetration, specific gravity, ductility, solubility decreased with the increase of polythene content with bitumen by 5 to 45% indicating the constant volume in hot weather, higher viscosity, resistance to heat, and also temperature susceptibility. The flash point and softening point increased with the increase of polythene content by 25 to 105 % indicating the reduction tendency of getting soft in hot weather and more susceptibility to temperature. The bulk specific gravity, stability, flow and OBC (Optimum Bitumen Content) of asphalt mixtures are affected by the addition of waste polythene. Due to higher elasticity of waste polythene, the stability and flow decrease with the increase in waste polythene contents. The values of stability and flow are both satisfied with the Marshall criteria. Addition of polythene with bitumen considerably increases the load carrying capacity and aggregate interlock with the decrease of pavement deflection. So polythene can be a good modifier of bitumen.

Key Words: *LDPE; Modifier; OBC; AASHTO; Pavement.*

1. INTRODUCTION

Population, urbanization and industrialization of asian developing countries have increased in which contribute to solid waste (SW) generation. For example, in India it was between 0.2 kg/capita/day and 0.5 kg/capita/day with 217 million people (Rajendra, 2012). Most of the wastes are non-biodegradable polythene. The common problems are lack of collection coverage, and open dumped landfill as the final disposal method. This disposal method gave the environmental pollution, such as the pollution of soil, surface and groundwater caused by leachate and GHGs emission caused by the waste decomposition process. An estimate of the future generation rate of waste in Dhaka indicates that the present generation rate of 3500 tons/day may exceed 30 thousand tons/day by the year 2020. The mixed waste dumped at dumping sites is characterized with high organic content and high moisture content (about 80% and 50-70%by weight, respectively) (JAEBS,2012) (Hai, F. Ibney. & Ali, M. 2005). Data were collected through pre-tested questionnaire from selected 21 BSCIC industries erected at different places of Mymensingh, Bogra and Rangpur districts. It was found that the waste generation from metal, plastic, aluminium, packaging polythene, LDPE and Soap industries varies from 2 to 9% of their total production capacity and 74.28%, 2.61%, 3.52%, 0.26%, 1.83% and 17.49% of total generated waste respectively (BSCIC, 2010) (Md. Mofizul Islam,June, 2006). Investigations in India and countries abroad have revealed that properties of bitumen and bituminous mixes can be improved to meet requirements of pavement with the incorporation of certain additives or blend of additives. (Biswanath Prusty, 2012). These additives are called “Bitumen Modifiers” and the bitumen

premixed with these modifiers is known as modified bitumen. Modified bitumen is expected to give higher life of surfacing depending upon degree of modification and type of additives and modification. Bituminous pavement are subjected to a variety of loading conditions which result in the development of internal tensile stresses. This source of failure which is likely to be induced in bituminous mixtures as a result of this inherent tensile characteristics in bituminous mixtures is cracking. A number of researchers have experimented with the use of various materials as additives and modifiers in bituminous mixtures. One of the major problems of Bangladeshi Roads is formation of Pot holes which usually occurs when vehicular loads induce shear stresses that exceed the shear strength of the materials contained in the pavement structure. This depends on vehicular loads and the visco-elastic properties of the bitumen binder. Bitumen binders are required to have high stiffness at high temperatures to resist rutting while talking to environmental pollution. In recent years, numerous waste materials result from manufacturing operations, service industries and households in which several millions of plastics are produced and plastics are not being readily biodegradable will persist in the environment in a more or less unchanged state of a considerable time. The need of the hour is to use the waste plastic in some beneficial purpose.

In this study an attempt was made to find solution to overcome above discussed problems. The aim of the project is to study the performance of Low Density Waste Polythene (LDPE) in modified bitumen. By doing this, we will be able to reduce the cost and also improve the performance of flexible pavement for future highways construction due to the involvement of a more environmental friendly materials. Here 80/100 garde bitimen has been used. Penetration Grade 80/100 is a standard penetration grade bitumen usually used as a Paving grade bitumen suitable for road construction and for the production of asphalt pavements with superior properties. Here 80 indicates minimum and 100 indicates maximum penetration value in milimeter.

There are several objectives that need to be achieved when completing this project. The objectives are, to compare, under controlled laboratory conditions, the performance of the bitumen modified with an optimum percentage of waste polythene using the standard 80/100, to evaluate the behavior of bituminous mix when added with waste polythene and compare the result with conventional bituminous mix, to assess the different engineering implications and physical characteristics with the addition of waste materials into the binder mixture, to evaluate the economical implication with the use of waste polythene modified bitumen mixture as compared with the standard mixture.

2. METHODOLOGY

For the binder the standard bitumen of 80/100 garde were used. The waste polythene were collected from the roadside waste garbage collectors and also from the domestic waste and dustbins. The polythene that has been used as modifier here is LDPE (Low Density Waste Polythene). This LDPE has been used because of some specific reasons. The LDPE is easily getable, very low costly, can be used very easily and less activities are needed to process it to use as modifier. Again HDPE (High Density Waste Polythene) is to some extent not properly available. That's the reaon why LDPE has been used here. The collected polythene wastes were washed, cleaned and dried. The polythenes were then shredded into very tiny pieces with klnife. The required quantities of polythene to be added with specified amount of bitumen for preparation of different percentage of polythene-bitumen. The blend were weighted and added in required percentage by weight of bitumen to the hot bitumen and the mixture was stirred well for about 30 minutes under temperature around 170-180°C. Clean waste polythene was shredded to 2-3 mm size which was used as recycled polythene. To investigate the effect of waste polythene on the properties of bitumen, five types of modified bitumen (MB) designated as MB_5, MB_{10}, MB_{15}, MB_{20}, MB_{25} by addition of 5, 10, 15,

20 and 25% of waste polythene in bitumen respectively. Routine tests and Marshall stability Test were performed on bitumen and modified bitumen as per AASHTO and test results were compared.

3. RESULTS AND DISCUSSION

Regular tests that were performed on conventional bitumen and modified bitumen and results of the tests are as follows:

Table 1: Conventional Test result performed on modified bitumen with different LDPE content

Types of Bitumen	Specific Gravity At 25/25^0 C	Penetration Test Value (mm)	Softening point Test Value (^{0}C)	Ductility Test Value (cm)	Solubility Test Value	Flash Point (^{0}C)
Conventional bitumen	1.01	81	45.2	79.6	96.7	340
5% LDPE	1.00	75	72	74.6	88.2	355
10% LDPE	0.99	69	68.8	65	83.5	365
15% LDPE	0.99	65	76	54.3	75.2	380
20% LDPE	0.98	57	84	49	69.2	400
25% LDPE	0.95	53	93	44	60.5	420

Table 1 shows the different test results performed on bitumen. From Table 1 it's been shown that the values were reduced from the roughly 100 mm of penetration to an average of 70 mm for LDPE. By norm the lower the penetration grade will imply a high viscosity, thus the modified bitumen has higher viscosity compared to standard bitumen. Another point to note would be the difference in terms of storage stability factor. This result shows that the modified bitumen has a large tendency for separation towards the top. The higher penetration value indicates the higher range of consistency. The softening point is generally higher for the polythene modified than the standard 80/100 grade bitumen. This phenomenon indicates that the resistance of the binder to the effect of heat is increased and it will reduce its tendency to soften in hot weather. Thus, with the addition of polythene the modified binder will be less susceptible to temperature changes. The results show that the ductility decreases with the increases of polythene content. No correlations could be found to indicate the relevance of the ductility in terms of fatigue or rutting resistance of asphalt. Specific gravity result indicates that the resistance of the binder to the effect of heat is decreased and it will reduce its tendency to increase its volume in hot weather. Thus, with the addition of LDPE, the modified binder will be susceptible to temperature changes. The solubility is generally lower for the LDPE modified and the standard 80/100 bitumen due to the increase of impurities. This phenomenon indicates that the resistance of the binder to the effect of heat is increased and it will reduce its tendency to soften in hot weather. Thus, with the addition of LDPE the modified binder will be less susceptible for pavement construction. The flash point is generally higher for the modified bitumen and the standard 80/100 bitumen. This indicates that the resistance of the binder to the effect of heat is increased and it will reduce its tendency to soften in hot weather.

Table 2: Marshall Test Result

LDPE (%)	Engineering Properties					
	Unit weight (lb./ft³)	Air voids (%)	VMA (%)	Stability (lb.)	Flow (0.01 in.)	OBC (%)
5	135.4	59	22.0	950	1.5	5
10	136.7	46	21.5	1022	1.7	
15	137.9	38	21.7	955	2.1	
20	138.2	32	22.2	750	2.7	
25	136.2	29	23.0	550	3.7	

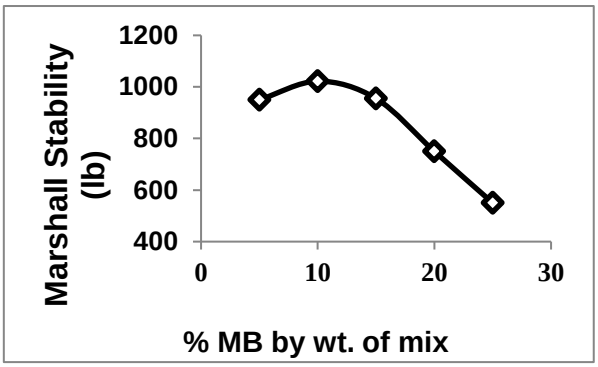

Figure: 1: Marshall Stability Vs. % MB wt. of

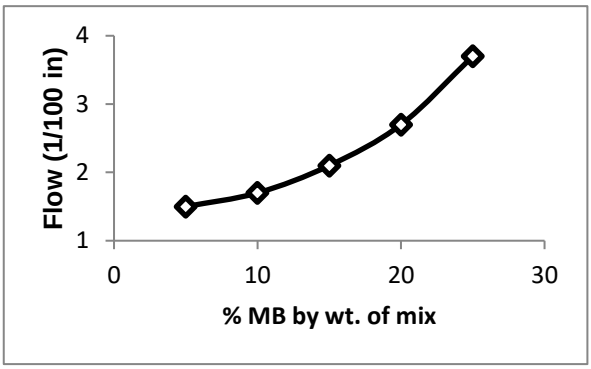

Figure: 2: Flow Vs. % MB wt. of mix

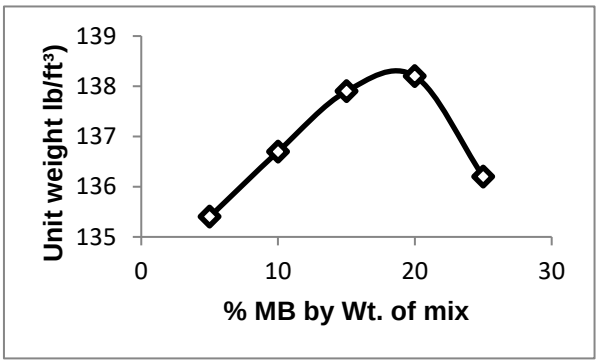

Figure: 3: Unit Wt. Vs. % MB wt. of mix

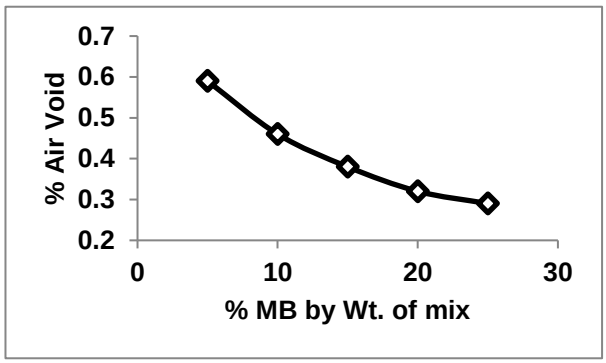

Figure: 4: % Air void Vs. % MB wt. of mix

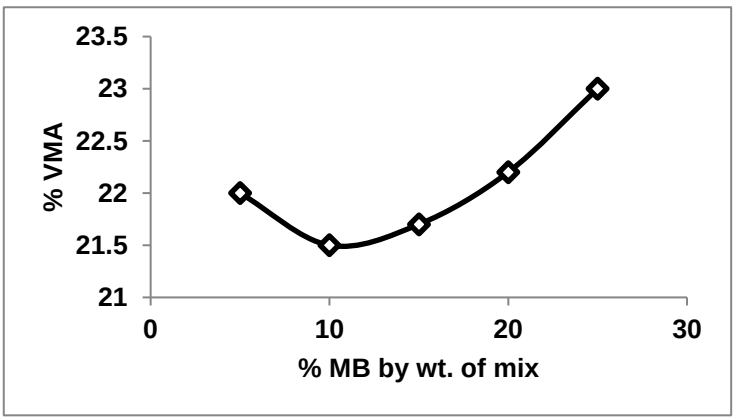

Figure: 5: % VMA Vs. % MB wt. of mix

From the figures 1,2,3 & 4 above, it was determined that maximum specific gravity is obayined at 5% of LDPE so as the other values decreasing from the tope with the addition of LDPE with bitumen. Thus, if average is taken of the values of LDPE the optimum bitumen content for the bituminous mixture is found as 5%. Table 2 shows the Marshal Test result where teh values for modied bitumens are provided. Marshal test was conducted on modified bitumen only and the variations of results were observed for differnet percentages of LDPE in bitumen. From table 2, it was found that the unit weight, stability, flow and OBC of bitumen mixtures are affected by the addition of waste polythene. Because the specific gravity of LDPE is far less than that of aggregate, the bulk specific gravity of LDPE modified asphalt mixtures decrease with the increase in waste polythene. Due to lower compressive strength and higher elasticity of waste polythene, the stability and flow decrease with the increase in waste polythene contents. The values of stability and flow are both satisfied with the Marshall criteria. The values of stability and flow are both satisfied with the Marshall criteria. The stability, VMA (%), and air void varied by 14%, 3.8%, and 39 % respectively. The same trend can be observed for Voids in Mineral Aggregate (VMA). With the addition of LDPE into the binder, the VMA reduced by 0.4% respectively. These variation were detemined by simple arithmatic calculation as the table shows the variations of results in case of stability, flow, % Air void and % VMA. Addition of polythene has considerably increased the load carrying capacity and aggregate interlock with the decrease of pavement deflection.

4. CONCLUSIONS

From the study, the following can be concluded that-

The incorporation of LDPE affects the properties of the conventional bitumen. This can be seen through the penetration and ring and ball test whereby the binder properties are observed to undergo changes due to the addition of the LDPE. From the penetration test results, the penetration values of LDPE modified bitumen are lower than the conventional bitumen. The penetration values decreased from around 100 mm for conventional bitumen to around 70 mm for LDPE modified bitumen respectively. This means that the incorporation of both additives results in the increase in stiffness of the conventional bitumen. The same trend can be observed for the ring and ball test. The test results show that the softening point value increased from 43°C for conventional bitumen to around 50°C for LDPE modified bitumen respectively. Hence, the inclusion of both the additives into the conventional bitumen increases the viscosity of the conventional bitumen. Besides that, in terms of storage, it can be concluded that modified bitumen are not suitable for long-term storage. After mixing with additives, modified bitumen should not be stored temporarily because separation process will occur between the bitumen and the additives. This is due to the fact that the LDPE did not dissolve fully in the mixing process and thus after it was stored for one day, separation process occurred.

For this study the mixture components selection were done in accordance with JKR recommendations. The mixture components consist of granite as the coarse aggregate, the river sand as the fine aggregate and the Ordinary Portland cement (OPC) as the filler. For the binder the standard bitumen 80/100 were used. One waste materials that have been identified are LDPE. The properties of the bituminous mixtures were determined from the results of the Marshall.

From the results the following conclusions can be drawn:

- The stability load increased extremely with the addition of LDPE. This is due to the formation of a stronger binder proving the formation of the binding gel.

- For LDPE modified mix has the lowest value of flow but the difference is roughly around 0.5mm compared to the conventional mix which is not that significant.
- The porosity of the binder is reduced with the addition of LDPE. The proportion of voids decreases with addition of LDPE which is justified by a courser binder resulting from the partial digestion of the crumb LDPE in the reaction with bitumen.

The result of Marshall Test that the influence on engineering properties of the LDPE modified bituminous mixture are not that significant except for the stability where the stability of the bituminous mixture improves tremendously after LDPE is added as additive into the bitumen.

4.1 Issues Identified & Recommendations for Further Research

This study presents laboratory findings of the influence of incorporating LDPE as additives to the binder and investigates the effect on the binder properties and the performance of the bituminous mixture. However, for a better assessment on their influences as additives to the binder as well as to verify and validate the results obtained in this investigation, the following recommendations are suggested:

In terms of modification of binder, there are other aspects affecting the performance of binder such as:

- The Type of Polythene – different polythene have different properties. For example, LDPE, HDPE etc.

- The proportion of LDPE added to the standard bitumen – Previous investigations have shown that the amount of additive added can cause adverse effect if too much or too less amount is added to the bitumen. Hence, further study need to be conducted using different percentage of additive to know the optimum content.

- The Temperature – The influence of temperature is known to be one of the factors to influence fatigue response of material. In this study, the performance test was only carried out at only one temperature. Therefore, in order to better understand the performance, test should be carried out at various temperatures preferably between the lowest and highest temperature the pavement may be exposed.

- The compatibility between the LDPE with the bitumen – It was mentioned earlier that the additives failed to dissolve completely in the bitumen after mixing. One thing that can be done to improve this is to conduct study by adding certain solvent such as extender oil or maybe gasoline to ensure the additives can dissolve completely. It is reported that the addition of extender

- Storage stability – Further study can be conducted to see how long a modified binder can last before separation process occur prior to mixing of bituminous mixture. It would be beneficial if the optimum storage can be estimated for economic purpose.

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EMPIRICAL ANALYSIS TO EXPLORE THE DEFICIENCIES IN PUBLIC TRANSPORT SYSTEM: A CASE STUDY ON GAZIPUR

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ABSTRACT

Public transport is an inescapable part of city living especially for developing country like Bangladesh. Mobility is inevitable for promoting economic growth, prosperity and healthy living of city dwellers, to control unplanned city growth as well. Service quality of public transport must be considered not only to attract its users but also for the reduction of traffic congestion. The objective of the study is to find out the deficiencies in service quality of public transport in the newly growing industrial city like Gazipur based on users' perspective. For empirical analysis, 400 data were collected through face to face survey from different bus stops of Gazipur city. The results showed, nearly 54.25% users believed that the bus service quality was unsatisfactory and 48% felt unsafe inside the bus. Besides, 44.5% users have had the poor experience with bus travel because of the worst facility, however, only 21% pleased with seat comfortability. Every service provider should be well aware of the quality of services to continue public transport as the main transport mode.

Key Words: *Service Quality, Public Transport, Mobility, Traffic Congestion*

1. INTRODUCTION

As the population of Dhaka city is growing rapidly, it is very difficult for the city's urban transport system to maintain the required operational standard to meet the needs of the ever-increasing population. People of different classes use the different mode of transport for their travel purposes (Rokibul, 2016). A huge number of people travel daily on foot, pedal rickshaws, auto-rickshaws, tempos, taxis, private cars, and a wide array of buses since Dhaka is the major economic, cultural and administrative hub of Bangladesh. Citizens, predominantly being upper-middle-class, are heavily dependent on the public transport system of the city (Hossain, 2006). In a developing country, the bus is the very significant mode of transport. About 31% of all transport trips comprise of bus trips. It is because of cheap fares, easy accessibility, extensive routing (OCG, 2015). Although most of the users are not satisfied at all with the quality of transport services. Arguably presence of the uncontrolled amount of private vehicles, about 73.33% in the traffic stream is one of the major reasons for traffic stop-and-go situations in Dhaka city (Hoque and Khan, 2013). Assessment of public transport service quality is not only vital for the improvement of user satisfaction, also gives an overview to policymakers to ameliorate their perception about to develop future transportation system (Das and Pandit, 2013).

Gazipur is a newly growing industrial city of Bangladesh. Present public transport service quality assessment of a newly growing city like Gazipur helps transport specialists to make the better decision on future transportation system to increase the quality of service, mobility, reduce pollution and provide vigorous city life to its dwellers. For empirical analysis, 400 data were collected through face to face survey from different bus stops of Gazipur city in order to explore the deficiencies in the public transport system. The objective of this research is to find out the deficiencies in the public transport system of Gazipur territory.

2. METHODOLOGY

Gazipur city has been selected as study area. In order to conduct this research, necessary data have been collected through face to face questionnaire survey. A questionnaire containing both close-ended and open-ended was prepared to collect data. Necessary suggestions from transportation experts have also been taken during the preparation of questionnaire. 20 expert enumerators were directly involved to carry out face-to-face interviews from different bus stops of Gazipur city throughout the month of January 2017. The target sample was 600 according to the demography and standard sample size practice. However, random data samples were restricted to 480 due to the unwillingness of the commuters, rush hour office/home movement, and other impending situations. After filtering the anomalies, the remaining final sample size was 400. The survey format was designed to explore the deficiencies in the public transport system of Gazipur city. Collected data were processed for subsequent analysis using software such as SPSS and Microsoft Excel.

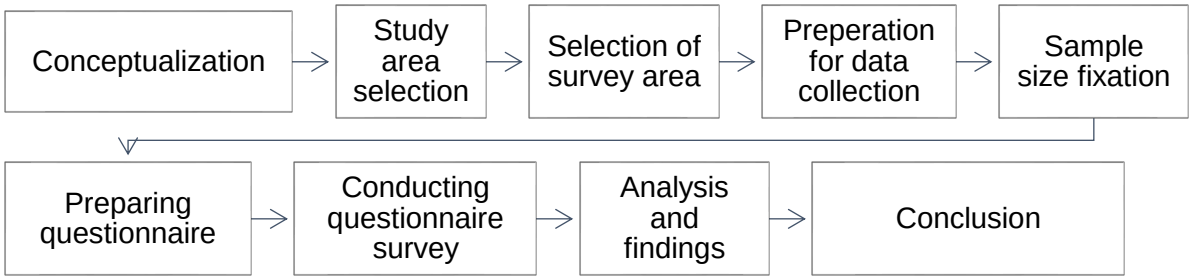

Figure 1: Methodological framework of the research

3. FINDINGS AND ANALYSIS

3.1 Mode of Transport

Most of the travel per day of the commuters is normally generated by bus. Figure 2 shows, 51% of the total people use the bus as their main mode of transport while 7% choose the car. Most of the people are living their life with moderate income.

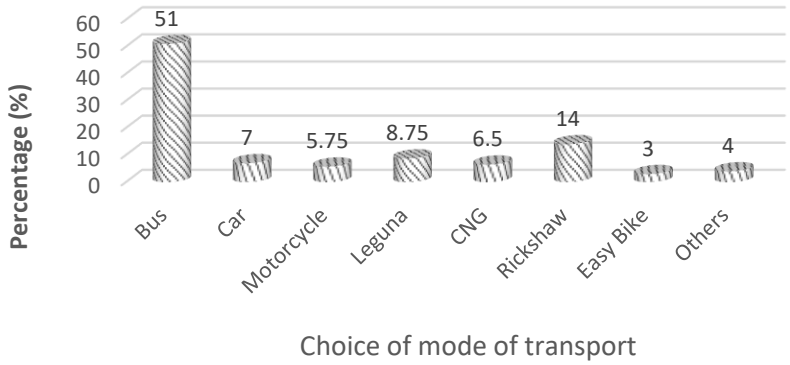

Figure 2: Mode of transport

Only a few had the ability to use private cars. So more people preferred bus services because of the availability and cheap fare. In developing countries, people think public transport means bus transport. Rickshaw is one of the most popular modes for short trips consisting 14% of the total trip. People preferred rickshaw as the second most popular mode of transport because of its availability. Though it has the vulnerability to ride on main roads. Road users also loved to use Leguna for moderate distance because it is not as

overcrowded as a bus. People at least find their seat in it and safer than CNG and small vehicles on the highway.

3.2 Deficiencies in Public Transport System

Deficiencies in public transportation system lead to reduce its users. Adequate service facility in public transport is very crucial to attract passengers and increase mobility.

3.2.1 Service on Weekdays and Weekends

Most of the people use a bus as their prime mode of transport. Figure 3 shows, about 18% passengers were satisfied with present bus service during weekdays while the majority of them nearly 82% were unsatisfied.

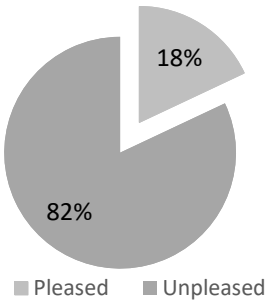

Figure 3: Travel time on weekdays

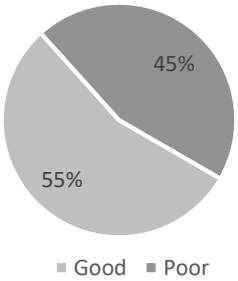

Figure 4: Travel time on weekends

But on the weekends the scenario was quite different than weekdays. Figure 4 shows, about 55% bus users believed that the service on weekend was good but 45% passenger thought that it was poor. Most of the user claimed that during weekdays their average travel time was much longer than the weekends' time. During weekdays, they have to wait a lot of time in order to get a bus as most of the buses are overcrowded with a poor sitting arrangement. About more than half of the respondents expressed that low travel cost was the main reason for overall satisfaction of bus service. But some buses took more time to collect passengers at weekends from bus stops.

3.2.2 Structural Condition and Ventilation System of Bus

Figure 5 shows, about 77% of the respondents claimed that structural condition of the bus in Gazipur route was poor while 23% users were satisfied. Many of the buses were too old to operate and some buses were expired but continuing their services because of the poor monitoring system.

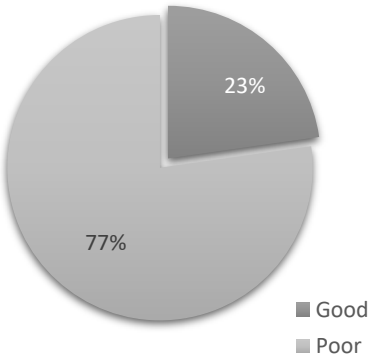

Figure 5: Structural condition of bus

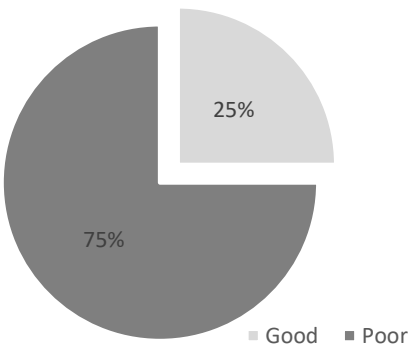

Figure 6: Ventilation system of bus

Besides, Ventilation system on buses was very poor according to 75% passengers and 25% thought that it was good to circulate the air throughout the bus shows in figure 6. Because of the poor ventilation system children and aged people suffered more than others. Many buses were unable to open of its maximum number of windows because of the poor structural condition. Passenger urges that these types of deficiencies in bus services should be monitored and upgraded as soon as possible.

3.2.3 Seat Availability and Seat Comfortability

Another major deficiency in the public transport system in Gazipur city was lack of seat availability and poor seat comfortability. Service providers preferred to collect standing passenger for more lucre from bus stand to the last stoppage after filling the seats of the buses. Most of the buses were overcrowded at the extreme level to breathe and move properly. As a result, just 1% user claimed the seat availability was excellent whereas 16% thought it as good shows in figure 7. Nearly 56% and 27% respondents expressed this seat available facility was very poor and moderate level among the rest 83% user.

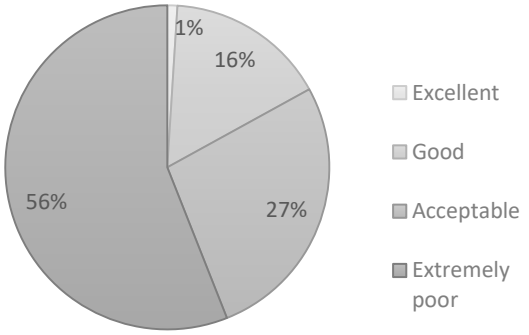

Figure 7: Seat availability on bus

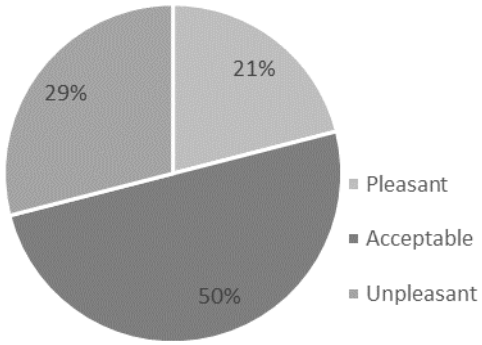

Figure 8: Seat comfortability on bus

Figure 8 shows, about 50% passengers thought seat comfortability was acceptable and 21% passengers were pleased with seat comfortability. However, 29% bus users were not pleased with the seating facilities of the bus in Gazipur city. It is quite difficult to place their legs in front of the seat as the spaces between two seats is so little for moderate height passengers.

3.2.4 Security and Safety Inside the Bus

Ensuring safe and secure bus service is always a great challenge for a developing country. Figure 9 shows that most of the passengers (48%) thought the safety and security of the bus were poor. Larceny was very hackneyed inside the bus in Gazipur territory because of the excess throng of people and lack of enough lighting system. Besides, female bus users felt unsecured both into the bus and bus stop due to harassment with them. But 38% passengers thought that the safety of the bus was acceptable.

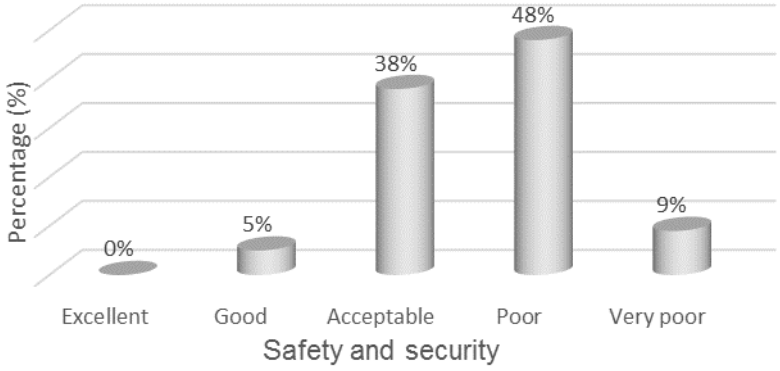

Figure 9: Scenario of security and safety

3.2.5 Quality of Bus Service

Figure 10 shows that 54.25% passengers expressed the present bus service quality in Gazipur city were unsatisfactory while 16.75% were satisfied. Lateness was a hackneyed scenario in public transportation system, especially in stoppages. Paying fare was one of the hardest things for standing passengers as buses were always overcrowded. Besides, it was hard to find out a single neat and clean bus in the territory. According to some passengers, they only used such poor quality public transport because there were no alternative options for them. Furthermore, mismanagement was a common thing with service providers.

Figure 10: Scenario of bus service quality

3.3 Experience of Bus Travel

Table 1 shows, only 4.75% passengers have had excellent experience and 2.5% have extremely worst experience with bus travel in Gazipur. Most of the passengers about 44.5% depicted that their bus experience was poor because of bad service facilities.

Table 1: Prevailing bus travel experience in Gazipur

Experience	Frequency	Cumulative Frequency	Percentage (%)	Cumulative Percentage (%)
Excellent	19	19	4.75	4.75
Good	78	97	19.5	24.25
Medium	115	212	28.75	53
Poor	178	390	44.5	97.5
Very Poor	10	400	2.5	100
Total	400		100	

Poor service quality was responsible for the poor experiences of bus travel. They were inured with services that provided by the authority. Most of the users think it is high time to

improve the quality of bus service to attract more passengers. Otherwise, public transport will lose its users day by day.

4. CONCLUSIONS

In this research, deficiencies in the public transport system have been analyzed based on user's view towards quality, safety, and security in Gazipur city. The quality of the bus service was unsatisfactory due to the poor structure and sitting arrangement. In spite of these negative views, passengers have had a positive attitude for bus service because of the low travel cost and safety than another mode of transport. About 51% people preferred bus as their main mode of transport in Gazipur. In order to sustain the existing users and to attract new users, the policies related to passengers' safety, security as well as fare, reliability and overall service offered by bus in Gazipur city must be taken into account in order to enhance its suitability as public transport.

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APPLICATION OF FUZZY INFERENCE SYSTEM TO EXPLORE THE BUS LEVEL OF SERVICE OF GAZIPUR CITY

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ABSTRACT

Measuring performance of diverse transport facilities is essential to identify gaps and problems in service level and solve those deficiencies by improving quality in a systematic way. Assessment of service quality (SQ) based on user preferences has become a primary concern for the transportation specialists. Most of the people in the developing countries like Bangladesh prefer bus as their main transport mode. The objective of this research is to find out bus level of service of Gazipur territory using fuzzy inference system. For the purpose of the study, 400 data based on users' perspective were collected from the different bus stops of Gazipur. Total 22 qualitative and quantitative attributes were selected according to transport expertise' opinion for the survey. According to the analysis, punctuality and reliability found to be the most significant attributes, which support the user-stated preferences. But presently service quality was not at the satisfactory level, 64% passenger thought the service quality was poor to attract new users toward bus as a mode of transport. However, only 3% were highly satisfied with current service quality, 27% thought service was good. So, better bus service could plummet not only the traffic congestion but also increase the standard of city living to enticing mass users toward it.

Key Words: *Fuzzy inference system, Service quality, Attribute, Transport*

1. INTRODUCTION

Cities play an indispensable role in promoting economic progress and prosperity of a country. The well-developed transportation system of a city is not only crucial for the mobility of resources but also for healthy living. As Bangladesh is a developing country has the vision to be reached in the standard of a developed country in upcoming years, so well planned public transportation system is inevitable(Hossain, 2006).Dhaka is one of the biggest megacity facing the problem of unbearable traffic congestion, unnecessarily burning of fuel, traffic-related pollutions, and safety, which are responsible for the huge amount of economic loss about US550 millions in each year(Hoque, 2004). Weak infrastructure (only 6% paved road), inappropriate transportation system, rapid growth of migrated population in Dhaka as business, political and cultural hub of Bangladesh, are responsible for worsening the roadway ambience, decreasing vehicular flow and deteriorating the overall performance of traffic system. Meanwhile, In Tokyo has 16% road of the total area of the city and 25% of total area in the majority of other developed cities (Habib, 2005). Indisputably, the excess presence of small vehicles (73.33% small private car and motorcycle), while only 1.65% registered public vehicles (bus, minibus) are present in Dhaka city(Khan, 2013). According to Economist Intelligence Unit (EIU 2016), Dhaka becomes the 4th worst city in the world because of poor infrastructure and violence. Public transport service quality assessment is not only vital for the improvement of user satisfaction, it also gives an overview to transport policymakers to ameliorate their perception about to develop future transportation

system(Pandit, 2013).Level-of-Service is a common measure to define good, poor and acceptable service levels for various service attributes of public transport based on user discernment(Pandit, 2013). An amendment of public bus service quality can reduce traffic congestion, air and noise pollution and energy consumption as users would prefer public services than individual transports(Cuomo, 2000). Adaptive neuro-fuzzy inference system proceeds the advantages of both ANN and fuzzy inference system in one. After generated input-output by training, the ANFIS can be used to recognize data that is similar to any of the examples shown during the training phase(Abdulkadir, 2006).

Gazipur is a newly growing industrial city of Bangladesh, the planned public transportation system is very crucial for healthy city living. Existing public transport service quality valuation of a newly growing city helps transport specialists to make the better decision on future transportation system to increase the quality of service, mobility, reduce pollution and provide vigorous city life to its residents. Otherwise, Gazipur will face numerous problems in upcoming days that Dhaka faces today due to the lacking of proper transportation planning. The objective of this research is to find out the bus level of service of Gazipur territory using fuzzy inference system and to recommends possible outlines to improve service quality.

2. METHODOLOGY

2.1 Data Collection and Study Area

Gazipur is a newly growing industrial city, has been selected as study area. According to transport experts, 22 attributes were selected to carry out the research. The target sample was 600 according to the demography and standard sample size practice. However, random data samples were restricted to 480 due to the unwillingness of the commuters, rush hour office/home movement, and other impending situations. After filtering the anomalies, the remaining final sample size was 400.The survey format was designed to explore the service quality of public transport system of Gazipur city. The sample is randomly divided into two sub-samples: a training sample consisting of 80% (320) of whole sample set and a forecasting sample which includes 20% (80) of the sample set and the model was developed and tested using ANFIS GUI of MATLAB 14.

2.2 Method

ANFIS tool has been used to determine the bus level of service of the study area as the technique has widely been applied in different fields like data classification, automatic control, expert system, decision making, robotics, time series analysis, pattern classification, system identification, and so on. The fuzzy inference system (FIS) is based on the concepts of fuzzy set theory. The first step in ANFIS modeling is the identification of the input and output variables. In Sugeno fuzzy inference system, two typical IF/THEN fuzzy rules can be stated when a set of two inputs (x, y) and one output (f) is measured:

Rule 1: IF x is A1and y is B1, THEN f1=p1x+q1y+r1

Rule 2: IF x is A2and y is B2, THEN f2=p2x+q2y+r2

Where, p1, p2, q1, q2, r1, and r2 are linear parameters; A1, A2, B1 and B2 are nonlinear parameters.

The ANFIS architecture consists of five-layers: fuzzification, fuzzy AND, normalization, defuzzification, and the output layer. These layers are connected to each other through direct links and nodes.The first layer is the fuzzy layer, in which all nodes are adaptive nodes. The membership relationship between the output and input functions of this layer given below.

$$O_i^1 = \mu_{A_i}(x); i = 1,2$$

$$O_j^1 = \mu_{B_j}(y); j = 1,2$$

Here, *x* and *y* are the input of nodes *Ai* and *Bj* respectively. *Ai* and *Bj* are the linguistic labels used in the fuzzy theory for dividing the membership functions.
All the nodes are fixed nodes in the second layer. They perform as a simple multiplier and are labeled with M. The outputs of this layer are firing strengths and the relationship given below.

$O_i^1 = w_i = \mu_{A_i}(x)\mu_{B_j}(y)$; *i =1,2*

The nodes are also fixed nodes in the third layer. They are labeled with N, indicating that they perform as a normalizer to the firing strengths from the previous layer. The outputs of this layer are called as normalized firing strengths which can be represented as:

$O_i^3 = \overline{w_i} = \frac{w_i}{\sum w_i}$;*i=1, 2*

In the fourth layer, the nodes are adaptive nodes. For a first order Sugeno model, the output of each node in this layer is simply the product of the normalized firing strength and a first order polynomial and the output given below.

$O_i^4 = \overline{w_i} f_i = \overline{w_i}\ (p_i x + q_i y + r_i)$; i=1, 2

In the fifth layer, the only one single fixed node performs the summation of all incoming signals that are labeled with ∑ and the overall output of the model can be expressed as.

$$O_i^5 = \sum_{i=1}^{2} \overline{w_i} f_i = \frac{\sum_{i=1}^{2} w_i f_i}{\sum w_i} \text{ ; i=1, 2}$$

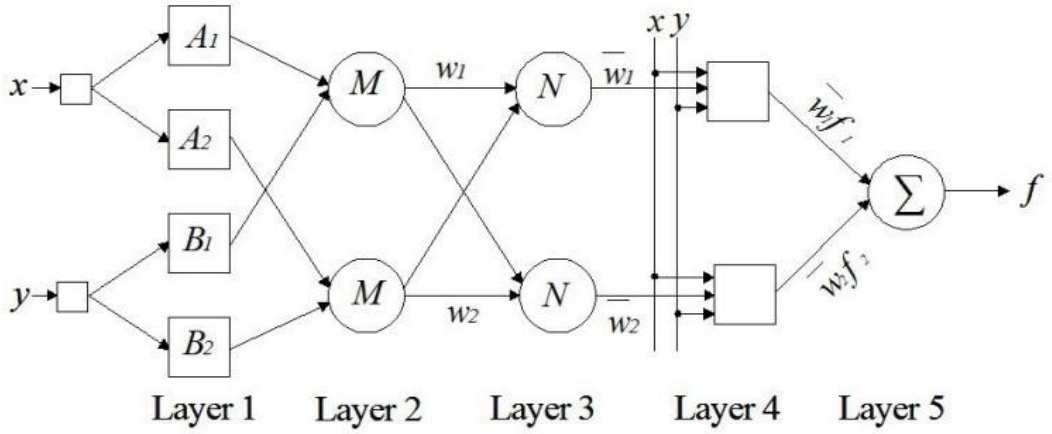

Figure 1: Architecture of Adaptive Neuro-Fuzzy Inference System (ANFIS)

2.3 Models Evaluation

To evaluate the performance of the model root-mean-square error (RMSE), correlation co-efficient (R) have been used.
Correlation co-efficient(R) is defined as:

$$R = \frac{\sum_{i=1}^{N}(O_i - O_{avg})(P_i - P_{avg})}{\sqrt{\sum_{i=1}^{N}(O_i - O_{avg})^2}\sqrt{\sum_{i=1}^{N}(P_i - P_{avg})^2}}$$

Where,
O_{avg}=mean of target classes; O_i = i^{th}target class; P_{avg}= mean of predicted classes; and P_i = i^{th}predicted class.
Root-mean-square error is defined as:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(O_i - P_i)^2}{N}}$$

Where,
N = total number of observations
Here, the lesser the value of 'R' and greater the value of 'RMSE', the corresponding attribute is more significant and vice versa.
Service quality (Sq),

$$s_q = \frac{X}{5}$$

Where,
X= Average weightage of scaling value 1-5 for each attribute.In where multiply by 5 with rank 1, 4 with rank 2, 3 with rank 3, 2 with rank 4 and 1 with rank 5.
According to public opinion, when the value of service quality (Sq) of an attribute is higher than others, then the attribute represents higher significant than other attributes.

3. ANALYSIS AND FINDINGS

3.1 Monthly Income

Total 400 bus users participated in the survey, among them 77% were male and 23 % female in Gazipur city. Nearly 30% bus user had monthly income 10-20k taka and normally generated at least 2 trips daily. About 19.5% passenger had monthly income 10k or less, 21.5% had 20-30k and 17.25% had 30-40k respectively. However, only 11.75% had monthly income more than 40K. Overall scenario clear the perception that most of the bus users were middle-class.

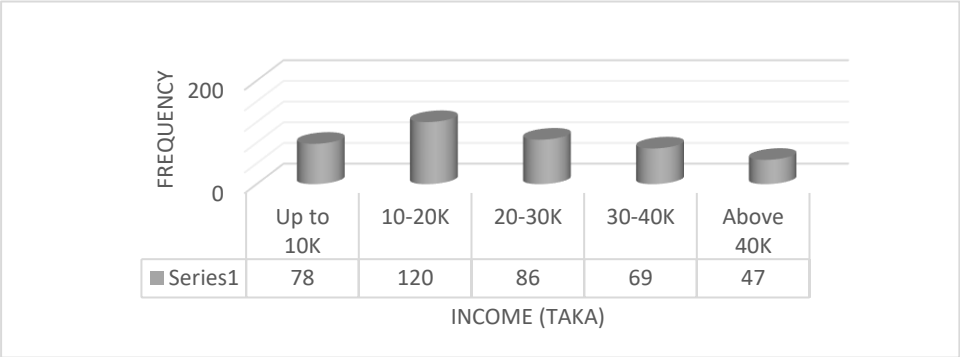

Figure 2: Income of Passenger

3.2 Age of Passenger

After analyzing, nearly 68% passengers were between 20 to 50 years old and most of them were involved in different professions, although few of them were student at the graduate level.

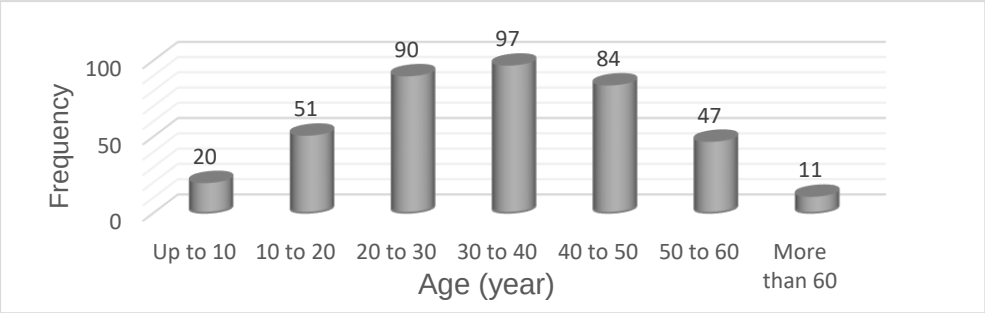

Figure 3: Age of Passenger

Bus users above 50 years old about 14%, were former professionals and few of them still continuing the jobs. Passenger below 20 years approximately 17%, most of them was student at various level and new professionals. But below 10 years, few of them involved with laborious works.

3.3 Attributes Ranking

Table 1 show that Punctuality and Reliability secure the rank 1 in both ranking method over 22 attributes due to the least R value and the largest RMSE according to ANFIS model. Passengers don't want to kill their valuable time on roads because of traffic congestion. On the other hand, Route information has largest R and lowest RMSE value, so rank 22 according to ANFIS model. On-time performance, Seat availability, On-board security, Structural condition bustook in top five places respectively. Bus users thought bus service providers would follow strict timetable to operate their service.

Table 1: Attributes Status Assessment

		ANFIS			Public opinion	
Sl. no	**Attributes**	**R**	**RMSE**	**Rank**	**Service Quality(Sq)**	**Rank**
1	Proximity from home	0.52692	0.57287	15	0.3612	19
2	Proximity from workplace	0.54052	0.55614	16	0.3204	22
3	Commuting frequency	0.47286	0.63752	11	0.4428	14
4	Service frequency	0.59759	0.42874	10	0.3508	8
5	Commuting period (weekdays)	0.38181	0.7691	12	0.5092	9
6	Commuting period (weekends)	0.23647	0.94953	9	0.5563	18
7	Ticketing system	0.49695	0.60834	13	0.4948	11
8	Fare expenditure (daily)	0.58301	0.48127	19	0.5100	20
9	Punctuality and reliability	0.20411	0.99111	1	0.5712	1
10	Seat availability	0.48898	0.62079	3	0.4108	2
11	Seat comfort	0.43883	0.7132	8	0.5012	10
12	Accessibility to/from bus	0.24422	0.91816	17	0.5124	12
13	Ventilation system	0.26622	0.90859	6	0.5536	5
14	On-board security	0.23952	0.93708	4	0.5561	3
15	Female harassment	0.55862	0.53717	18	0.3356	21

16	On-time performance	0.22850	0.98314	2	0.5556	4
17	Bus staff courtesy	0.36821	0.78351	21	0.4788	17
18	Structural condition	0.54502	0.55158	5	0.4940	7
19	Interior cleanliness	0.36160	0.88269	7	0.5172	6
20	Noise level	0.50492	0.59877	14	0.4676	15
21	Commuting experience	0.58962	0.46235	20	0.4876	13
22	Route information	0.69297	0.35306	22	0.4624	16

According to public opinion, Seat availability, On-board security, On-time performance, Ventilation system secured top five positions respectively. However, Proximity from workplace marked as lowest according to passenger discerning. Now people prefer private cars over public transports because of poor bus services. Consequently, traffic tail log is a common scenario in Gazipur and its surrounding areas. Better public transport could plummet not only the traffic congestion but also increase the standard of city living to enticing mass users toward it. The outcome of this study will convey some valuable suggestions to the service providers, operators, policymakers and transportation authorities about how to amend the bus SQ in view of attracting more passengers. However, due to inadequacies in resources of developing countries like Bangladesh, it is merely impossible to improve all the SQ attributes at once. This study delivers a platform for staged improvement with the most significant attributes to start with.

3.4 Bus Service Quality

Figure 4 shows overall service quality was not at satisfactory level. Based on passengers' thinking, only 3% were highly satisfied with current service quality, 27% thought service was good. But 64% passenger thought the service quality was poor to attract new users toward bus as a mode of transport. Also, 6% users claimed the service quality was very poor to use, they preferred another option for moving one place to another.

Figure 4: Bus Service Quality

4. CONCLUSIONS

This study focused on predicting the bus level of service of a newly growing city using fuzzy inference system to helps transport specialists to make the better decision on future transportation system to increase the quality of service, mobility, reduce pollution and provide vigorous city life. Punctuality and reliability found to be the most significant attributes in Gazipur city based on users' perception. However, present service quality was not at the satisfactory level, 64% passenger thought the service quality was poor to attract new users toward bus as a mode of transport. But 27% user accepts the present service quality because of their income level. Alarming thing is that a large number of people prefer private cars and other small vehicles over bus because of poor service quality. So better service of

public transport could fascinate mass users toward it over others mode of transport to reduce congestion and improve mobility.

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APPLICATION OF NUMERICAL RATING APPROACH FOR PEDESTRIAN SERVICE QUALITY PREDICTION OF DHAKA

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ABSTRACT

In a successful city, there is a clear trend towards plummeting the effect of motor traffic to improve the quality of life and make them more attractive to live in and to do business. Dhaka is one of the biggest metropolitan city in the world, although the living standard is getting worse. Involving more people in walking can reduce environmental impact, traffic trail log, in contrary increase longevity as well as social cohesion. Pedestrian service quality has a great impact on walkability. The objective of this research is to find out the pedestrian level of service using numerical rating approach based on users' perception of the Dhaka city. For the purpose of the study, nearly 400 data were collected from several points of the Dhaka city. The significant observation from the finding was that only accessibility, width, connectivity and sight distance of the footpath of the study area fulfill the pedestrian requirement with poor scoring. The findings would be extremely useful in decision making for the amendment of the pedestrian facility, to improve the living environment.

Key Words: *Numerical rating approach, level of service, walkability, pedestrian*

1. INTRODUCTION

Area of Dhaka is 1528 square kilometers with 10,000 per square kilometer population density. Being the metropolis, Dhaka is one of the least motorized cities in the world where 60% of trips are on foot (Rahaman, 2010). People tend to use walking as a mode of transport for their short trips. When pedestrian demand exceeds the walkway capacity, improperly designed walking facilities may fail to operate at satisfactory levels. In this situation, available space for pedestrian movement can drop drastically and there is a possibility of crowd-related problems, thus stampede at the Love Parade dance music festival in 2010 and stampede during the 2013 New Year's firework show in Ivory Coast (Sharifi, 2016). Walking facilities are designed effectively to provide a safe environment with preferred level-of-service for future pedestrian demand (Manik, 2013).

Pedestrians are the most vulnerable users of the road space in a broad sense. Lack of safety provisions or measures offers the pedestrian very dangerous situation. Discontinuation of the walkway alignment provides inconvenience for the older citizen and lack of separation of the walkways from the road space offers to treat to the accident for the school going children (Sakib, 2016). It is more severe for developing countries. In this situation, it is an important part to know the level of Service (LOS) of the Pedestrian so that the policy makers or the transport planners can understand the extent of problems that the pedestrians are facing in their daily life(Zhang, 2012). Every day a large number of people travel through the Shahbag, New Market, and Dhanmondi areas. For this reason, the study aims at finding the existing Pedestrian Level of Service (PLOS). The objective of this research is to find out the pedestrian level of service using numerical rating approach based methodology.

1.1 Study Area

Shahbag, New Market, and Dhanmondi have been selected as the study area to assemble different information and Level-of-Services of the walkways. It is the connecting point of old and new Dhaka and one of the congested place of the city. Major educational and medical institutions are located there. A huge number of new and local people are using the pathways regularly. So this location could provide the overall pedestrian service quality of the city according to its users.

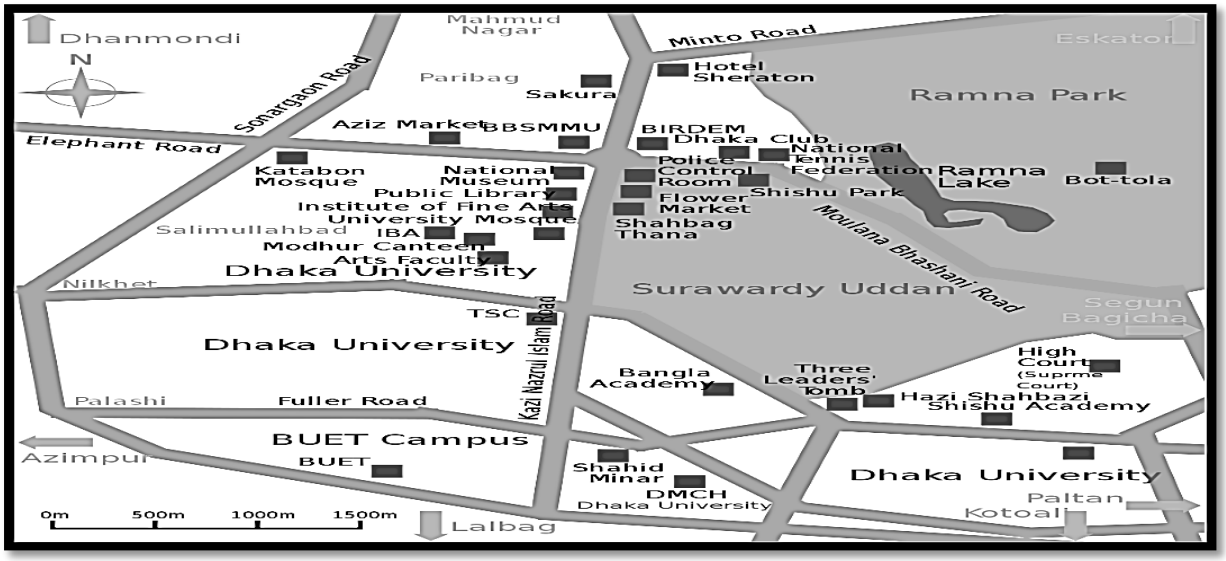

Figure 1: Map of Shahbag

1.2 Data Collection

In order to conduct this research, required data have been collected through face to face questionnaire survey. The questionnaire was pretested before final data collection. Necessary suggestions from transportation experts have also been taken during the preparation of questionnaire. The questions were properly explained and then they were asked to write their viewpoints. Total 400 data were collected from several points of the study area at the different time to include different aging groups of the city. The survey format was designed to explore the pedestrian level of service of the Dhaka city. Collected data were processed for subsequent analysis using software such as SPSS and Microsoft Excel.

1.3 Method

Numerical rating approach is a simple conventional weighted average method used to calculate Level-of-Service index (LOSI) for pedestrian (Shalini KANUGANTI, 2013).

$$\text{LOSI} = W_i \times R_i \quad (1)$$

Where,

W_i : Relative weight associated with the i^{th} services attribute

R_i : Service quality for the i^{th} services attribute for the existing situation

We find relative weight,

$$W_i = \frac{X}{\sum X} \quad (2)$$

Where,

X : Average weightage

$\sum X$: Total average weightage

And service quality,

$$R_i = \frac{X}{5} \quad (3)$$

Where,

X : Average weightage

2. DATA ANALYSIS AND FINDINGS

2.1 Gender Distribution

About 400 people participated in the survey among them 76% male and 24% female. The survey was carried out at the different time of the day to observe the effect of the pedestrian during rush hours and also during dull hours. The people from all age groups were asked to jot down their perception.

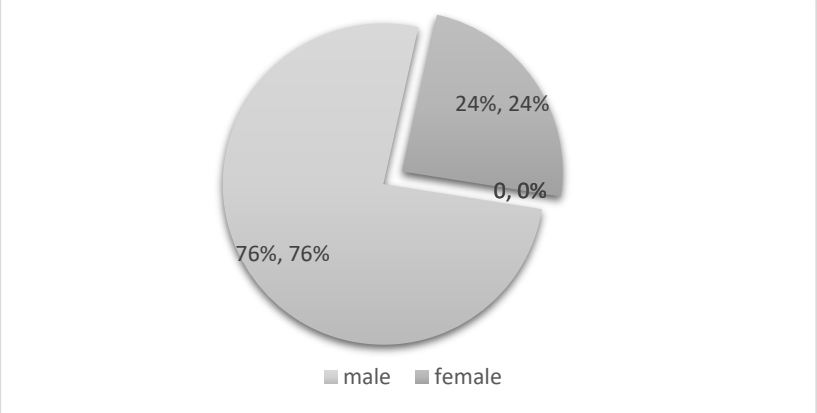

Figure 2: Gender Distribution

2.2 Pedestrian Level of Service

If the scale for weight associated with the service characteristics is such that $\sum_{i=1}^{n} W_i = 1$, and the value score is expressed with respect to unity, then the maximum possible LOSI as per equation (1) is one. LOSI values closer to 1 indicate very high LOSI, whereas, closer to 0 indicates very poor service level. However, the practically pedestrian system is expected to provide a LOSI as high as 1. Thus, it is important to know the accepted LOSI, by the users, in a developing country like India. It has been observed that 0.6 may be used as the value for accepted service level (Shalini KANUGANTI, 2013).The same value has been considered in this study also.

As per the objectives framed for this study, data analysis was done using conventional weighted average method for all the pedestrian services considered for this study, the detailed calculations and results are shown in Tables 1, 2, and 3, as for example. Pedestrian's opinions are then averaged. The results shown in column 8 of Table 1 represent a weighted average opinion on the importance of service quality of the nineteen attributes for the pedestrian on a conventional rating scale of 1-5, with ‘e’ being ‘very bad’ and ‘a’ being ‘excellent’ condition. It is evident from the results showing relative weights in Table 1 that Accessibility, Connectivity, and Sight Distance have comparatively high weightage.

Table 1: Relative Weight of the attributes

Attributes	**Number of passengers putting weights on**					**Average weightage (X)**	**Relative weight** $W_i = \frac{X}{\sum X}$
	a*5	b*4	c*3	d*2	e*1		
Accessibility	23	114	150	89	24	3.06	0.07
Width	0	145	153	102	0	3.11	0.07
Surface Quality	0	45	99	165	91	2.25	0.05
Support Facility	0	44	89	123	144	2.08	0.04
Connectivity	14	123	155	108	0	3.11	0.07
Environment	0	0	55	162	183	1.68	0.04
Potential Vehicular Conflict	0	56	167	100	77	2.51	0.05
Cleanliness	0	78	111	113	98	2.42	0.05
Lighting Facility	0	88	60	159	93	2.36	0.05
Comfortableness While Crossing	0	16	55	141	188	1.75	0.04
Comfortableness While Heavy Vehicle Approaches	0	14	60	200	126	1.91	0.04
Comfortableness while Lighter Vehicle Approaches	0	67	118	124	91	2.40	0.05
Comfortableness while Non-Motorized Vehicle Approaches	0	145	156	99	0	3.12	0.07
Safety Barrier	7	102	128	122	41	2.78	0.06
Volume	0	73	109	89	129	2.32	0.05
Sight Distance	45	151	102	83	19	3.30	0.07
Personal Security	0	48	59	117	176	1.95	0.04
Aesthetic	0	51	201	113	35	2.67	0.06
Non-Pedestrian Activity on Footpath	0	11	69	131	189	1.76	0.04

According to pedestrians' opinion, there were better connectivity, width of pathway and visibility than others, though it was not so satisfactory level. At night poor visibility was a hackneyed scenario because of the lacking of the adequate lighting system.

Table 2: Service Quality with respect to Unity of the Attributes

Attributes	**Number of passengers putting weights on**					**Average weight (X)**	**Service quality (X divided 5)**
	a*5	b*4	c*3	d*2	e*1		
Accessibility	23	114	150	89	24	3.06	0.61
Width	0	145	153	102	0	3.11	0.62
Surface Quality	0	45	99	165	91	2.25	0.45
Support Facility	0	44	89	123	144	2.08	0.42
Connectivity	14	123	155	108	0	3.11	0.62
Environment	0	0	55	162	183	1.68	0.34
Potential Vehicular Conflict	0	56	167	100	77	2.51	0.50
Cleanliness	0	78	111	113	98	2.42	0.48
Lighting Facility	0	88	60	159	93	2.36	0.47
Comfortableness While Crossing	0	16	55	141	188	1.75	0.35
Comfortableness While Heavy Vehicle Approaches	0	14	60	200	126	1.91	0.38
Comfortableness while Lighter Vehicle Approaches	0	67	118	124	91	2.40	0.48
Comfortableness while Non-Motorized Vehicle Approaches	0	145	156	99	0	3.12	0.62
Safety Barrier	7	102	128	122	41	2.78	0.56
Volume	0	73	109	89	129	2.32	0.46
Sight Distance	45	151	102	83	19	3.30	0.66
Personal Security	0	48	59	117	176	1.95	0.39
Aesthetic	0	51	201	113	35	2.67	0.53
Non-Pedestrian Activity on Footpath	0	11	69	131	189	1.76	0.35

On the other hand, non-pedestrian activity on footpath, comfortableness and personal security scored the lower as second poorest services. Larceny and female harassment was a trite matter in Dhaka. Poor security system for female discourages them to walk lonely. At night both male and female felt uncomfortable at several locations of the pathway only for burglary. Sometimes it was a deadly thing for the pedestrian to walk lonely when they met with robbers.

Table 3: Deficiencies on pedestrian level of service

Attributes	Relative weight (Scale Value) (1)	Service quality (2)	LOSI (3) = (1)*(2)	Acceptance Level (60% of Scale Value) (4)	Deficiencies from acceptance Level (5)=(3)-(4)
Accessibility	0.066	0.612	0.040	0.039	0.001
Width	0.067	0.622	0.042	0.040	0.001
Surface Quality	0.048	0.449	0.022	0.029	-0.007
Support Facility	0.045	0.417	0.019	0.027	-0.008
Connectivity	0.067	0.622	0.042	0.040	0.001
Environment	0.036	0.336	0.012	0.022	-0.010
Potential Vehicular Conflict	0.054	0.501	0.027	0.032	-0.005
Cleanliness	0.052	0.485	0.025	0.031	-0.006
Lighting Facility	0.051	0.472	0.024	0.030	-0.007
Comfortableness While Crossing	0.038	0.350	0.013	0.023	-0.009
Comfortableness While Heavy Vehicle Approaches	0.041	0.381	0.016	0.025	-0.009
Comfortableness while Lighter Vehicle Approaches	0.052	0.481	0.025	0.031	-0.006
Comfortableness while Non-Motorized Vehicle Approaches	0.067	0.623	0.042	0.040	0.002
Safety Barrier	0.060	0.556	0.033	0.036	-0.003
Volume	0.050	0.463	0.023	0.030	-0.007
Sight Distance	0.071	0.660	0.047	0.043	0.004
Personal Security	0.042	0.390	0.016	0.025	-0.009
Aesthetic	0.057	0.534	0.031	0.034	-0.004
Non-Pedestrian Activity on Footpath	0.038	0.351	0.013	0.023	-0.009

Dhaka may present the poorest scenario concerning others Megacity. Nearly 89% pedestrian felt that the walkway environment was very unpleasant not only for the deficiency of amenities but also for its milieu. The environmental effect with aesthetic view imparts predominating criteria on the pedestrians generally as dirt roads and surfaces are avoided by the general people of all classes.

3. RECOMMENDATIONS

Some recommendations and policy measures are given for the amendment of the service quality of the pedestrian pathways. Walking is very crucial for healthy living and effective transportation system.

3.1 Educational Measures

Continuous road safety and educational campaign are indispensable to aware, motivate, educate and above all to change the attitude of our people regarding traffic rules and regulation. Proper road behavior instructions, with focused messages should be broadcast through the mass media and separate topics may add on traffic rules and regulation in the institutional academic book mainly for children. Target programs should be arranged for high-risk pedestrian and driver groups.

3.2 Policy Measures

Most of the unsafe situation occurred on the road for the competition attitude of the drivers. So, for safe, reliable and friendship movement, all of the mass transit may be offered by one or two larger company. The detail land use master plan must be established and proper implementation should be ensured. Roadside base multi-storied commercial development should be controlled.

3.3 Amendment of Footpath

Attractive and user-friendly footpath facility must be ensured by eliminating retailer traders and hawker gradually. Besides this, it will be geometrically and aesthetically improved for increasing attraction and comfort, as pedestrians are encouraged to use the footpath. Haphazard parking on a roadside, illegal use of footpath like a garage, building material should be eradicated. Install pedestrian fencing or other barrier types on the approaches and in the nearby zones of high risk. Pedestrian support facilities like potable water, toilet system, seating, and other amenities must be provided for better walkability in the Dhaka metropolis.

4. CONCLUSIONS

Numerical rating approach has been used to find out the pedestrian level of service in Dhaka metropolis to amend the quality in the nearest future for better walkability. According to the objective, the environment of the footpath was ranked poorest in quality based on the perception of the Dhaka city walkers. Waste containers and spreading squalorson the pathways discourage users to walk. Besides, non-pedestrian activity on the pathways, comfortableness, and security were second poorest services in the study area. Few points of the footpaths were blocked by vendors to selling their goods to obstruct flowing and force to use the main carriageway of the road which could be responsible for conflict with vehicles. However, width and connectivity of the pathway were acceptable but not in satisfactory. Overall pedestrian service quality was very poor to attract users to walk than another mode of transports. So adequate support facilities and policy measures would improve the quality of the footpath and efficacy of the overall transportation system of the Dhaka city.

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EFFECT OF ROAD INFRASTRUCTURES ON CASUALTY OCCURRENCE IN BANGLADESH

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ABSTRACT

Every year a considerable number of casualties befall by dint of road crashes which ensure that Bangladesh is a crash prone country. Different independent factors are directly and indirectly associated with these casualties emanated by road incidents. With this note a firm model is incumbent to explore the adverse effects of different structural elements, aka road infrastructures on the injuries caused by crashes in context of Bangladesh for road safety. Considering all districts of Bangladesh, 13 types of road infrastructures, and different types of roads and highways have been taken as predictors to identify their probable detrimental effects on the casualty pattern around the country in terms of road infrastructures. Fatal, grievous, and simple injuries have been taken as response variables in this study. Count data models i.e. Poisson Regression has been applied on the data to come up with a functional form between road casualties and road infrastructures. The reason of choosing the model is that the data consist of non-negative integer values of casualty for all 64 districts from 2009 to 2013. The results display whether several infrastructures e.g. Box culverts, bridges made of PC girder, RCC girder, Steel beam and RCC slab (SBRS), Truss with Steel Deck (TSD) etc. have positive or negative effect on the resulting casualties.

Keywords: *Road infrastructures; crash; injury; poisson; casualty*

1. INTRODUCTION

Road safety has become a global issue of concern for both developing and developed countries where road crash injuries are of concern. It needs efforts from the ground level to avoid thousands of lives being lost in road crashes around the world (Kapila, Prabhakar & Bhattacharjee, 2013). An estimation from World Health Organization (WHO) indicates that worldwide every year approximately 1.2 million deaths and about 40 million injuries result from traffic accidents and it causes considerable economic loss due to treatment cost and productivity loss for those killed or disabled by their injuries (WHO, 2017). The scenario is worse in developing countries. About 90% of worlds' fatalities occur in low and middle-income countries. Crash rates are 10-70 times higher in developing countries than the developed ones (Sheikh, 2004). WHO fears that by 2030 road crash will be promoted to fifth position of leading cause of death that may approximately result in 2.4 million fatalities per year (WHO, 2017).

As a developing country, Bangladesh is no exception. Fatality rate here is almost 25 times higher than that of most of the developed countries, 8 times higher than that of Thailand and 3 times higher than that of India (Jahan, 2006). Every year nearly 5000 accidents occur in Bangladesh (Hoque et. al., 2006) of which about 60% of the accidents occur on national and regional highways and 40% on urban roads (Hoque, 2004).

The risk of casualties and severe injuries are influenced by multiple factors, for example, vehicle features, road network design and operation, driver and driving characteristics, environmental conditions, and so on. The injury risks of individuals in traffic crashes are influenced by a multitude of factors including vehicle features, roadway design and

operation, driver characteristics, type of collisions and environmental conditions. However, when the traffic casualties are grouped in a larger spaced based scale such as county, ward or state rather than on a particular road segment or at an intersection, many factors related to road infrastructures can be examined (Rifaat, Rahman, Mohammed & Pasha, 2014). An important aim of transport policy is to reduce the road traffic casualties. To fulfil this objective, it is essential to know what factors are responsible for traffic casualties before any efficient policy response can be identified (Wang, Quddus & Ison, 2009). Considering Bangladesh as its study area, the objective of this research is to identify and examine the effects of district wise road infrastructures on the casualty occurrences of this country.

2. LITERATURE REVIEW

Considerable number of research works explored casualty or injury occurrence with other explanatory variables to show relationships among them. Khan, Shanmugam & Hoeschen (1999) explored the relationship between crash injuries of different types with traffic volume, road segment length, and vehicle miles travelled (VMT). The main focus here was to investigate which count models could perform better. Quddus, Noland & Chin (2002) examined the effect of road types, and their engineering characteristics, type of collision that occurred, type of motorcycle, rider demographic characteristics, and environmental factors on injury severity of motorcycle accidents. In 2006, Chang and Wang developed a Classification Analysis and Regression Trees (CART) model to understand the relationship between injury and driver or vehicle characteristics, and come up with a result of being most contributing variable is vehicle types. Pedestrians, motorcyclists, and bicyclists are considered to be high vulnerable groups associated with injury severity. Mohamed, Saunier, Miranda-Moreno & Ukkusuri (2013) examined pedestrian injury severity analysis using statistical regression and data mining techniques. This study used road geometry, built environment, and socio-demographic characteristics as the contributing factors. From the results, they found that pedestrian age, location type, driver age, vehicle type, alcoholic drivers, road lighting conditions etc. are associated with crash injuries and deaths. Anarkoli et al. (2017) made a research on roll over crash and injury. Random effect generalized ordered probit model was used to analyse injury severity pattern. In the results discussion part, they concluded identifying the major problematic variables of insufficient lighting, rainy weather, improper overtaking, vehicle age, traffic volume, and unsafe roadside conditions. Chong et al. (2017) investigated the paediatric road traffic injuries by performing paediatric retrospective chart view of road crash injuries. Child pedestrians, bicyclists, and motorcyclists were found to be vulnerable.

Moreover, some studies examined injury severity pattern when changing mode of transport from car to bicycle (Nilsson, Stigson, Ohlin & Strandroth, 2017), to investigate the relationship with highway design and crash injury count to identify significant road features (Raihan, Hossain & Hasan, 2017).

Various studies have been performed using the primary traffic data of Bangladesh. For example, Ahsan et al. (2011) evaluated various types of road traffic injuries resulting from car accident in Bangladesh. Using ordered probit models Kamruzzamana, Haque & Washington (2014) made an analysis on how roadway, traffic, and environmental factors influence injury severity of road traffic crashes. Raihan, Hossain & Hasan (2017) investigated the hazardous clusters of traffic crash and injury to evaluate their performance in manifesting crash causes in Bangladesh.

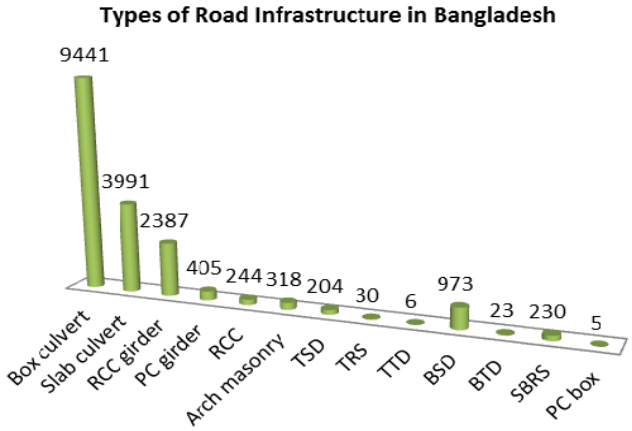
From the above discussion, it is evident that most of the studies are based on the aggregate level of casualties or injuries that incurred from road accidents but none of these studies have included different types of road infrastructures and disaggregate level of injury data in their research. In this study, we have used 13 types of road infrastructures and their lengths, highway lengths of both urban and rural areas as new contributing factors in road safety

literature and traffic injuries. We used the data of all the districts of Bangladesh to investigate the relationship between them.

3. DATA COLLECTION

In our study, district level data had been taken as the unit. We have managed to get data of crash injury of all 64 districts in Bangladesh. Accident Research Institute (ARI), Bangldesh University of Engineering and Technology (BUET) provided all the district wise data of Fatal, Grievous and Simple injuries from years 2009 – 2013. The aggregated sample from 2009 – 2013 are 10947, 5261, 1912 for fatal, grievous, and simple injuries respectively. It is important to note that in Bangladesh crash report data are not comprehensive enough. Some study revealed that most of the crash and injury data collected in Bangladesh are underreported (Raihan, Hossain & Hasan, 2017).

From RMMS (Road Maintenance Management System) data base of Roads and Highway Department (RHD), we have collected 13 types of road infrastructures constructed in Bangladesh. Figure 1 shows the types of infrastructure and the number of structures existing in Bangladesh in all 64 districts.



[Here, TSD = Truss with Steel Deck, TRS = Truss with RCC Slab, TTD = Truss with Timber Deck, BSD = Baily with Steel Deck, BTD = Baily with Timber Deck, SBRS = Steel Beam and RCC Slab, PC = Pre-stressed concrete]

Figure 1: Types of Road Infrastructure in Bangladesh (Source: RHD)

The fair condition of national highway, regional highway and zilla road comprises 2932 km, 2264 km, 8337 km; minor damage condition comprises 661 km, 661 km, 1611 km; major elemental damage are in 644 km, 969 km, 2317 km; major structural damage remain in 108 km, 224 km, 764 km respectively. The data of earthen and pavement roads of upazilla, union and village are extracted from the Local Government and Engineering Department (LGED).

4. METHODOLOGY

In this study, Poisson regression model was used as a method because of its wider use in rare, discrete and non-negative event data modelling. At first, we conducted negative binomial regression to track the dispersion parameter whether it is significantly over dispersed or under dispersed. As we found this parameters' value close to zero, we preferred Poisson regression model to analyse the data.

4.1 Poisson Regression

If event 'n' occurs according to a Poisson process with parameter μ, then the Poisson distribution can be written as:

$$P(n_{it}) = \frac{e^{-\mu_{it}} \mu^{n_{it}}}{n_{it}!} \quad (1)$$

where, μ_{it} is the Poisson parameter for road segment 'i' in time 't', which is road segment i's expected number of injuries, E[n_{it}], 'n_{it}' is the probability of 'n' injuries occurring on roadway segment 'i' in the time 't'. Poisson regression specifies the Poisson parameter μ_{it} as a function of explanatory variables by using log-linear function:

$$\mu_{it} = e^{\beta X_{it}} \quad (2)$$

where, $\mathbf{X_{it}}$ is a vector of explanatory variables and **β** is a vector of estimable parameters [38]. The Poisson distribution has the limitation that the variance and mean should be approximately equal i.e.

$$\text{Var}(n_{it}) = E(n_{it}) = \mu_{it} \quad (3)$$

If this equality does not hold, the data are said to be under-dispersed (E [n_{it}]>Var [n_{it}]) or over-dispersed (Var [n_{it}] > E [n_{it}]). In our case, the assumption is not violated. So, we can go for Poisson regression as stated earlier.

In this study, 95% confidence interval was used, p value was used to describe the variables significance in the developed model. The determinants with p-value less than 0.05 were considered as the statistical significant factors in this model.

4.2 Model Evaluation

The statistical models are evaluated to select the best model from the competitive set of models. The evaluation will be done with the help of two statistics: Likelihood Ratio Test and Log-likelihood Ratio Index
(ρ^2).

$$X^2 = -2[(\boldsymbol{\beta}_R) - (\boldsymbol{\beta}_U)] \quad (4)$$

Where, ($\boldsymbol{\beta}_R$) is the log likelihood at converges of the 'restricted' model and ($\boldsymbol{\beta}_U$) is the log likelihood at converges of the unrestricted model. The test statistic is X^2 distributed with the degrees of freedom equal to the difference in the numbers of parameters in the restricted and unrestricted model.

To measure the overall goodness of the models, the log-likelihood ratio index will be calculated which is shown below:

$$\rho^2 = 1 - \frac{L(\beta)}{L(0)}^2 \quad (5)$$

where, L(**β**) is the log likelihood value of the fitted model and L(0) is log likelihood value of the model only with constant term.

5. RESULTS AND DISCUSSION

Table 1 shows the summary of the descriptive statistics of the independent variables and Table 2 shows the results and estimations from the final model. Due to large volume of data we presented the mean and standard deviation of the significant variables in Table 1. In general, the 3 individual traffic injury models fitted the data well with fairly large chi-square goodness of fit. We reported The pseudo square R for all models as well. We considered a varible statistically significant if the p-value is ≤ 0.05. We also presented the discussions on the effects of significant variables in these three categories.

Table 1: Descriptive statistics of the significant independent variables

Variables	Mean	Standard Deviation
Road Infrastructure National Highways (km)		
PC Girder	546.78	1001.84
Steel Beam and RCC Slab	55.03	132.03
Box culvert	225.70	255.54
Truss with RCC Slab	89.29	368.35
Truss with Timber Deck	24.32	137.53
RCC	24.59	78.25
RCC Girder	497.46	732.42
Pre-stressed concrete	111.73	537.85
Regional Highway (km)		
Arch Masonry	6.78	18.87
Baily with Steel Deck	149.45	270.11
Steel Beam and RCC Slab	18.48	75.48
RCC Girder	312.12	354.15
Slab Culvert	36.06	68.39
Zilla Road (km)		
Arch Masonry	5.86	10.77
PC Girder	368.16	598.53
Baily with Steel Deck	558.37	783.18
RCC Girder	908.43	638.26
RCC	48.03	71.65
Pre-stressed concrete	4.91	38.94
Slab Culvert	122.49	115.80
Truss with RCC Slab	22.76	107.74
Highway length (km)		
National Highway	55.92	50.62
Union Road	704.37	357.85
Upazilla Road	602.80	210.04
Village Road	1768.79	950.32
Lengths that are not surveyed	22.71	31.09
Union Road (km)		
Rigid Pavement	12.11	31.79
Brick pavement	49.78	69.41
Structure Span	1012	650.78
Upazilla Road (km)		
Rigid Pavement	20.02	36.15
Brick Pavement	22.67	27.12

Earthen	116.87	121.75
Structure Span	965	594.15
Village Road (km)		
Structure Span	1296	931.94
Earthen type	1600.80	873.48
Rigid pavement	11.54	20.98
Number of existing gap	438	388.75

In National Highways, PC girder, Box culvert, RCC bridge, and RCC girder made structures promote casualty swelling that means if the number and length of these structures increase the probability of any of the casualty occurrence due to road crashes also increase. Narrow widths of the structures, less carriageway, less shoulder width may be the reason of this unsafe condition. On the contrary, SBRS, TRS, TTD structures that are made of steel materials tend to decrease casualties. This result indicates that steel made structures may promote safety improvement in the national highways for any types of injury occurrence which indicate satisfatory roadside condition for driving ensuring drivers' cautious driving.

In the rigional highways different type of road incrastructures had mixed effect on the casualty occurrences. We discovered structures that are construted with Arch masonry and RCC are safe for slight injury and serious injury occurrences respectively. On the other hand, BSD, SBRS type strucutres are found less safe for this particular type highway which is the opposite scenario we found in the case of national highways. Drivers attitude may one of the reasons for this result. In regional areas drivers may face less hindrance in speeding up as the traffic volume of those roads is less than this of the national higways. So, speeding is one of the causes of injuries and deaths in this region due to the presence of these types of structure. Maintenance should be considered as one of the key issues as timely maintenance and retofitting of the structures are contributory factors to the sustainability of that particular structure for a long time without interruption in the operation of traffic network.

Table 2: Parameter estimates of all 3 casualties

Variables	**Estimated coefficient (β) and p-values of casualty models**		
	Fatal	**Grievous**	**Simple**
Road Infrastructure National Highways (km)			
PC Girder	0.00018 (0.000)	-	-
Steel Beam and RCC Slab	-0.00069 (0.000)	-	-
Box culvert	-0.00077 (0.000)	0.00078 (0.000)	0.00063 (0.000)
Truss with RCC Slab	-	-0.00084 (0.000)	-
Truss with Timber Deck	-	-	-0.00164 (0.000)
RCC	-	-	0.00226 (0.000)
RCC Girder	-	-	0.00015 (0.014)
Pre-stressed concrete	-	-	-0.00031 (0.003)
Regional Highway (km)			
Arch Masonry	-	-	-0.00544 (0.002)
Baily with Steel Deck	0.00103 (0.000)	-	0.00010 (0.010)
Steel Beam and	0.00406 (0.000)	0.0054 (0.000)	-

RCC Slab			
RCC Girder	-	-0.00067 (0.000)	-
Slab Culvert	-	-	0.00241 (0.000)
Zilla Road (km)			
Arch Masonry			0.00525 (0.021)
PC Girder	0.00071 (0.000)	0.00087 (0.000)	-
Baily with Steel Deck	-0.00161 (0.001)	-	-
RCC Girder	-0.00029 (0.000)	-	-
RCC	-	-	-0.00299 (0.000)
Pre-stressed concrete	-	-	-0.00266 (0.001)
Slab Culvert	-	-	-0.00321 (0.000)
Truss with RCC Slab	-	-	-0.00164 (0.000)
Highway length (km)			
National Highway	0.00894 (0.000)	-	-
Union Road	-	-0.01188 (0.000)	-
Upazilla Road	-	0.00280 (0.000)	-
Village Road	-	0.00020 (0.001)	-
Lengths that are not surveyed	0.008 (0.000)	-	-
Union Road (km)			
Rigid Pavement	0.0083 (0.000)	-	0.00402 (0.000)
Brick pavement	0.003716 (0.001)	-	-
Structure Span	-	-0.0078 (0.000)	-
Upazilla Road (km)			
Rigid Pavement	-	-0.00364 (0.014)	-
Brick Pavement	-	-	0.003275 (0.005)
Earthen	-	-	0.001614 (0.000)
Structure Span	-0.000029 (0.015)	0.00587 (0.000)	-0.00412 (0.000)
Village Road (km)			
Structure Span	0.000061 (0.000)	0.00142 (0.000)	0.0002237 (0.003)
Earthen type	-	-0.00092 (0.000)	-
Rigid pavement	-	0.01873 (0.000)	-
Number of existing gap	-0.000048 (0.000)	-	-
Number of observation	64	64	64
LR χ^2	882.70	377.11	749.89
Pseudo R^2 (%)	0.7807	0.6481	0.4757
Log likelihood	-124.01048	-102.38766	-413.17315

Our results indicate that, in Zilla roads, serious injuries are not so frequent with the presence of any of the structures along the roads. It shows the same results that were found in the national highways for causing fatal and slight injuries. Some facts are needed to be clarified here is that if the roads here do not promote severe injury occurrence, the reason may be the reduced speeding of the vehicles. In Zilla roads, roads are narrow and drivers face obstacles in the roads while driving, so they may not feel comfortable to speed up their vehicles in those roads. On the contrary, if the scenario is opposite that means if frequent casualty occurrence is found here then the possible reasons may be the inattentiveness of

both drivers and pedestrians. In Zilla areas several village roads are present. So, open air markets beside the roads, risky crossing of the road without looking elsewhere is frequent. Also, vehicle type is an important factor that is needed to be mentioned here. In some cases fatality occurred because of the collision of motorcycle and tructors though both of the vehicles are low speed vehicle.

From our analysis the results show that national highways and the roads that are not surveyed yet, tend to increase more casualties. In the highways, the exposure and road environment are different from place to place. Drivers may feel uncomfortable in unfamiliar roads and the perception reaction time in those new roads may decrease. As a result, the probability of occurring casualty increases. In the sub-urban areas i.e., union roads and upazilla roads made of brick pavement are likely to increase fatal and slight injury casualties. Also, rigid pavement roads are vulnerable for fatal injuries in union areas. During rainy season these roads in the sub-urban areas may deteriorate in quality. As the demand and traffic flow in these road networks are less, these roads may not be constructed with great care. In the sub-urban areas if a road gets damaged, it takes many days and months to repair it in a good way for traffic movement. Also, the ESAL (Equivalent Single Axle Load) value that was initially taken for the road design may over exceed the demand of the road. Because, heavy vehicles mingling around those areas are likely to be responsible for road damage more than relatively lighter traffic.

Earthen type structures in the village areas are likely to be safe against serious injuries. Also, the number of structural spans show mixed result for the occurrence of casualties in the union, upazilla, and village areas. Another statistically significant variable in the model is the existing gap which means the gap in the continuous road network. These gaps decrease the demand of traffic by providing alternative routes and modes. By minimizing traffic exposure these gaps may reduce casualty occurrence.

6. CONCLUSIONS

In this paper, we present the effects of road infrastructures on different types of traffic casualties occurred in Bangladesh. It is an initial attempt that we made to show whether there exists any relationships among them. From the research output, we found some notable relationships, for example, steel made structures are found safe for the national highways, some concrete made structures in the regional highways are found safe for fatality and slight injuries, more national highways promote more injuries, rigid and brick pavements are found vulnerable for fatal injuries, lengths that are not surveyed yet may provide vulnerable environment for the drivers, vehicle occupants, and for the pedestrians.

There are some limitations in the model used in this study. We did not consider the traffic volume of each of the roads due to resource constraints. As we have made an early attempt to come up with a relationship between road infrastructures and traffic injuries, there are plenty of opportunities to improve this concept by conducting several researches. We can include different types of vehicles in the model to show which vehicle influence more on the traffic injuries if road infrastructures are present in that road. We can also include weather factors, socio-economic demographic factors in the model to show the variation of the result and to discover more significant findings.

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Simulating Hazardous Traffic Condition for Urban Expressways - A Micro-Simulation Approach

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ABSTRACT

Micro-simulation approach is a profound tool used by researchers to determine and analyze traffic characteristics. Micro-simulation approach gives access to car following as well as lane changing behavior of individual vehicle and allows analyzing their interactions by changing the parameters. CUBE Dynasim is a micro-simulation software developed by CITILABS which was used in this study. In CUBE Dynasim the normal traffic condition was created by using aggregated flow data obtained from Route 3 and Route 4 of Tokyo Metropolitan Expressway. The value of the parameters were altered to create hazardous traffic flow condition. In this study procedure to create a micro-simulation model is discussed in detail.Best possible result was obtained by changing the values of car-following maximum threshold and mean of threshold value for car following rules. Again, in case of lane changing behavior changing of heavy vehicle threshold, light vehicle average time, light vehicle minimum time, light vehicle maximum time, light vehicle standard deviation, light vehicle minimum distance, heavy vehicle average time, heavy vehicle minimum time, heavy vehicle maximum time, heavy vehicle standard deviation, heavy vehicle minimum distance reflected best result.

Keywords: *Micro-simulation; Hazardous Traffic Condition; Car-following; Lane Changing; Pro-active Road Safety*

1. INTRODUCTION

Objectives of urban expressways are to reduce travel time, mainly during the peak hour connecting major traffic attractions and productions. They are by design highly access controlled and can be quite expensive to construct. Urban expressways in general have fewer numbers of lanes than freeways or surface roads. In many cases they are privately operated as well. Hence, when there is a crash occurring on the urban expressways, the consequences are high. A crash during peak hour on an urban expressway can heavily impact the travel time, which was the primary objective of building such structures. At the same time, it results in heavy loss of revenue and low accessibility can make rescue activity quite challenging as well.

Remarkable developments in the field of Intelligent Transportation System (ITS), is seen in past two decades. These have promoted several studies on improving safety aspects of access controlled roads. Now a day, many of the expressways in the developed world are instrumented which are generating a substantial amount of data on the current traffic condition in real-time. This has opened the door to monitor traffic condition closely and identify any anomaly that can evolve into a hazardous traffic condition elevating the probability to make driving errors. This one and a half decade old field in transportation deals with predicting crash probability in real-time and the resulting models is called real-time crash prediction models.

Speed variation was a prime variable on likelihood of occurrence of crash which was developed based on real data (Oh et al. 2001). By establishing relationships between

coefficient of variation in speed, traffic density and speed difference to determine likelihood of crash occurrence, a log linear model for freeway and ramp was developed by Lee et al. (2003). Separate real-time crash prediction model was developed by Hossain and Muromachi, (2011). Clustering analysis to establish connection between different traffic states and crash risks on freeways was used by Xu et al. (2012). Crash prediction models were also developed using crash reports, real-time traffic and weather data (Yu and Abdel-Aty 2014).

For a proactive road safety management system, after predicting crashes, it is important to be able to identify how to bring the traffic condition back to normal. Several studies have shown that it is possible to bring the traffic condition back to normal by the implementation of different interventions.

Variable Message Signs have been incorporated in many metropolitan cities in the world (Van Eeden et al., 1996) in the hope that the information provided by these signs will alter drivers' behaviour in appositive manner. Louma and Rama (2001) studied the comprehension of pictograms for VMS conducted on European drivers, demonstrated how difficult it is to find images which are readily understood.

The relationship between speed and accidents is a complex one. Worldwide 5 to 15% accidents occur due to over speed. Anderson and Nilsson (1997) reports that the reduction of speed by 1 mile/h (1.6 km/h) reduces the casualties by 5% and reduction of mean speed by 10% results in a reduction in fatalities by 40%. Finch et al. (1994) suggests that an increase in mean speed by 2 to 4 miles/h (approximately 3 to 6 km/h) results in an increase in fatalities by 19 to 34%. Variable speed limits are commonly used with variable message signs in order to reduce the speed of vehicles to relieve congestion or warn of an unseen danger downstream (Gayah et al., 2006). VSL are used to increase average headways and reduce variances in speed (Borrough, 1997; Ha et al., 2003; Pilli-Sivola, 2004). This translates into fewer crashes (Smulders, 1990). Borrough (1997) found that the use of VSL and strong enforcement (video cameras) greatly reduce the number of crashes (28% over 18 months). The effect was attributed to not only a smoothing of traffic conditions through longer following distances, but also through reducing the number of lane changes during congestion (Borrough, 1997). Lee et al. (2004) used VSL to try and reduce crash potentials. Abdel-Aty et al. (2006) used a longer stretch of freeway from I-4 in Orlando to test the effect of VSL. Gayah et al.(2006) showed in their study that VSL had little to no effect on the crash risk index during the low-speed condition. This is most likely caused by the fact that during the low-speed scenario vehicles are travelling at congestion well below posted speed limit and, therefore, the change in speed limit on the roadway will not effectively change the speed the vehicles are travelling at.

The objective of ramp metering is to reduce delay and maintain capacity flow on a freeway by regulating access of ramp traffic to the mainline. Empirical studies have shown that ramp metering reduces turbulence in the merge zone, reduces variance in speed distributions, and thereby improves traffic safety i.e. reduces sideswipe and rear-end crashes (Lee et al., 2006). Ramp metering is used to reduce congestion by limiting the number of vehicles entering a freeway at a given time to avoid bottlenecks that typically occur at freeway on-ramps (Gayah et al., 2006). Empirical studies suggested that ramp metering reduces crash rate (Cambridge Systematics, 2001) and more specifically rear-end and sideswipe crashes in the freeway mainline (Cleavenger and Upchurch, 1999). Many studies in North America and Europe have assessed the benefits of ramp metering quantitatively through field tests and simulation experiments. Thill et al. (2004) defined safety benefits of ramp metering as a decrease in crash frequency at the merging of ramp and freeway lanes from the baseline number of crashes. Currently, ramp metering is used throughout the United States in California, Minnesota and New York, as well as many countries throughout Europe (Gayah et al., 2006).

Considering these opportunities, some new studies are now taking place to evaluate the effectiveness of these road safety improvement solutions in real-time, when coupled with real-time crash prediction models. These studies take various traffic flow variables as input and from that apply various traffic interventions to bring the hazardous traffic conditions back to normal. As due to safety reasons these studies cannot be conducted in real life, researchers opted for either microscopic traffic simulation (Lee et al., 2006; Abdel-Aty et al., 2006, 2007, 2008) or driving simulator (Lee and Abdel-Aty, 2008) based approaches. The recommended countermeasures so far have been posting warning message (Lee and Abdel-Aty, 2008), variable speed limits (Abdel-Aty et al., 2006, 2008; Lee and Abdel-Aty, 2008) and ramp metering (Lee et al., 2006;Abdel-Aty et al., 2007),which have proven track record as effective solutions as discussed in the aforementioned subsections.

Simulation based approach are favoured because those could evaluate different scenarios as well as could reflect accuracies. For studies involving crash data it is not possible to recreate the environment in real field. That's why simulation based studies have been the key focus of the researchers. Methods like using a driving simulator or microscopic simulator are the prime method of such studies.

The use of driving simulator is not incorporated in this study because it would involve a lot of time as well as it would not be cost effective. Although it is to be noted that driving simulator could capture individual driving behaviour at a greater depth. But again it will depend much on the respondents. So in this study a micro-simulation based approach was chosen. CUBE Dynasim was used as the micro-simulation software.

In general, micro-simulation models are built to replicate normal traffic behaviour. But for road safety related studies it is important to know how to simulate hazardous traffic condition. So this study is focused on identifying and extracting hazardous traffic conditions from matching detector and crash database along with calibrating car-following and lane changing models to reproduce the hazardous traffic condition in a micro-simulation environment.

2. METHODOLOGY

2.1 Study area and the data

It is necessary to select such an area where it is possible to observe substantial amount of crash as well as means to collect crash data along with high resolution traffic flow data. High accuracy is also needed.

The data used in this study was collected from two parts of the Tokyo metropolitan expressways. The first one is Shibuya and the other one is Shinjuku 4 expressways. They were collected for a period of months from May to August on the year of 2014. The total length of the two expressways are 25.4 km. Shibuya Route (also known as the Route 3) is one of the radial routes of the expressway system in the Tokyo area. Route 3 runs southwest from Tanimachi Junction (with the Inner Circular route) in Minato-ku and runs for 12 kilometers through Shibuya-ku, Meguro-ku, and Setagaya-ku. The Route 3 designation ends at the Yoga Rampway (Tokyo Interchange) and the expressway continues as the intercity Tomei Expressway to Nagoya. Whereas, Route 4 (also known as the Shinjuku Route) is another radial routes of the Expressway system in the Tokyo area. It runs west from Miyakezaka Junction (with the Inner Circular Route) in Chiyoda-ku and runs for 13.5 kilometers through Shinjuku-ku, Shibuya-ku, and Suginami-ku. The Route 4 designation ends at the Takaido Interchange and the expressway continues as the intercity Chūō Expressway to Nagoya via Yamanashi and Nagano Prefacture.

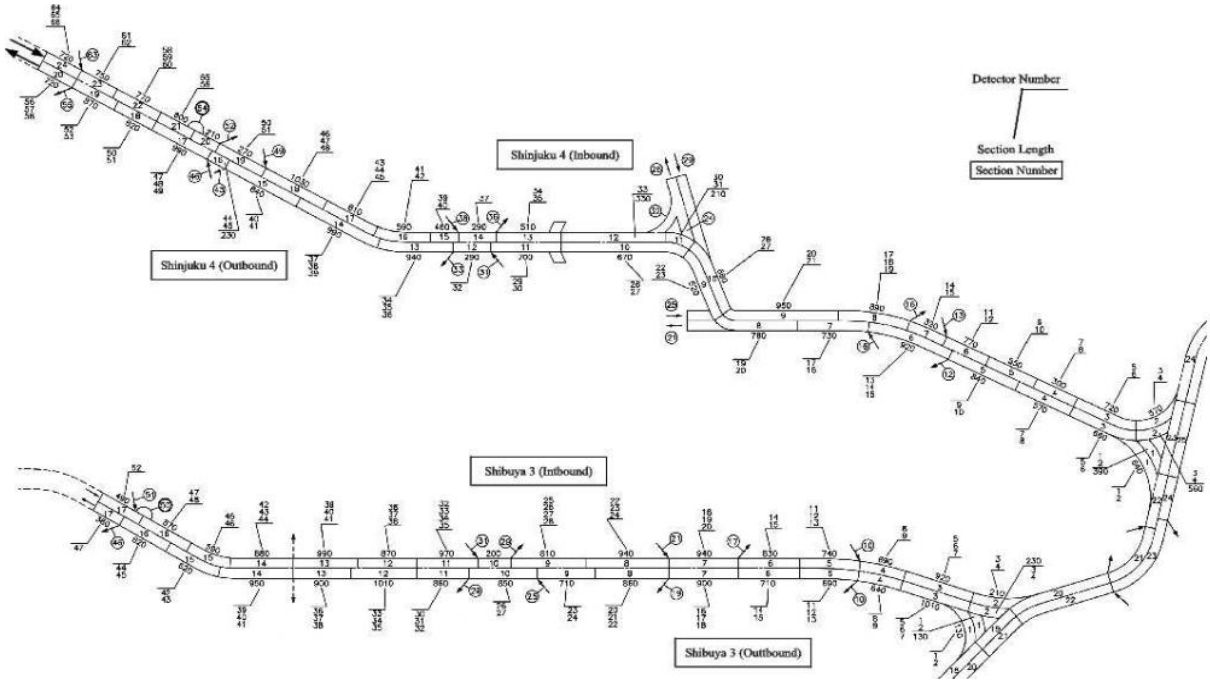

Figure 1: Schematic diagram of Route 3 and 4 of Tokyo Metropolitan Expressways (diagram not drawn to scale)
Source: provided by Tokyo Metropolitan Expressway Company Limited

A total no. of 24 ramps are present in the selected study area and approximately a total of 210 loop detectors were established there. A total 610 crashes were observed during the study period. Three classes of data were collected. These are detector data, crash data and road geometry data. The parameters set for collecting detector data were speed, flow, occupancy, number of heavy vehicles for each lane and ramps. Date, time, location, vehicles involved, types, lane were the parameters for collecting crash data. Road geometry data focused on location of ramps, position of detectors, section length.

2.2 Experimental setup

Data are preserved for each detector for every eight mili-seconds in Tokyo Metropolitan Expressways. Data is also stored for each lane covering information on speed, flow, occupancy and no. of heavy vehicles. Data for every one minute for each detector were aggregated and provided for the purpose of this study. Crash data including information on date, time, location, vehicles involved and types of lane were also added.

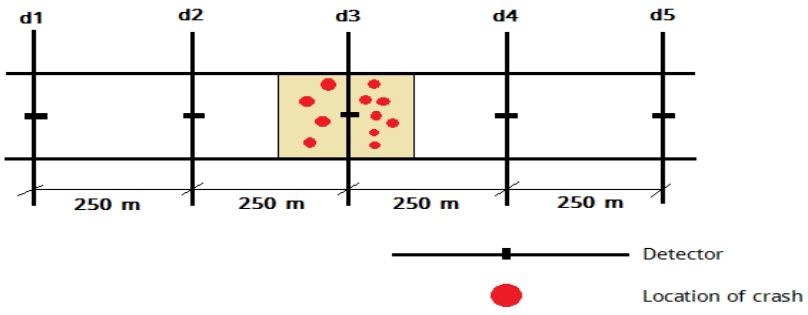

Figure 2: Position of detector and location of crash

The experimental setup was made as shown in the figure 2. Each crash points were associated with its corresponding 250meter section. For every section two upstream

detectors, two downstream detectors and the detector within the section were identified. Two traffic conditions were identified hazardous traffic condition and normal traffic condition. For hazardous traffic condition (D_H^{ij}) 1 minute aggregated data for all lanes before i (i=1, 2, 3, 4, 5) minutes crash at j (upstream or downstream) junction were collected. On the other hand, for normal traffic random sampling of 1-minute aggregated data from any timeslot where no crash took place before or after that time period. The data collected from the detectors were then sorted and organized so that it can be easily incorporated in analysis. Each crash was given a single identification no. and speed, flow, occupancy data for 5 detectors as mentioned in the next segment was sorted.

2.3 Data Preparation

As it was mentioned, a total 210 detectors are placed in the two routes, when both directions are considered. The primary task was to identify nearest detector, upstream detector and downstream detector for each crash point, a sample of which is shown in table 1.

Table 1: Crash data with unique ID and detector located near crash (sample)

Crash Id	Date	Time	Day of week	Kilo-meters	Segment-s	Kilo post	D2D	D1D	D0	D1U	D2U
481	4/30	06:46 pm	Wed	0	1	0.10	04	01	03	-	-
482	6/14	11:24 am	Sat			0.20	02	04	01	03	-
483	3/27	07:03 pm	Thurs			0.20	02	04	01	03	-
484	3/21	07:13 pm	Fri		2	0.30	02	04	01	03	-
485	7/7	11:15 am	Mon			0.30	02	04	01	03	-
486	3/30	07:54 pm	Sun		3	0.60	06	05	02	04	01
487	5/23	09:53 am	Fri			0.60	06	05	02	04	01
488	6/7	02:02 am	Sat	1	1	1.00	08	07	06	05	02

Here, D0 = Detector in the segment

D1D = First detector in the downstream

D2D = Second detector in the downstream

D1U = First detector in the upstream

D2U = Second detector in the upstream

Then it was needed to sort the data from all detector and combine them together so that it can be easily found and used during the course if this study. A sample of such work is shown in table 2.

Table 2: Crash data with unique ID and detector located near crash (sample)

Crash ID	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Date	6/7	6/10	6/29	3/21	8/15	8/18	6/29	3/13	8/7	8/27	8/28
Time	21:25	02:28	03:26	17:47	08:01	16:22	11:06	21:25	17:58	19:47	9:14
Kilo post	0.00	0.10	0.10	0.10	0.10	0.10	0.20	0.20	0.20	0.20	0.20
D1D_f_15	4	13	3	2	18	7	28	11	21	4	24
D1D_f_14	10	8	2	2	23	16	22	12	9	18	13
D1D_f_13	13	4	1	2	27	19	21	9	18	13	23
D1D_f_12	12	8	3	5	20	16	29	9	18	13	26
D1D_f_11	10	8	2	2	19	17	25	14	15	10	22
D1D_f_10	10	11	7	1	20	22	19	4	20	14	19
D1D_f_9	11	13	2	2	20	8	25	16	15	16	19
D1D_f_8	14	18	0	1	23	19	23	15	17	19	23
D1D_f_7	12	4	5	4	22	19	22	7	12	22	13

Here, D1D_f_t = flow data of detector at time t minutes before crash

2.4 Microscopic Traffic Simulation with CUBE Dynasim

In microscopic traffic simulation it is possible to model traffic behavior by calibrating car following and lane changing parameters. The methodology followed to calibrate these parameters are discussed in detail in the following sections.

2.4.1 Car Following Rules

There are two car following rules followed in CUBE Dynasim. First one is MGA, which is acronym for General Motors Ahmed and the other one is PLP7. The car following depends on speed, space headway, density, relative speed, free-flow acceleration, headway threshold and reaction time distribution. Most algorithm used in MGA was taken from a paper written by Kazi Iftekhar Ahmed in 1999. Whereas, PLP7 is a simple acceleration model. In it only three parameters are considered. This is very useful in modelling congestion in urban traffic. The acceleration of vehicle 2 which follows vehicle 1 is determined by the speed and the distance from the vehicle which precedes it according to the formula:

$$A2*(t+0.25) = \alpha* [\, V1(t) - V2(t)] + \beta* [\, X1(t) - X2(t) - \tau* V2(t) - L\,] \quad (1)$$

Here, A1 = Acceleration of vehicle 1
A2 = Acceleration of vehicle 2
t = Time at any instant
V1 = Velocity of vehicle 1
V2 = Velocity of vehicle 2
X1 = Position of vehicle 1
X2 = Position of vehicle 2

Table 3: Value of α, β, τ

A1(t)	**A**	**B**	**T**
< -0.6 m/s2	0.7	0.03	1.82
[-0.6 ; 0.6]	1.1	0.2	0.52
> 0.6 m/s2	0.36	0.03	1.82

2.4.2 Lane Changing Parameters

In CUBE Dynasim two types of situations can lead to a lane change. The first one is a lane change imposed by the path the vehicle takes to reach its destination, conditioned by "Insertion gaps" and a the other one is a lane change due to the vehicle's behavior usually conditioned by "Behavior associated with lane satisfaction". Insertion gaps determine whether the vehicle will be able to change lanes depending on the traffic in its target lane. Behavior associated with lane satisfaction can be of two sorts. First one is current lane satisfaction, which determines whether or not a vehicle is satisfied with the traffic conditions in the current lane. Whereas, target lane satisfaction determines whether a vehicle wants to change lanes depending on the traffic in adjacent lanes.

A vehicle that wants or needs to change lanes must make sure, in terms of safety, that the vehicles in front and behind in its target lane are at a sufficient distance from its front and rear bumpers. This is done using lag and lead insertion gaps. In CUBE Dynasim the calculated acceptable gap distance depend on the instant speed of the vehicle V(t), the speed of the vehicle in the target lane V_C(t). The minimum acceptable gap for changing lanes is determined by following formula (Dynasim Manual, 2014):

$$G(t) = \exp\left(C_1 + C_2 Max(0, V_c(t) - V(t)) + C_3 Min(0, V_c(t) - V(t)) + C_4 n + N(0, C_5^2)\right) \quad (2)$$

Here, C_1 = Constant.

C_2 = Positive speed differences (*dv+*), i.e. the difference between the instant speed of the vehicle in the current lane V(t) and the speed of the vehicle in the target lane $V_c(t)$

C_3 = negative speed differences parameter (*dv-*), i.e. the difference between the instant speed of the vehicle in the current lane V(t) and the speed of the vehicle in the target lane $V_c(t)$

C_4 = Aggressiveness parameter associated with a random selection n which serves to reflect different types of driving

C_5 = Standard deviation of the normal distribution centered on 0

It is very important to note that in CUBE Dynasim a lane change not imposed by a vehicle's destination depends on the lane satisfaction in the current and adjacent lanes. The behavior assigned to a lane in a trajectory will define the conditions in which the vehicles concerned will want to move to the target lane. In fact, if a vehicle does not satisfy the lane satisfaction condition on its current lane, but satisfies the condition on the target lane it will change lanes. Current lane satisfaction depends on the instant speed of the vehicle V(t) and the desired maximum speed of the vehicle V_1(t). The probability that a vehicle is not satisfied in its current lane is as follows (Dynasim Manual, 2014) :

$$P(t) = \frac{1}{1+e^{(C_1+C_2(V(t)-V_1(t))+C_3\delta_{PL}+C_4\delta_{PA})}} \quad (3)$$

Here, C_1 : Constant.

C_2 : A *dV* maximum parameter relative to the difference between the instant speed of the vehicle V (t) and the desired maximum speed of the vehicle $V_1(t)$

C_3 : An *HV* penalty parameter, used for vehicles whose length in m exceeds the threshold specified in the *Heavy thr* field

C_4 : A tailgate parameter (TG) relative to the distance between the vehicle and the vehicle directly behind it, used for vehicles whose speed is greater than the tailgate speed threshold specified in the *Speed thr* tail field

δ_{PL}= 1, If the length of the vehicle considered is greater than the value specified in the *Heavy Thr* field

δ_{PA}= 0, if the distance between the vehicle considered and the vehicle directly behind it is less than 10

Target lane satisfaction depends on the instant speed of the vehicle V(t), the maximum desired speed of the vehicle V_1 (t), the speed of the lag vehicle V_P (t), in the current lane the speed of the lag vehicle and of the lead vehicle in the target lane V_CP (t) and V_CS (t) respectively. The probability that a vehicle will want to change to a target lane is as follows (Dynasim Manual, 2014):

$$P(t) = \frac{1}{1+e^{(C_1+C_2\left(V_P(t)-V_1(t)\right))+C_3\,(V_{CP}(t)-V_1(t))+C_4(V_{CS}(t)-V_1(t))}} \quad (4)$$

Here, C_1: Constant

C_2: A *Dvfront* parameter relative to the difference between the speed the vehicle wants to reach V_1(t) and that of the vehicle in front V_P(t)

C_3: A Dv lead parameter relative to the difference between the speed the vehicle wants to reach V_1(t) and that of the vehicle in front in the adjacent laneV_{CP} (t)

C_4: A Dvlag parameter relative to the difference between the speed vehicle V (t) and that of the vehicle behind in the adjacent laneV_{CS} (t)

3. ANALYSIS AND RESULTS

This section reflects upon how to build a model in CUBE Dynasim step by step as well as how to calibrate the parameters to find out the expected flow-occupancy relationship.

3.1 Importing Map

The first step in modelling with CUBE Dynasim is to select and input the map in the software. The map could be in two formats, vector maps with DXF format and bitmaps in BMP, JPEG and GIF formats.

3.2 Drawing Network

In CUBE Dynasim network are drawn with handles and trajectories. Handles are defined by its position, its orientation and its number of attachment points. On the other hand, a trajectory is defined between two different handles. It can link one or more attachment points on the handles. A single lane is modelled by a trajectory that links a single attachment point on each handle. In certain conditions, the vehicles can change lanes depending on their behaviour, or to reach their destination**.**

3.3 Network and Flow Scenarios

The first step to take in defining a network scenario is to make a layer. Usually the very first layer is defined as Base. After a layer is created the next step to take is to define the network scenario. In the new network the created layer, input maps are selected. In CUBE Dynasim different types of flow scenarios are also included. These are aggregate, generator, assignment, estimation, export-import, sub-network etc. and for the purpose of this study aggregate flow value of 15 minutes was introduced as input.

3.4 Driving Behaviour

In microscopic traffic simulation individual driving behaviour is influenced by car following and lane changing parameters. As a detail discussion of car following and lane changing is done in the methodology section, in this section only the parameters which were changed from default value to obtain the hazardous traffic condition will be shown. In table 4 software specific car following parameters and the calibrated parameters for obtaining specified objectives are shown. It is observed that car following maximum headway was changed from 6 s to 4.5 s and mean of threshold was changed from 3.17 to 2 to obtain the goals of the study.

Table 4: Software specified car following parameters and calibrated value of parameters

Parameter	**Software Specified Value**	**Calibrated Value**
Free Flow Minimum Headway (sec)	0.50	0.50
Car-Following Maximum Headway (sec)	6.00	4.50
Mean of Threshold (s)	3.17	2.00
Standard Deviation	0.87	0.87
Stopped Headway (ft)	32.81	32.81

Table 5: Software specified lane changing parameters and calibrated value of parameters

Parameter	**Software Specified Value**	**Calibrated Value**
HV Threshold (m)	9.00	9.00
LV Average Time (sec)	1.80	0.80
LV Minimum Time (sec)	0.70	0.45
LV Maximum Time (sec)	3.00	2.00
LV Standard Deviation	1.50	1.50
LV Minimum Distance (m)	5.00	3.50
HV Average Time (sec)	2.50	2.50
HV Minimum Time (sec)	1.50	1.50
HV Maximum Time (sec)	5.00	5.00
HV Standard Deviation	1.00	1.00
HV Minimum Distance (m)	7.00	7.00

Table 5 illustrates that light vehicle average time, light vehicle minimum time and light vehicle maximum time values were changed from the software specified values for calibrating the lane changing parameters in the software.

The reason for changing those values was to see how the speed, flow and occupancy relationships change with the alteration in such values. And thus field condition was portrayed exactly on the simulation software and necessary conclusions were drawn observing the results.

3.5 Results

In order to draw conclusion that the simulation is a match to the field condition, the speed, flow and density relationship should be as shown in figure 3. These relationships were obtained by statistical analysis of the field data obtained from detectors.

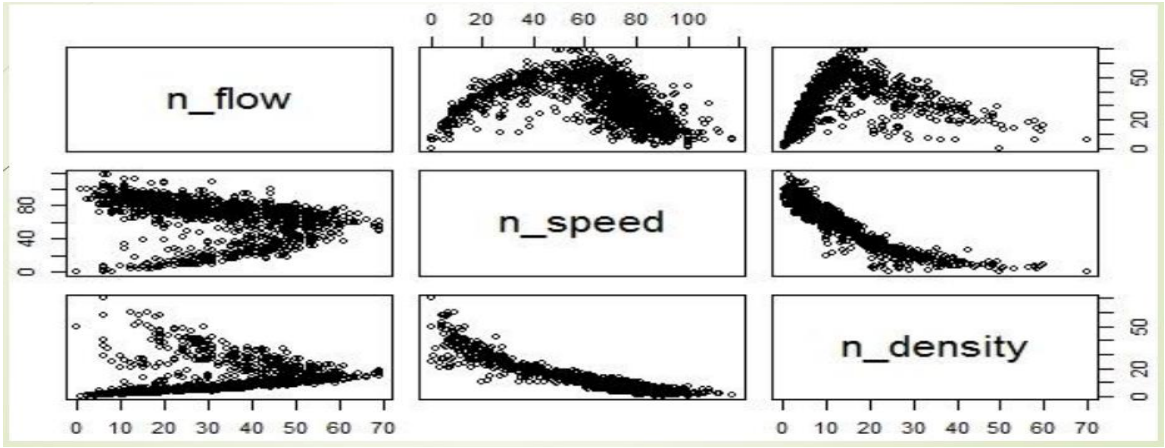

Figure 3: Relationship between flow, speed and density

The left hand side of figure 4 was obtained after the first simulation run in which no change in the software specified parameters were done. It is observed that most of the vehicles are operating at a very high speed rather than giving a good speed-flow relationship. Whereas, on the right hand side of figure 4 it is observed that the relationship has changed from the previous run. This change in relationship was observed due to calibration of the parameters as mentioned in the earlier section. It is understood by comparing the relationships that the relationship obtained after calibrating the parameters are much more satisfactory than that of the earlier.

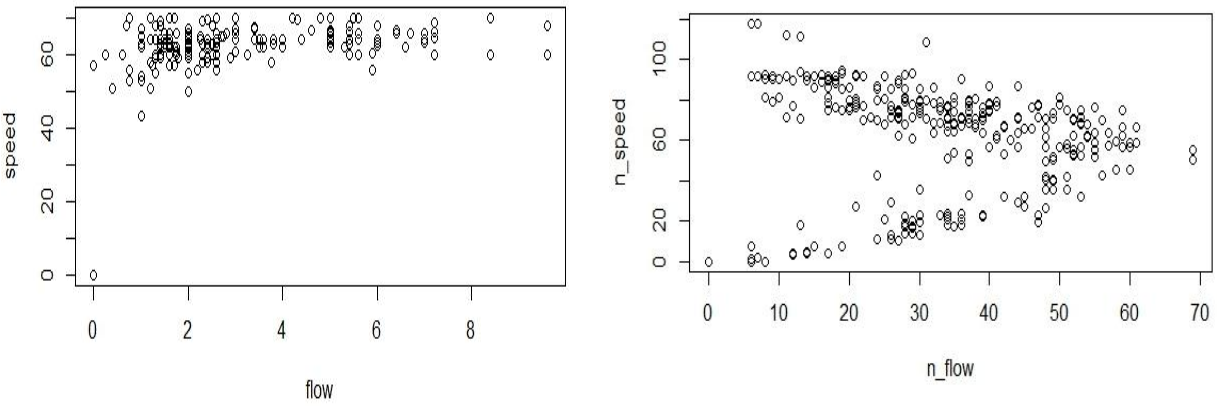

Figure 4: Flow vs Speed relationship with software specific value (left hand side) and Flow vs Speed relationship with calibrated value (right hand side)

4. CONCLUSIONS

Finding out realistic solution to ensure road safety is very important in transportation sector. In this regard it is necessary to define normal and hazardous traffic condition with a micro-simulation approach as micro-simulation approach is less time consuming and dangerous in defining hazardous traffic condition. In CUBE Dynasim car following and lane changing behaviour parameters were altered to create different flow patterns. Changing the values of car-following maximum threshold and mean of threshold value for car following rules and in case of lane changing behaviour changing of heavy vehicle threshold, light vehicle average time, light vehicle minimum time, light vehicle maximum time, light vehicle standard deviation, light vehicle minimum distance, heavy vehicle average time, heavy vehicle minimum time, heavy vehicle maximum time, heavy vehicle standard deviation, heavy

vehicle minimum distance brought the best possible outcome. The limitation of the study could be the use of only 300 as input in CUBE Dynasim. This was done so owing to limitation of time.The constriction of time during analysis was there because of the fact that a huge amount of time was spent for learning the software and simulation model building. In future this study could be further used to find out the inclusion of interventions and their effects to turn a hazardous traffic condition back to normal. This study was done based on data of Japan if adequate data could be formulated such study could be carried out for expressways in Bangladesh as well.

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

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ABSTRACT

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

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

1. INTRODUCTION

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

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

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

2. LITERATURE REVIEW

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

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

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

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

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

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

Table 1: Level of service

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

Source: (Kadiyali, 2006)

3. STUDY AREA AND METHODOLOGY

3.1 Study Area

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

3.2 Methods

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

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

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

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

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

Table 2: Standard area for each type of vehicle

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

[a]LCV indicates light commercial vehicle.

Source: (Chandra & Sikdar, 2000).

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

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

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

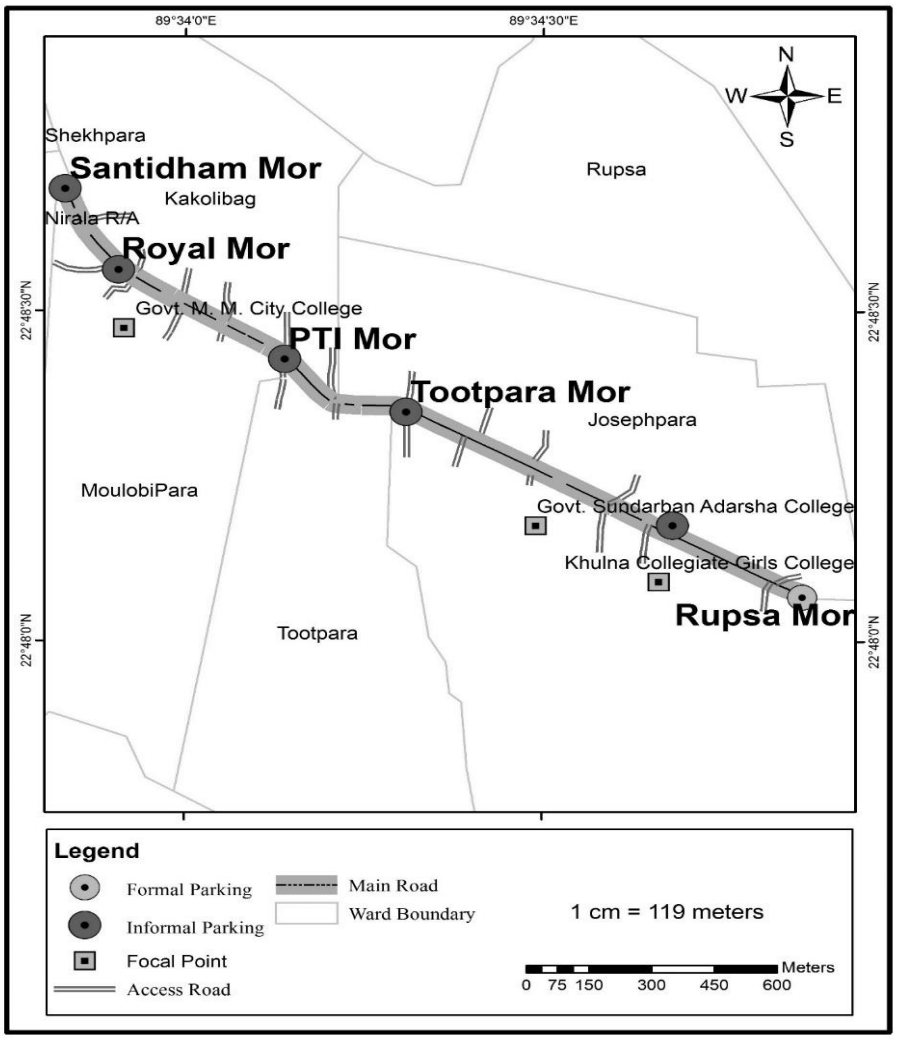

Figure 1: Study Area

Table 3: Estimation of PCU for each type of vehicle

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

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

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

Table 4: The formula and determinants of indices

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

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

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

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

4. ANALYSIS & INTERPRETATION

4.1 Cross Sectional Geometry of Road

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

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

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

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

Source: Field survey, 2016

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

4.2 Relation between Carriageway Width and PCU of Vehicles

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

4.2.1 The Effect of Carriageway Width on PCU for Motorized Vehicles

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

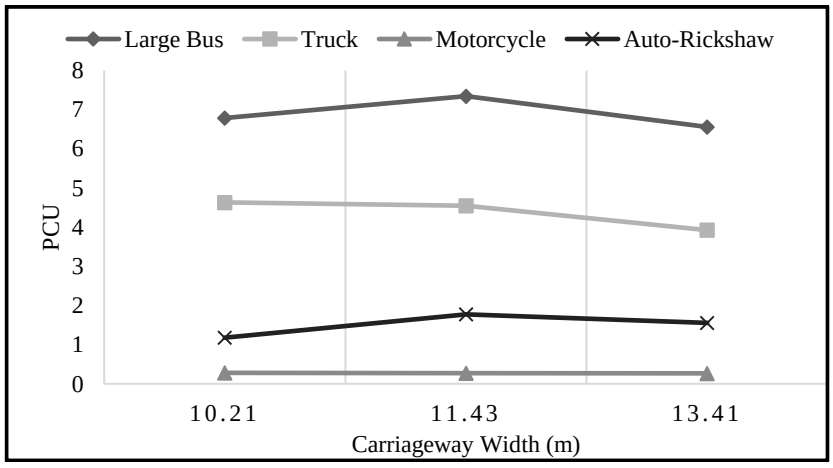

Figure 2: The Effect of Carriageway Width on PCU for Motorized Vehicles

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

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

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

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

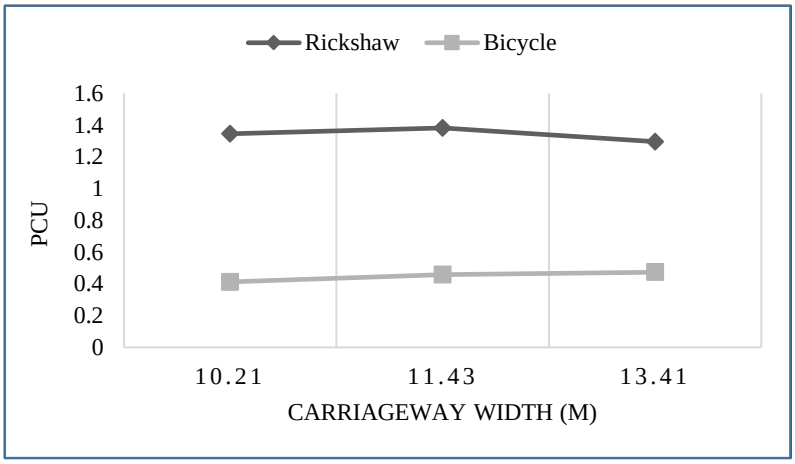

Figure 3: The Effect of Carriageway Width on PCU for Non-Motorized Vehicles

4.3 Relation between Volume and Rate of Congestion

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

Table 6: The value of Indices at Different Sections

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

Source: Field Survey, 2016

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

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

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

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

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

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

Source: Field Survey, 2016

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

4.5 Effects of Formal and Informal Parking on Congestion

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

4.6 User Opinion regarding Physical Features

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

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

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

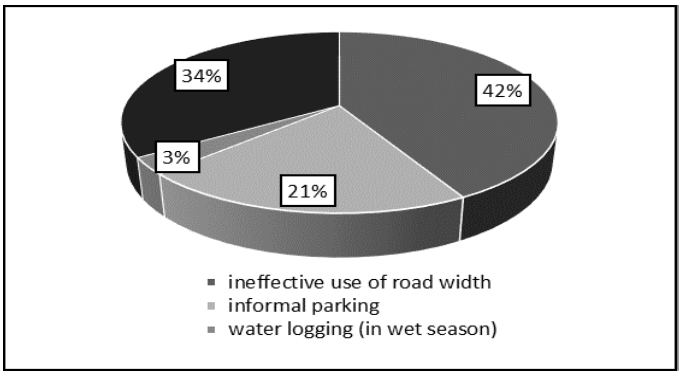

Figure 4: Causes behind Congestion (according to Users' Opinion)

5. CONCLUSIONS

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

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ANALYSIS OF SCHOOL TRAFFIC IN DHANMONDI RESIDENTIAL AREA

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ABSTRACT

Dhanmondi is one of the major residential areas in Dhaka City. It was planned and developed by the Public Works Development (PWD) in 1952. Although, primarily designed for residential use, non-residential uses have taken up to a percentage of 52.91 by the year 2006 (Ahmed, 2011)*. Often addressed as the 'School Parha'(Area scrammed with schools), Dhanmondi has 106 schools located in it* (Sharmin et al., 2004)*, withholding excessively more area than the permissible 0.34% set by Rajdhani Unnayan Kartripakkha (RAJUK). The surplus of schools is giving rise to traffic volume which is surpassing the carrying capacity of existing roads. Traffic during school opening and closing peak hours is creating an immense blockage within the area and obstructing car movement for up to 4 hours. To lessen this congestion, in this paper an extensive analysis of current scenario of the study area is represented and a suitable scheme of viable solutions is discussed. After conduction of three major surveys at Road no. 30 (Old), Road no. 31 (Old) and Road no. 27 (Old), the chief suggestible solutions are offered as compulsory school bus transportation, one-way movement during school hours, parking restriction during peak drop-off and pick-up hours, carpooling and cordon pricing; which could reduce overall residential traffic (inclusive of school traffic) by a significant amount.*

Keywords: *Residential area, school traffic, congestion*

1. INTRODUCTION

With the rapid rate of urbanization of Dhaka Metropolitan City, traffic congestion has become an acute problem of daily life. A clear reflection of this issue is seen in the day-to-day traffic routine of Dhaka's one of the most affluent residential areas, Dhanmondi. The main contributor of Dhanmondi's traffic congestion is the unplanned development of schools in the area. Dhanmondi was planned and developed by the Public Works Development (PWD) in 1952 according to the order Dhaka No. 11413 requ-.9th December 1952 (Mahabub-Un-Nabi and Hashem, 2007). Although, primarily designed for residential use, non-residential uses have taken up to a percentage of 52.91 by the year 2006 (Ahmed, 2011). Often addressed as the 'School Parha'(Area scrammed with schools), Dhanmondi has 106 schools located in it (Sharmin et al., 2004) withholding excessively more area than the permissible 0.34% set by Rajdhani Unnayan Kartripakkha (RAJUK). The surplus of schools is giving rise to traffic volume which is surpassing the carrying capacity of existing roads. Due to having a grid iron road network pattern, the roads are easily baffled with traffic during school opening(7:00AM-9:00AM) and closing(12:00PM-2:30PM) peak hours,creating an immense blockage within the area and obstructing car movement for up to 4 hours. The road network, originally developed for convenient use of the residents is facing a hard time coping with the ever increasing traffic volume resulting from school traffic with it's very limited aptitude. Dhanmondi is one of the most densely built up areas of Dhaka City, thus extension of road capacity is most likely an impossible consideration. Under the circumstances, a viable solution to this problem has to be originated.

2. METHODOLOGY

2.1 Selection of Study Area

Dhanmondi is one of the most affluent residential areas of Dhaka City. It spans over an area of 4.34 km² and it comprehends 33451 houses and 106 schools. Regarding the analysis of school traffic, three field surveys were conducted in the area as it is home to a great number of schools and therefore can be thoroughly investigated.

2.2 Data Collection and Analysis

Both primary and secondary data were attained for further analysis regarding the research. Primary data such as approximation of cars entering into the area during school peak hours and formation of multiple temporary car lanes during school peak hours were obtained from first-hand observations. Secondary data such as information taken from school authorities and security guards were collected through detailed interviewing. Other secondary data such as statistics and examples of feasible solutions to such congestion problems which are practiced around the world were also acquired through desktop studies. After completion of data collection, the data were analyzed in a quite simple and candid way. The significant points were noted, arranged and categorized from observations and interviews.

3. FINDINGS

According to the surveys conducted at Dhanmondi Road no.27 (old), Road no.30 (old) and Road no.31 (old) on June 2017,information about school traffic occurring at the mentioned roads which are the main access routes to the said schools(Sunbeams, Sunnydale and Mastermind respectively) have been collected and an analyzed representation of the data has been included in this section.

Table 1: Traffic Details of The Said Schools

Schools	Location	Students	Vehicle Usage	Situation, Morning	Situation, Noon	Vehicles Parked Around	Approximate Number of Vehicles
Sunbeams	Rd. 27, Dhanmondi	350	85%	Drop off for an hour; 300 vehicles (Approx)	Pick up for half an hour; 300 vehicles (Approx)	20 - 30	Car-153 Cycle Rickshaw-129 Motorcycle-18
Sunnydale	Rd. 30, Dhanmondi	300	70%	Drop off for an hour; 210 vehicles (Approx)	Pick up for half an hour; 210 vehicles (Approx)	20 - 30	Car-87 Cycle Rickshaw-92 Motorcycle-31
Master Mind	Rd. 31, Dhanmondi	1300	80%	Drop off for an hour; 1000 vehicles (Approx)	Pick up for half an hour; 1000 vehicles (Approx)	30 - 40	Car-728 Cycle Rickshaw-178 Motorcycle-94
Master Mind	Rd. 30, Dhanmondi	550	85%	Drop off for an hour; 450 vehicles (Approx)	Pick up for half an hour; 450 vehicles (Approx)	20 - 30	Car-213 Cycle Rickshaw-167 Motorcycle-70

Source: Field Survey,2017

The data represented in the above table were collected through interviews with the school authorities of each stated school and the daily approximate number of cars was estimated from first-hand observation and partially collected from the information given out by the school security guards . From the table, it was concluded that on an average 80% of the school students use vehicles for travelling to and from their schools.

Figure 1: School Traffic Scenario During Peak Closing Hour of Sunbeams(Rd. No.27)

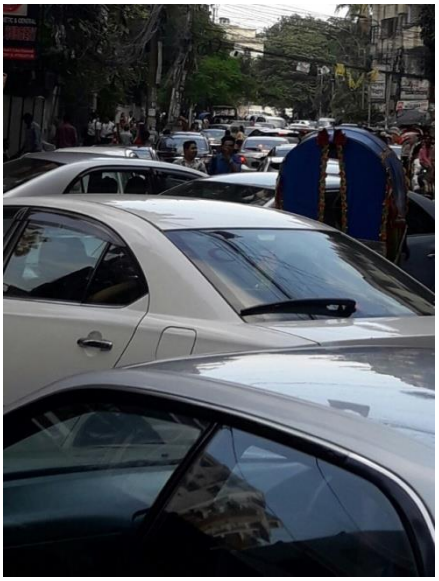

Figure 2: School Traffic Scenario During Peak Closing Hour of Sunnydale(Rd. No.30)

Figure 3: School Traffic Scenario During Peak Closing Hour of Mastermind(Rd. No.31)

From 'Approximate Number of Vehicles' section of Table 1, calculation of Peak Hour Maximum Passenger Car Units (PCU) was executed by using the following formula of Simple Method,

$$PCU = \sum(PCU\ Value * Number\ of\ Vehicles) \quad (1)$$

PCUs were calculated as per the PCU values/factors given in Geometric Design Standards Manual of RHD (Revised) 2005 and have been presented below,

Table 2: PCU Value for Different Types of Vehicle

Vehicle Type	PCU Value
Truck	3.0
Bus	3.0
Minibus	3.0
Utility	1.0
Car	1.0
Baby Taxi	0.75
Motor Cycle	0.75
Bicycle	0.5
Cycle Rickshaw	2.0
Bullock Cart	4.0

Source: (Geometric Design Standards Manual of RHD (Revised),2005)

Table 3: Calculated PCU of The Roads Beside The Mentioned Schools

Name of School	Peak Hour Maximum Passenger Car Units(PCU)
Sunbeams	424.5
Sunnydale	294.25
Master Mind (Road No.31)	1154.5
Master Mind (Road No.30)	599.5

From a desktop study on Road Design Standards (2004) prepared by the Planning Commission of Government of the People's Republic of Bangladesh, it was found that the

standard value of Peak Hour Maximum Passenger Car Units (PCU) for feeder road (carriageway width 3.7 m /12 ft) is 290.
It is known that feeder roads are those which feed traffic to main highway or freeway. All three of the selected roads of this research fall into the category of feeder road, as they set off from primary roads and their width varies within 3.5~4 meters. After comparing the standard value of PCU to the calculated values, it was seen that the calculated values deviate greatly from the standard one. The huge deviation indicates that an excess of vehicular flow is occurring on the roads and the capacity of the roads is insufficient for supporting such heavy flow.

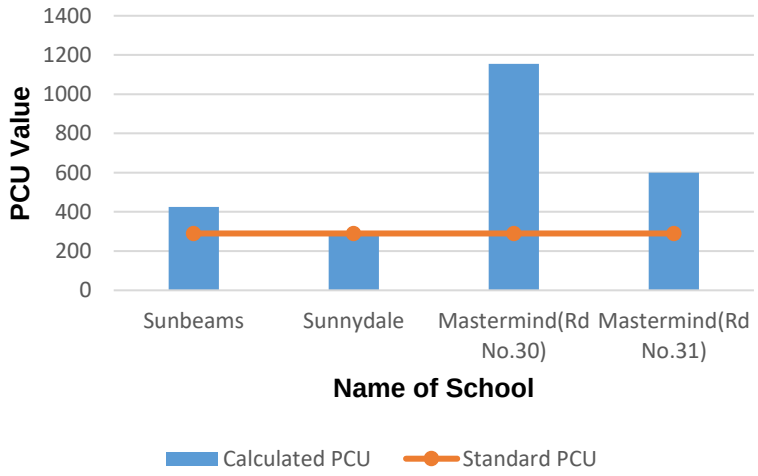

Figure 4: Graphical Representation of Standard and Calculated PCU Values

4. RECOMMENDATION

As private cars are the main contributors of the school traffic, measures have to be taken to control their number into the residential area. The probable solutions to such congestion problem whose applications are seen in many countries around the world have been mentioned and their suitability in the context of Bangladesh has been discussed in the following section.

4.1 Endorsing Compulsory School Bus Transportation

Endorsement of Compulsory School Bus Transportation will lessen the need for private transportation. It will lower the number of private vehicles and rickshaws entering into the area during school opening and closing peak hours. Also, it will save a significant amount of conveyance money of those who do not own any private vehicle.

Considering the socio-economic condition of Bangladesh,encouraging compulsory school bus transportation can save a handsome amount of money by the end of the month for all income groups of the society as school bus transportation service charges a nominal monthly fee. But in case of higher and upper-middle income groups, they rarely show interest in sending their children to school by school buses. The reason behind their disinterest is the unguaranteed safety of their children. Provision of high configured school buses with properly functional locks and air conditioning system can ensure both safety and convenience of the students and ultimately solve the safety issue.

If a bus with a capacity of 50 passengers is considered as a standard school bus then the number of total school buses required for each stated school can easily be calculated by the below simple method,
Number of School Buses=Number of Students÷Capacity of A Single School Bus

From the above formula the numbers were calculated to be 6 buses(Sunbeams), 5 buses(Sunnydale), 20 buses(Mastermind at Road No.31) and 9 buses(Mastermind at Road No.30). The PCU values for the newly attainted number of buses have been shown in the table below.

Table 4: Estimated PCU For Newly Obtained Number of Buses

Name of School	Peak Hour Maximum Passenger Car Units(PCU)
Sunbeams	18
Sunnydale	15
Master Mind (Road No.31)	60
Master Mind (Road No.30)	27

Comparing the actual PCU values with the estimated PCU values it can easily be concluded that PCU values of the roads connected to Sunbeams, Sunnydale, Mastermind(Road No.31) and Mastermind(Road No.30) will be lessened by 95.76%, 94.9%, 94.81% and 95.5% respectively. It goes without saying that the reduction of PCU values of the streets will definitely play a vital role in reducing school traffic congestion.
Thus, implementation of the idea of endorsing compulsory school bus transportation will be fruitfully sustained.

4.2 Compulsion of One-way Movement During School Hours

The road network of the study area is not capable of supporting heavy two-way traffic movements. The roads measure up to 3.5~4 meters in width and can only be used as two lanes when there is minimal traffic. During school hours, the roads are oppressed to hold cars in two lanes, thus creating congestion as vehicles cannot freely move. A probable solution to this problem can be the implementation of one-way traffic movement during school peak hours(7:00AM-9:00AM And 12:00AM-2:30AM). The vehicles will be entering through road no.31(13 new) and road no.30(14 new),then accessing Mirpur Road and finally setting off to road no.27(16 new).

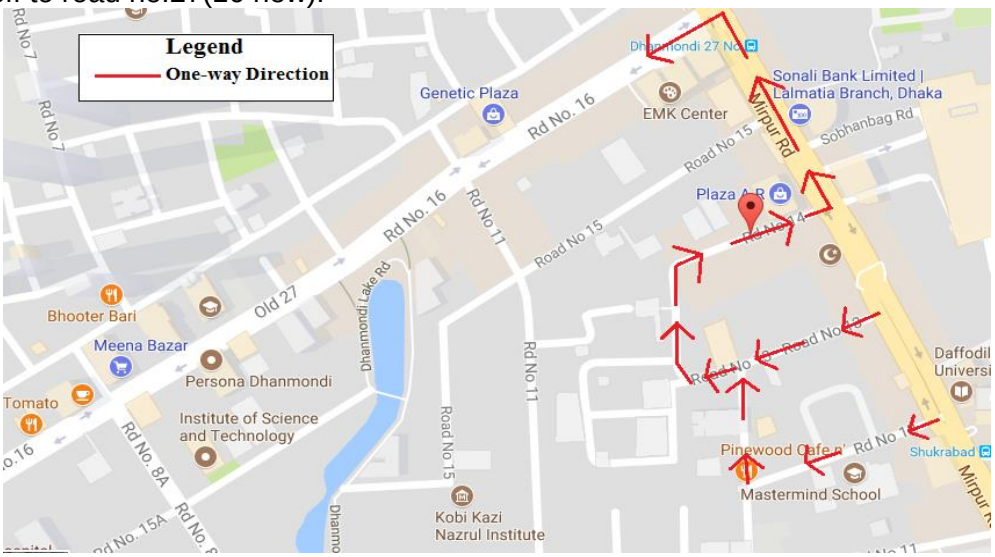

Figure 5: Proposed One-way Movement Direction

In context of the study area,the feeder roads are always scrammed with dense traffic during peak hours and free vehicular movement is close to impossible. Thus,channelizing one way traffic to primary roads will escalate free movement within a single lane. This is a moderately appropriate solution for school traffic, however, it may not always be found to be suitable as it will obstruct any residential traffic movement during peak hours because it will only permit movement in one-way.

4.3 Enforcing Parking Restriction During Peak Drop-off and Pick-up Hours

The roads of the study area are simultaneously used as parking spaces anytime during the day and most recurrently during school peak hours. There are signs currently present on the road sides which read “No Parking”, yet they are disregarded and not paid heed to. Hence, enforcement of parking restriction (e.g. Parking Fine) during peak drop-off and pick-up hours can be a way out of this problem. Parking restriction will free up space within the roads and promote free movement of vehicles and provide more accessibility.

Bearing in mind the societal and socio-economic condition of Bangladesh, implementation of such parking restrictions is only workable with proper law enforcement. Continuous surveillance of traffic polices at the important nodes of the area will create awareness among the vehicular users to abide by the parking restrictions. This idea of solving school traffic can be deviced if and only if the Government issues traffic polices at the respective points.

If the average number of vehicles parked around the schools during peak hours is omitted from PCU value calculation then the values will be lessened to 399.5, 269.25, 1119.5 and 574.5 for Sunbeams, Sunnydale, Mastermind(Road No.31) and Mastermind(Road No.30) respectively. The decreased values of PCU indicate that there is a good chance of traffic being reduced if parking restriction is enforced.

4.4 Promoting Carpooling

Carpooling refers to the sharing of car journeys, so that more than one person travels in a single car. It’s aim is to decrease the number of single car users and increase the number of multiusers of the same car. Although a safety issue arises with the implementation of carpooling, still it can be considered as an escalating solution to the congestion problem.

In recent time, carpooling has gained some popularity in Dhaka City. ‘Uber’ is the most known carpooling service which is trending at present. The students travelling from the same area can share a single car provided by ‘Uber’ or other carpooling services(DhakaRides, Taxiwala etc.). This will not only reduce the number of cars entering into the study area, but also it will significantly reduce conveyance money as the service fee will be equally divided and imposed on the passengers and no passenger will have to solely pay the fee himself. But considering the safety issue that arises, carpooling should not be considered as the prime solution to the existing problem, rather it may be considered as an optional resolution for when other options are malfunctioning.

Assuming that 3 students will travel in a single car from the same area, the total number of cars travelling to Sunbeams, Sunnydale, Mastermind(Road No.31) and Mastermind(Road No.30) will be 100, 70, 333 and 150 respectively. The calculated PCU Values considering these number of cars are found to be 100, 70, 333 and 150 respectively. It can be said without any doubt that these PCU values indicate much less school traffic than the school traffic that is already occurring in the study area everyday.

4.5 Implementing Cordon Pricing

4.5.1 Charging Area

The residential area surrounded by Road No. 27(old)(16 new),30(old)(14 new) and 31(old)(13 new) were taken as Charging Areas and they were bounded by the red line given in Figure 6.

Figure 6 : Proposed Cordon Pricing Zones

Vehicles will be charged each time they enter into the zone. Only the private vehicles will be charged (e.g. Private Car, Motorcycle). Other vehicles such as Taxis, CNGs, public transport modes, school buses, police cars, government automobiles and emergency vehicles will be discharged. No charge will be implied on the exit of the vehicles.

4.5.2 Charging Hour

There are definite peak hours within which traffic volume is the highest within the selected part of the residential area. It is when school traffic bursts out. The peak school hour at morning is 7:00AM-9:00AM and at midday it is 12:00PM-2:30PM.

4.5.3 Congestion Charge

Congestion charge was estimated on the basis of the annual per capita GDP of Bangladesh. As following the idea of London Congestion charge, comparing their charge of BDT1192.66 and annual per capita GDP (Purchasing Power Parity, PPP) of BDT30,58,333 with per capita GDP of Bangladesh of BDT1,66,666 (PPP), congestion charge was estimated to be BDT 65. Cars owned by the residents will enjoy 90% exemption, i.e. they have to pay BDT6.5 every time they enter into the area. But to enjoy this benefit, residents' cars will have to register first with a minimal cost of BDT 100 (Hasnat and Hoque, 2014).

4.5.4 Technology/ Charging Mechanism

Most common charging mechanisms are: (JICA, 2010)

1. Area Licensing Schemes (ALS): Need to buy and display coupon or license.
2. Electronic Road Pricing (ERP): Based on in-vehicle transponder units (IUs) that accept stored-valued smart cards for payment, each time vehicles pass through a gantry when the system is in operation, the ERP charges will be automatically deducted.

3. Electronic Toll Collection (ETC): Based on microwave technology and in-vehicle tags. When a car passes tolled booths the system reads data about the car taking into account the time and place of the passing.
4. Initial Electronic Security Systems (IESS): Cameras record images of traffic and send them to a central processor to have their number plates read and checked against the list of vehicles that have been paid for.
5. Tag and Beacon Technology: Tag and beacon involves cars having an electronic tag on the windscreen, which emits radio signals when it passes a roadside beacon, automatically paying the congestion charge.
6. Global Positioning Systems (GPS): Motor vehicles have a tracking device which constantly records the time and location of the vehicle through satellite.
7. Among the above mentioned methods tag and beacon with ANPR (Automatic Number Plate Recognition) camera could be considered as most effective according to the cases around the world as shown in Table 5.

Table 5: Technology Considered for Congestion Charging Around The World (Ahmed, 2012)

	ANPR	**Tag and Beacon**	**GPRS Type**
Local Scheme			
London	✓	✓	
Geona	✓	✓	
Copenhagen	✓	✓	
Prague	✓	✓	✓
Helsinki			✓
Stockholm	✓		✓
San Francisco	✓	✓	✓
Seattle	✓	✓	✓
Auckland	✓	✓	✓
Shanghai	✓	✓	
Hong Kong			✓
National Scheme			
England			✓
Netherlands			✓

Considering the local condition in Bangladesh, a tag and beacon system may seem to be too costly. Thereby the ANRP (Automatic Number Plate Recognition) usage should be enough. There are several ways by which Automatic charge can be collected such as, using cell phones or a simple procedure of sending a text message while a vehicle drives into the charging zone. GPRS is also a popular type of congestion charging in many countries but unfortunately it is too costly for Bangladesh. In GPRS system all the vehicles of the city have to be equipped with an in-vehicle unit costing, BDT12,500 each unit (Hasnat and Hoque, 2014).This procedure does not prove to be feasible as it will require a large amount of capital. Charge can also be collected online, by text messaging, by post services. The users are permitted to pay in advance or the day on which they enter into the charging zone. A penalty is to be imposed on the late payers. Charge collection by mobile phone or by text message may prove to be most convenient for the users (Hasnat and Hoque, 2014).

4.5.5 Enforcement

Available most common enforcement techniques are: (JICA, 2010)
X-Wave Camera: Analogue, colour and is used to give an image of the vehicle in the context of it's surroundings.
CCTV Camera: Analogue, monochrome and provide images for reading number plates.
Automatic Number Plate Recognition (ANPR) Technology: All images are sent to the ANPR via a telecommunications system. This system is based on dedicated DWDM (dense wave division multiplexing) technology which links the central data hub with each of the network

cameras over analogue video circuits. The ANPR creates a data block for each recognized number plate showing the time and date that the images were taken. These are then checked against a database to verify payment or eligibility for discounts and exemptions.

5. CONCLUSIONS

To keep under control the ever increasing school traffic of Dhanmondi Residential Area, it is necessary to increase the capacity of the existing roads. But increasing road capacity of an already developed urban area such as Dhanmondi is not only idealistic but also impossible, thus certain alternative way of traffic management must be applied to reduce congestion resulting from school traffic in the residential area. Cordon pricing has proven it's feasibility in many developed urban areas all around the world. Although considering it's high technological value, it comes with high installation cost which is a little less optimistic for Bangladesh, but bearing in mind the benefits it provides, it holds a good chance of resolving the congestion problem in Dhanmondi residential area by a significant amount. Other alternative ways of resolving the problem were also mentioned in the 'Recommendation' section, among which endorsement of mandatory school bus transportation and enforcement of parking restriction during peak drop-off and pick-up hours are very pragmatic and optimistic ideas which can bring a quick solution to the congestion problem.

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EVALUATING OPERATIONAL CHARACTERISTICS OF PUBLIC TRANSPORT SYSTEM OF KHULNA- JESSORE HIGHWAY, BANGLADESH: A CASE STUDY ON PHULTALA TO AFIL GATE MID-BLOCK

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ABSTRACT

This study aimsatevaluating the operational characteristics of public transportation system from Phultala to Afil Gate mid-block in Khulna-Jessore highway, Khulna. For achieving this, the study focuses on three core studies related to the speed for evaluating the existing situation: (i) spot speed, (ii) running speed and (iii) journey speed. This research is based on primary source data in the form of both physical and social survey; collected from users, drivers and traffic polices; and a GIS based secondary analysis of the study area has been carried out later on. Different indices; PHF (Peak-Hour Factors) and Lindley's Index, have been used for comparing the obtainedvalues to the standard values. The outcomes of this study suggest that the speed fluctuation of the study area of different vehicles isn't likely to differ from the standard value. The LOS found for the study area is A, where volume to capacity ratio has been located less than 0.6 and the delay time is less than 10 sec.;which indicates it allows free flow with low volume and high speeds.PHF value is 0.67 and according to Lindley's index V/C <0.77; which also remarks that Congestion phenomenon isn't presentin the study area.

Keywords: *Traffic congestion, Speed performance, Road network, Traffic control and Management*

1. INTRODUCTION

Public transportation is a shared passenger-transport service which is available for use by the general public. A well planned public transportation provides economic opportunities and drives community growth revitalization (Akmal Abdelfatah, 2015). The common modes of public transportation in Khulna are rickshaw, baby taxi,battery bike etc. There is also a public bus service named Nagor Paribahan which runs frequently within Khulna city. Recently BRTC bus services have been also introduced to carry traffic volume along the Khulna-Jessore Highway. In respect of Khulna division's transportation system, Khulna-Jessore Highway is the most important road network for both intra and intercity connectivity. Besides after the completion of Padma Bridge transportation between Khulna region and Dhaka region will become even easier which will increase the economic activities of Khulna. To support this economic growth and future public demand a well-planned transportation system is prerequisite(Akmal Abdelfatah, 2015).

The objective of the research is to evaluate the operational characteristics of public transportation system from Phultala to Afil Gate mid-block in Khulna- Jessore highway, Khulna. In order to evaluate the operational characteristics several traffic studies e.g. volume study, speed study etc. have been carried out. The speed study will help to enforce control systems ensuring safe, rapid and convenient transit of people and goods. It will also help determining nodes where proper management is necessary. Thus, this study will help to develop a proper transportation system. Finally, the output of the project may be helpful in further projects related to the Khulna-Jessore Highway.

2. LITERATURE REVIEW

Traffic speed analysis is a compulsory part for a proper transportation planning. Accident analysis, road maintenance, and congestion are the modern fields of traffic engineer, which uses speed data as the basic input(Tyburski, 1989).The designing of road geometry requires the speed study. To assume the proper location of signs, signals, safe speed and speed-zones, speed study is required.

A study conducted in Barcelona evaluated the level of reduction in the number of road collisions, number of injuries, and number of cars affected by an accident due to the presence of speed cameras on Barcelona's obeltway. The study compared accidents on two road segments, where one road had no speed cameras installed and one with speed cameras installed. The analyses of the study were based on collisions and accidents' data. The results of the study concluded that speed cameras are effective in reducing the number of accidents and, therefore, the number of injured people (Perez et al, 2007).

In another study in London, UK, (Walter et al, 2011) presented the impact of increasing the police enforcement within an urban area. The researchers reported the effect of setting speed radars and more static and mobile police enforcement that are easily recognizable by the drivers. The authors concluded that there was a systematic speed reduction along the considered corridor due to the application of the enforcement measures. However, there was no effect of these enforcement measures on the use of seatbelts and mobile phones.

In a study at Vidya Path in Chandigarh (Amanpreet Kaur, 2014) the objective was to analyze the speed characteristics along the study stretch and to determine the speed percentiles, which were useful in designing and regulating the traffic. The data gathered in spot speed studies are used to determine vehicle speed percentiles, which are useful in making many speed-related decisions. And the outputs of the study were the maximum speed limit on the road is equal to 58 Kmph for 2-wheelers as well as for 4-wheelers. All the 2-wheelers and 4-wheelers plying on the road moved with a speed ranging between 13-58 Kmph. Maximum 2-wheelers moved with the average speed of 31 Kmph and maximum number of 4-wheelrs moved with an average speed of 26 Kmph. The 85th percentile speed i.e. the critical speed for 2-wheelers is 42 Kmph and for 4-wheelers is 40 Kmph. The 15th percentile speed i.e the minimum speed for 2 wheelers is 22 Kmph and for 4- wheelers is 16 Kmph.

So, the highway services can be divided in six categories which ranked as Level of service(LOS)is a qualitative measure used to relate the quality of traffic service, used to analyze highways by categorizing traffic flow and assigning quality levels of traffic based on performance measure like speed, density etc. LOS describes the quality of operational condition within a traffic stream. Six LOS are defined according to the Volume to Capacity Ratio or V/C) –if V/C ≤ 0.6, then it indicates Level of service (LOS) "A". Similarly LOSB≤ 0.7, LOS C≤ 0.8, LOSD≤ 0.9, LOSE≤1 and LOSF>1 (Kadiyali, 1978)

3. STUDY AREA AND METHODOLOGY

3.1 Study Area

Khulna city was selected as the study area. Khulna is a low-lying city which has developed in a linear pattern alongside the Bhairab and Rupsha Rivers in south western Bangladesh. The linkages of Khulna city with other towns and growth centers can enhance the importance of the city.

"Phultala to Afil Gate" (Figure: 1) section which is in the Khulna-Jessore Highway was selected as our study area. The section is about 4.8 km long and is a two lane road. The

study area is about 52.5 km away from Jessore, 1.7 km from Jahanabad Cantonmentand 16.2 km from Khulna city center. Two renowned Jute mills named Alim jute mill and Eastern jute mill are located along the highway. There exists two influential industriesso that a large number of attraction and distribution factors functioned here. The section of the study area is too busy as it is linked with By-pass.

3.2 Methods

After the selection of the study area, preliminary data was collected through the desktop research and reconnaissance survey. Where the physical features were measured by using measuring tape. Here the volume study was conducted by using tally system for counting different types of vehicle on a weekday and aweekend at 3 peak periods and 2 off-peak periods to measure flow fluctuation by calculating PCU.

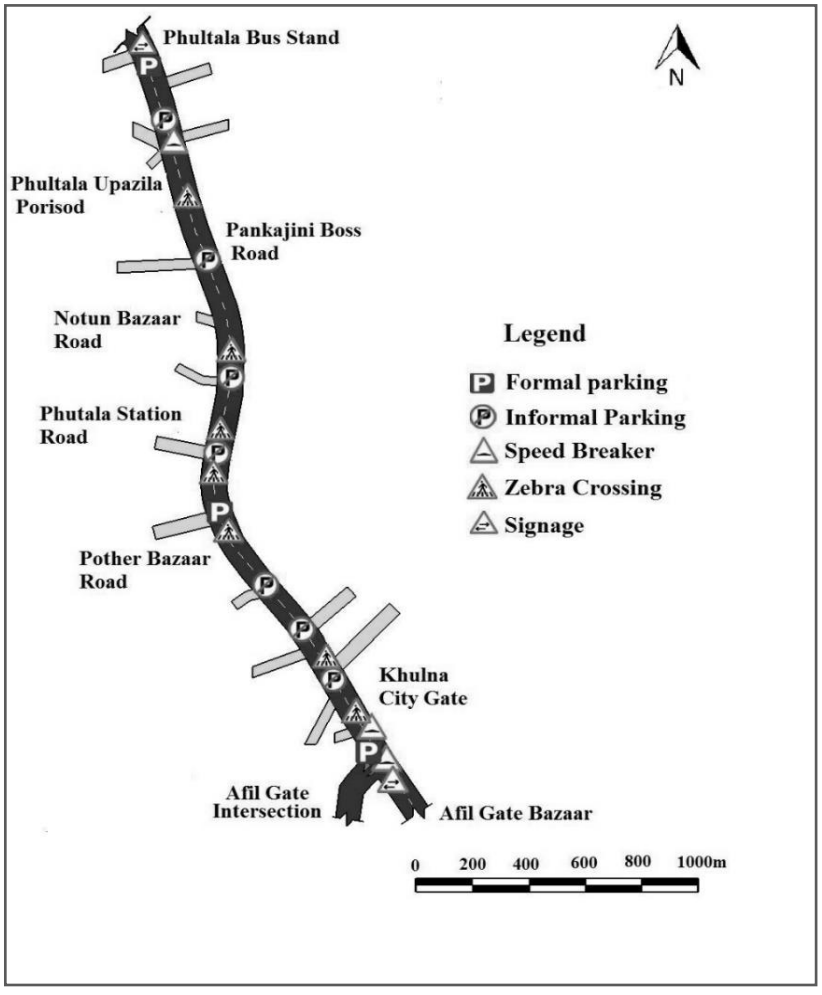

Figure 1: Study Area, Phultala to Afil Gate (Author, 2017)

Spot speed of different vehicles running on the stream was calculated from the time required to complete a distance of 60 ft(Kadiyali, 1978).

$$\text{Spot Speed} = \frac{\text{Distance}}{\text{Time taken by vehicle to pass the distance}} \quad \text{Km/hr.(Kadiyali, 1978)}$$

After that, speed survey was conducted by using a test car and bus from Afil Gate to Phultala in both direction to calculate journey speed and running speed along with opinion survey of 100 users, 7 drivers and 4 traffic polices.

The data collection for journey speed and running speed was conducted by Moving Observer Method (Kadiyali, 1978). The calculation is given below –

The Passenger Car Unit (PCU) for North bound, $q_n = (\frac{x+y_n}{t_a + t_w})$ PCUs/min

The Passenger Car Unit for South bound, $q_s = (\frac{x+y_s}{t_n + t_s})$ PCUs/min

Where, x = Total PCU of that bound

$y_n = y_s$ = Number of overtaking vehicles – Number of overtaken vehicles of each bound

$t_a = t_n$ = Total journey time of south bound (Minute)

$t_w = t_s$ = Total journey time of north bound (Minute)

Now, $\bar{t_n} = (t_n - \frac{y_n}{q_n})$ minute

And $\bar{t_s} = (t_s - \frac{y_s}{q_s})$ minute

Mean journey speed in north bound direction = $\frac{d}{\bar{t_n}}$ Km/min

Mean journey speed in north bound direction = $\frac{d}{\bar{t_s}}$ Km/min

Where, d = Total road distance

Mean running time in north bound direction = $\bar{t_n}$ – stopped time

Mean running time in north bound direction = $\bar{t_s}$ – stopped time.

Finally, collected data had been analyzed to measure capacity and level of service (LOS) and some indices had been set to measure congestion i.e. flow rate of vehicles . At last, some recommendations had been provided based on some policy and physical measures for free flow of vehicles.

4. ANALYSIS & INTERPRETATION

Cross sectional elements have a great impact on the speed of the vehicles. If the cross sectional elements like Right of way, Carriage way, Side walk, Shoulder, Parking space are kept in the road, then smooth and efficient flow will be ensured. From (Table 1), it is seen that almost all of elements are present in Phultala to Afil Gate road section as per their need except formal parking provision.

Table 1: Road way geometry at a glance

Name of the intersection	Right of way (feet)	Carriage way (feet)	Sidewalk (feet)	Shoulder (feet)	Bicycle route (feet)	Parking space (feet)	Extra space (feet)
Phultala bus stand	87.4	34.6	14	3	12	10	
Pother bazar	61	35		3			10
Khulna-Jessore bypass	50	34	5	3			
Alim gate	42	30	3	3			
Afil gate bazar	72	34	6	3			10

(Field Survey, 2016)

4.1 Formal and informal parking

One of the main reasons for speed fluctuation is the presence of parking space. Where parking space is available i.e. formal, no congestion arise in this section. On the other hand, informal parking causes congestion as well as decreases speeds of vehicle.

Within our study area, formal parking as well as informal parking were found. There had been found three formal parking provision whereas seven found informal. All of these informal parking cause congestion in these nodes of the surrounding area (Figure 1). It also leads to decrease in vehicle speed which affects in the productivity of goods and causes unexpected delay as well as loss for serious patients inside ambulance.

4.2 Vehicle composition

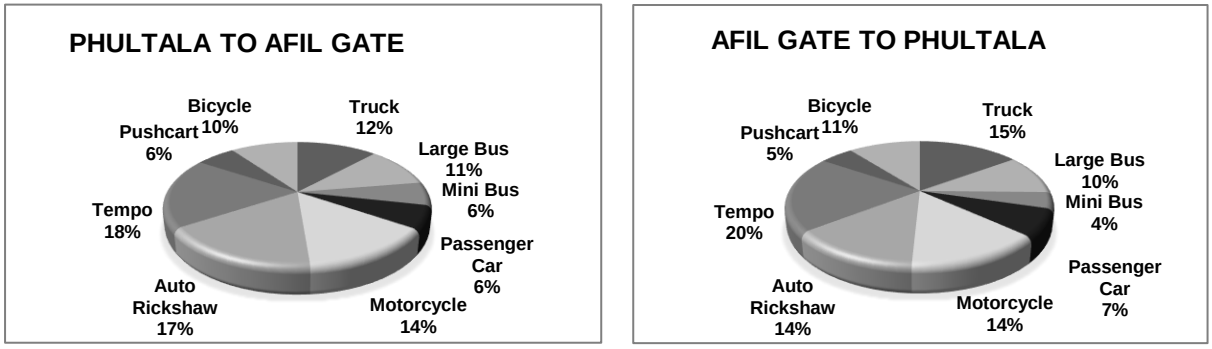

Figure 2: Comparison between Compositions of Traffic in both Direction (Source: Field Survey, 2016)

From the (Figure 2) from both direction that tempo and auto rickshaw are the most popular vehicle in the road section for their comfortless and availability though they are more costly than others. As a result, there arises congestion in the stream though total PCU value generated from these two vehicles is not so much. Again, speed of these three wheelers are also low. On the other hand, public transport i.e. bus are lower in number though these could be helpful in fulfilling majority public demand with its higher speed as well as lower cost.

It can be concluded that the spot speed (Table 2) of motorcycle is very high in Afil Gate to Phultala but in Phultala to Afil Gate passenger car's spot speed is very high. The speed of bus is moderate in both direction.

Table 2: Spot speed in both direction

Vehicle Type	Spot Speed for Afil Gate to Phultala (KPH)	Time (Second)	Spot Speed for Phultala to Afil Gate (KPH)	Time (Second)
Passenger Car	51.62	4.18	49.34	4.33
Truck	35.08	6.16	36.76	5.88
Bus	38.74	5.58	37.83	5.71
Tempo	27.54	7.84	26.68	8.10
Motorcycle	53.38	4.05	47.45	4.55
Easy bike	24.56	8.79	21.43	10.08

(Field Survey, 2016)

Almost all the vehicles travel in the road section in their own design speeds which indicates an efficient traffic flow. Reason behind this is that volume of traffic moving in the stream is lower than the capacity of the road section.
Another reason might be due to having two traffic police boxes in this road section, one for bus, truck and another for tempo, auto; speed of the vehicles is maintained as per rules.

4.3 Journey Speed & Running Speed

For analyzing journey speed and running speed a survey was conducted by car and bus from Afil Gate to Phultala in both directions.

Table 3: Running and Journey speed in both direction

Bus	
Vehicle per minute, q	8
Mean Journey Time(min)	8.12
Mean Journey Speed (Km/hr.)	35.48
Mean Running Time(min)	7.86
Mean Running Speed (Km/hr.)	36.64

Micro bus	
Vehicle per minute, q	7
Mean Journey Time(min)	7.33
Mean Journey Speed (Km/hr.)	39.29
Mean Running Time(min)	7.07
Mean Running Speed (Km/hr.)	40.73

(Author, 2016)

The distance from Afil Gate and to Phultala was 4.8 km. Time required for travelling from Afil Gate to Phultala was 8.58 min including delay time of 0.26 min and from Phultala to Afil Gate, it was 8.05 min where delay time was 0.26 min. Journey speed of bus was calculated by moving observer method which was 35.48 km/hr. and running speed was 36.64 km/hr. which was obtained by deducting delay time from the total journey time. Again, journey speed of car was 39.29 km/hr. and running speed was 40.73 km/hr. from Phultala to Afil Gate.

It is observed from (Table 3) that bus required more journey time than car as bus had to stop frequently in different stoppages for boarding and lighting passenger. So they needed more time and had less journey speed. On the other hand, car required less journey time as delay time is lesser and speed is more than bus.

4.4 Flow analysis

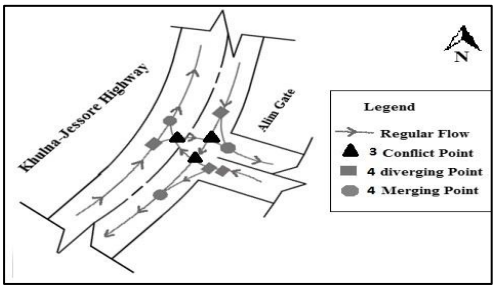

Figure 5: Intersections ofKhulna Jessore Highway and Alim Gate,*(Author, 2017)*

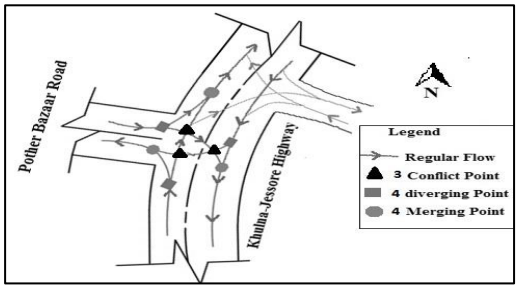

Figure 6: Intersections ofKhulna Jessore Highway and Pother Bazar, *(Author, 2017)*

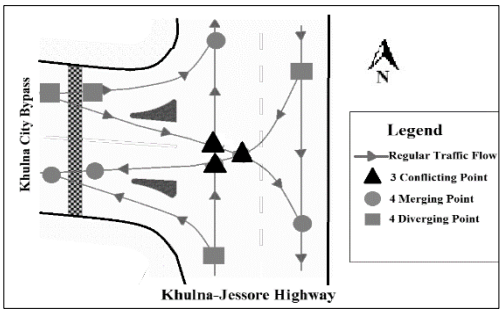

Figure 7: Intersections of Khulna-city Bypass and Khulna Jessore Highway, *(Author, 2017)*

From the (Figure 5, 6 &7) intersection nodes, it is noticed that our study area is not so risky as only three conflicting points in each node were found in the above three major intersections. But it seems a congestion prone area as all the intersections are “T shaped”. Due to having two secondary roads in the Pother Bazar, there arises some irregular flows and to restrict these flows formal parking is provided in this section.

Table 3: Duration of delay time and causes of delay within study area

Location	Delay time(min)	Delay cause
Afilgate bazaar Mor-Afilagte	0.05	Traffic congestion
Alimgate-Pother Bazaar	0.10	Speed breaker
Phultala Bazaar-Phultala Bus Stand	0.04	Traffic congestion
Afilgate-Alimgate	0.09	Traffic congestion

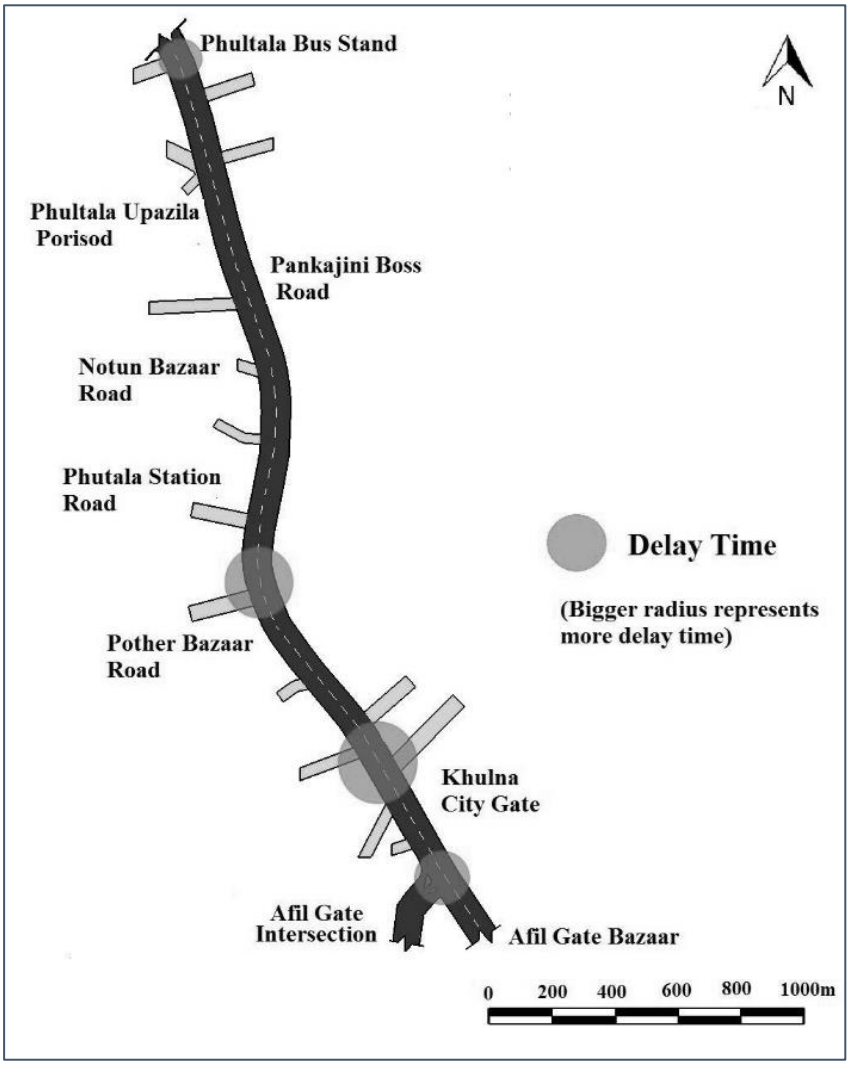

Figure 8: Ranking According to Delay Time(Field Survey, 2016)

In the direction from Phultala to Afil Gate,it is seen that volume of traffic are high in the pick hours. At 8.30-9.00, it is seen that traffic volume is very high as people from there come to Afil Gate as there remains Alim Gate jute mills and eastern jute mills where maximum of the people work. Again, at 5.00-5.30 maximum people return to home and people go to Khulna for shopping purpose

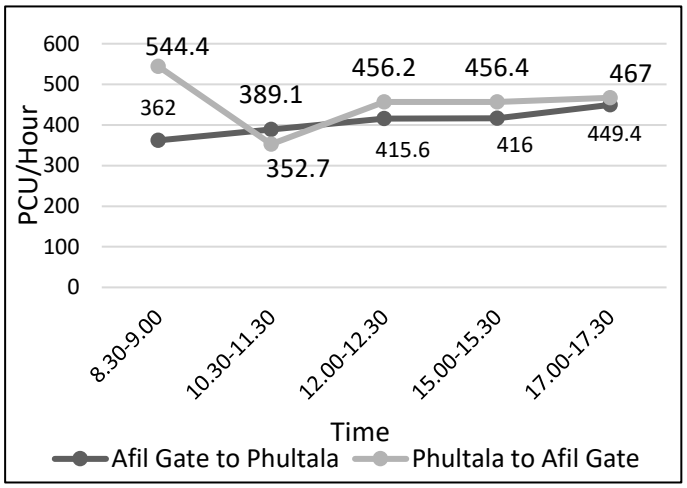

Figure 9: Flow Fluctuation (Field Survey, 2016)

4.5 Capacity & Level of Service

For calculating Level of Service (LOS) different types of measure were taken. Here, total volume(PCU/Hour) was calculatedand Capacity of a road section was taken as 1400 PCU per hour per lane(DITS, 1994).As there remains one lane in Phultala to Afil Gate roadway section so it was adopted.

Table 5: Volume to Capacity Ratio at Different Intersections

Intersection	Volume to Capacity Ratio									
	8.00 – 9.00		10.00 – 11.00		12.00 – 13.00		14.00 – 15.00		17.00 -18.00	
	To Fulbari Gate	To Jessore	To Fulbari Gate	To Jessore	To Fulbari Gate	To Jessore	To Fulbari Gate	To Jessore	To Fulbari Gate	To Jessore
Afil Gate	0.39	0.26	0.25	0.28	0.33	0.30	0.33	0.30	0.34	0.32
Pother Bazaar	0.35	0.23	0.27	0.27	0.31	0.28	0.33	0.31	0.37	0.34
Phultala	0.38	0.28	0.25	0.27	0.34	0.31	0.32	0.32	0.36	0.35

(Field Survey, 2016)

For Afil Gate Intersection**:**

- For peak hour:

Volume/Capacity value at 8.00-9.00 is = (0.39+0.26)/2 =0.325

Volume/Capacity value at 12.00-13.00 is= (0.33+0.30)/2 =0 .315

Volume/Capacity value at 17.00-18.00 is = (0.34+0.32)/2 =0.330

So Average Volume/Capacity value at peak hour is = (0.325+0.315+0.330)/3 = 0.32

- For Off peak hour:

Volume/Capacity value at 10.00-11.00 is= (0.25+0.28)/2= .265

Volume/Capacity value at 14.00-15.00 is= (0.33+0.30)/2= .315

So Average Volume/Capacity value at off- peak hour is= (0.265+0.315)/2 =0.24

Table 6: Level of Service (LOS) At Different Intersections (Volume/Capacity)

Road Intersection	Time	Lane	Volume/Capacity		Level of Service(LOS)	
					Level	Service
Afil Gate	Peak Hour	1	**0.32**	≤0.6	**A**	Allows free flow, with low volume and high speeds
	Off-Peak Hour	1	0.24	≤0.6	**A**	
Pother Bazaar	Peak Hour	1	0.31	≤0.6	**A**	
	Off-Peak Hour	1	0.29	≤0.6	**A**	
Phultala	Peak Hour	1	0.34	≤0.6	**A**	
	Off-Peak Hour	1	0.29	≤0.6	**A**	

(Field Survey, 2016)

In Level of Service (LOS) 'A', road provides the opportunity of free flow, with low volumes and high speed traffic and the traffic density is low with speeds controlled by driver's desired speed limits and physical road way conditions. Little or no restriction in maneuverability due to presence of other vehicles and drivers can maintain their desired speeds with little or no delay.

Table 7: Level of Service (LOS) at Different Intersections (Delay Time)

Road Intersection	Delay time (sec)		Level of Service(LOS)	
			Level	Service
Afil Gate	3	<=10	**A**	Allows free flow, with low volume and high speeds
Pother Bazaar	6	<=10	**A**	
Phultala	2.4	<=10	**A**	

(Field Survey, 2016)

Every intersection of the road section contains Level of Service (LOS) 'A' category which was gained from "Volume to Capacity Ratio" and "Delay Time". Again, overall speed of different vehicles couldn't be calculated but different vehicles were found moving at their own design speeds in average. So, it can be said that Phultala to Afil Gate road section has achieved level of service "A".

Some barrier such as slow and high speed vehicles move in the same road and same time in the same direction. Again, pedestrians crossing the road to and fro and boarding - alighting passengers every point of the road may cause the delay. As the highway road in the city area its need for every vehicles to moving in a limited speed range to avoid road accident.

4.6 Measurement Indices

According to Lindley, 1987 the volume capacity ratio of an intersection must be same or less than 0.77 for efficient run of the vehicle so that no congestion occur in that road. But if the value is greater than 0.77 it indicates that there exists congestion in the intersection.

$$\text{Lindley's index} = \frac{Volume}{Capacity}$$

Table 8: Volume in each intersection

Road Intersection	Time	Lane	Volume/Capacity
Afil Gate	Peak Hour	1	0.32
	Off-Peak Hour	1	0.24
Pother Bazaar	Peak Hour	1	0.31
	Off-Peak Hour	1	0.29
Phultala	Peak Hour	1	0.34
	Off-Peak Hour	1	0.29

(Field Survey, 2016)

So,it can be concluded from the analysis that road intersections of the study area is congestion free zone as all values of the vehicle to capacity ratio were less than the standard value 0.77 .Another measuring index is peak-hour factors (PHF) that states that typical peak-hour factors for freeways range between 0.80 and 0.95. Lower factors are more typical for rural freeways or off-peak conditions. Higher factors are typical of urban and suburban peak-hour conditions.

$$PHF = \frac{total\ volme\ during\ peak\ hour}{4 * v_{30}\ (peak\ rate\ of\ within\ the\ hour)}$$

Table 9: Flow rate in intersection at different time

Time	Volume		Rate of Flow	
	Afil Gate-Phultala	Phultala- Afil gate	Afil Gate-Phultala	Phultala- Afil gate
8.30-9.00 am	158	237	158*4=632	237*4=948
12.00-12.30 pm	182	196	728	784
5.30-6.00 pm	204	200	816	800
	V= 544	**V= 633**		

(Field Survey, 2016)

$$PHF_{(Afil\ Gate-Phultala)} = \frac{544}{816} = 0.67$$

From the standard of PHF value it can be easily said that the direction from Afil Gate to Phultala and vice versa have moderately steady flow at the peak hour.

$$PHF_{(Phultala-\ Afil\ Gate)} = \frac{633}{948} = 0.67$$

5. CONCLUSIONS

The analysis of roadway geometry and physical features gives an overview on the fixed facilities, control system and support system of the study area and which was not so satisfactory. The speed analysis identifies the operational cases of this transportation system. The results from the analysis has helped to identify the locations where improvement of operational features are required such as speed recording camera, rationale traffic facilities etc. According to that, various recommendations are proposed. The recommendations include establishment of signs and signals on various points, speed-breakers and other facilities for both the drivers and the pedestrians. This will help to improve the transportation system as well as to reduce the causes of accidents caused by vehicular movement for achieving a sustainable transportation system.

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RELATIONSHIP BETWEEN DWELL TIME AND NUMBER OF PASSENGER BOARDING: A REFLECTION OF BATTERY BIKE IN KHULNA CITY, BANGLADESH

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ABSTRACT

This research intends to find out the relationship between no of passenger(s) boarding and battery bike dwell time. It also tries to observe the variations in dwell time during peak and off peak hour of a day. This study was conducted in Khulna city (the third largest city of Bangladesh). The data has been collected on 10 variables from two intermediate stoppage during different time of a day. These variables have been selected based on literature review and visual observation and analyzed by multiple regression. The study showed that battery bike dwell time and the influencing factors vary based on time. It is also found that dwell time depends on payment duration, waiting time, boarding and alighting time instead of number of boarding and alighting passengers. But during off peak hour, number of boarding passenger plays an important role in the dwell time. Besides, passenger behavior has an impact on boarding and alighting time. In this paper, it is also recommended the maximum dwell time, the battery bike should spend at each stoppage during different period of a day. Therefore, the result of this research will help the transportation agencies and decision makers to ensure overall reliability and quality services as well as to reduce traffic congestion through schedule planning.

Keywords: *Passenger, battery bike, dwell time, Khulna, Bangladesh*

1. INTRODUCTION

Success of a public transport largely depends on how well it is designed (route, vehicle, ticketing, fare etc.) for the target people and its reliability on performance. One of the significant factors for public transport reliability and quality is dwell time. Dwell time is the amount of time the public transits stop at the stoppage for boarding or alighting passengers (Li et al., 2012). Dwell time is influenced by several factors e.g. no of passengers boarding and alighting, payment method, weather condition, traffic, location of the stoppage, parking space, time of the day and so on (Gopinath et al., 2015). It is found that dwell time contributes a lot to the total travel time of the public transport. For example, dwell time consumes 26% of total travel time of the public bus (Fletcher and Geneidy, 2013).

There are several types of public transport all over the world like metro rail transit (MRT), light rail transit (LRT), bus rapid transit (BRT) and so forth. In developing countries high-end public transport like MRT and LRT is not practiced for high capital and operating cost. As a result, Motorized vehicles (MT) are dominating in both public and private sector of these countries. Among this, MT vehicles, bus, minibus, CNG driven auto rickshaw and taxi are very common in Bangladesh. In 2009 battery bike as a MT was first introduced in Bangladesh. In Khulna, like other cities in Bangladesh, battery bike became a major transportation mode, especially for the low income peoples and students due to its low cost and availability. Every day approximately 17,000 battery bikes are running in this city providing more than half (65%) of the total transport demand in Khulna city (Lubna et al, 2014). This increasing number of battery bikes is also causing traffic congestion in the cities due to lack of fixed dwell time at the stoppage along with haphazard parking and stopping on road.

Dwell time plays an important role on system performance, service reliability and quality for any mode of public transport. Till now no literature has been found on battery bike dwell time analysis. Most of the earlier studies on dwell time analysis were found particularly for public bus and train considering different variables. For example, San and Masirin (2016) and Shockley et.al (2016) found that dwell time is sensitive to passenger volume (total number of passenger boarding and alighting). It is also found that "passengers alighting will not contribute to overall dwell time unless there are far more of them than boarding passengers" (Shockley et al., 2016). Another research by Ahrin (2016) has identified that dwell time varies during different time of the day.

In Khulna city the battery bike runs both as transit and paratransit. It can carry 6 persons per trip with an average speed of 30km/h (Iqbal et al., 2013). Khulna University Masters of Urban and Rural Planning Discipline (Batch 16, 2017) found that these types of three wheelers stop suddenly here and there for boarding or alighting passengers. The hypothesis of the research is that Battery bike dwell time increases if the number of passenger boarding increases. In line of the hypothesis, the objective of this research is to find out the relationship between the Battery bike dwell time on the stoppage and the number of passenger(s) boarding. Furthermore, this study attempts to see the variation in dwell time during different time of a day, e.g., peak hour and off peak hour. In doing so, this research can contribute to the broader understanding about the motorized three wheelers in Khulna city and beyond. In addition, the findings of this research can help the transportation agencies and decision makers to ensure overall reliability and quality services as well as to reduce traffic jam through schedule planning.

2. THEORETICAL FRAMEWORK

This study explores the factors affecting battery bike dwell time. First, in general terms, battery bike is a battery driven three wheeler. Secondly, dwell time refers to the time in which the public transport stops at a station for serving the passengers. The dwell time therefore depends on number of passenger boarding and alighting. It basically begins when the public vehicles stop at a station and lasts till to move away (Li, 2012; Zhang and Teng, 2013, Fernandez et al., 2010).

Li et al, (2013) recommends two aspects of dwell time for studying: (1) dwell time method which reveals the relationship between dwell time and relevant factors; and (2) Physical factors affecting dwell time e. g platform, boarding floor and vehicle floor height, number of doors, payment methods and so forth. This study focuses on the former aspect as it suits well with battery bike.

2.1 Factors Affecting Dwell Time

Several factors affect dwell time. Gopinath et al. (2015) divide these factors into two parts: person/passenger variables and design factors. Person variables include number of passenger boarding and alighting, platform and door crowding and congestion, human behavior and human choice. Design factors comprise type of vehicles, number of doors for getting in and out, payment method and location. Again Jaiswal et al. (2009; 2010) divide the dwell time data into two components: bus side data and passenger side data. The bus side data contains queuing time, and door opening and closing time. The passenger side data comprises walking time from waiting position to bus door, platform density, and queuing time. Besides, there are another factors related to weather which affect dwell time, e. g, time of a day and weather condition (Zhang and Teng, 2013).

2.2 Prior Studies on Dwell Time Factors

Several scholars have conducted researches considering different factors to estimate public transit dwell time. For example, Jaiswal et al. (2010) and Li et al., (2012) found that dwell time is significantly dependent on number of passenger alighting and boarding. Shalaby and Farhan (2003) assumed that boarding passengers at each bus stop have a more significant effect on bus dwell time at that stop than alighting passengers. Sometimes, this passenger boarding and alighting process becomes affected by the passenger profile. For example, passengers with strollers or luggage and those who require special assistance (visually impaired and on wheelchairs) would extend the process of boarding and alighting (Douglas, 2012).

Along with passenger alighting and boarding factors, several researchers took into account several other factors in order to get more accurate result. For example, speed of boarding and alighting passenger, passenger conflict, fare collection method, vehicle capacity, crowding and so forth. According to Weston (1989) dwell time depends on speed including number of passenger boarding and alighting and found that mixed flow of passengers requires more dwell time than uni-directional flow.

In spite of this, Peng and Yang (2002) found that the location and the waiting point of the bus stop along with period of time influence the dwell time. For example, on hills, the effect of gravity on already weak diesel engines can lead to considerable additional delay if a bus has to accelerate from a stop (Furth and San Clemente, 2006). Jaiswal et al (2010) established that passenger walking distance from station to bus door leads the bus to experience higher dwell time.

On the other hand Zang and Teng (2013) proved that crowding, fare collection method, vehicle capacity along with passenger boarding and alighting number increases the dwell time accuracy. For example, Jaiswal et al. (2007) suggested that platform crowding pattern has a significant effect on dwell time. It affects the passengers' maneuverability and obstructs the clear line of sight to approaching buses. Dorbritz et al. (2008) and Jaiswal et al (2009) found that the payment method could affect the bus dwell time. Farnandez et al (2009) showed that the dwell time variability is affected by the platform height, door width and fare collection method. Result shows that by removing on board ticketing system, the boarding time could decreased by about 15%.

Furthermore, after analyzing the boarding process at a bus stop and a busway station, Jaiswal et al. (2009) established that at the bus station where boarding is predominant, an increase in the platform crowd increased the passenger–bus interface duration which leads to loss of time for buses and increases the bus dwell time. Furthermore, according to Li et al. (2012) conflict between the boarding and alighting passengers also rises dwell time.

In case of train, it is found that dwell time is very much influenced by the passenger volume, though at different rates due to factors such as door widths, platform gaps and movement of passengers. A mixed flow of passengers and on-board crowding are also expected to increase dwell time (San et al., 2016).

Additionally, to find out the weather impact on dwell time, Bladikas et al. (2009) examined bus travel time in different weather condition and found that bus dwell time (boarding and alighting times) increases in bad weather condition.

2.3 Methods

Several types of statistical models are used in dwell time analysis. Traditionally, linear regression model were used for finding the relationship between dwell time and its relevant factors (Rashidi and Ranjitkar, 2015). Levinson (1983) used a regression approach for developing bus dwell time and established the total number of boarding and alighting passengers is the major factor of bus dwell time. However due to its simplicity and achieving more accuracy, some scholars use non-linear approach e.g. multiple logit model, error component model (Tirachini et al., 2013; Li et al., 2012). For example Li et al. (2012) perform non-linear regression model considering number of passenger boarding or alighting. They also added number of standing commuters on vehicles and platform and found that conflict between the boarding and alighting passengers also rises dwell time. Kittelson and Associates (2003) established a multivariate linear regression model for dwell time estimation considering boarding and alighting passengers as separate variables. Beside these, statistical simulation technique is another approach for dwell time modelling. Time series data like moving average, random walking is also used by some scholars for predicting dwell time (Rashidi and Ranjitkar, 2015).

From the above discussion, it can be concluded that all researches on dwell time analysis are particularly for public buses and trains. However, no research has been conducted in Bangladesh with empirical data on public bus or battery bike.

Battery bikes are a distinct identity of public transport in all divisional cities, Bangladesh – they are virtually everywhere. It is being extensively used for short distance travel providing cheap alternative to rickshaw and other modes of public transport like bus, van and auto-rickshaw. Recent study by Lubna et al., (2014) found that battery bike has the highest spatial coverage. Because they are best suited to narrow and crowded streets. As a result, they can cover longer distances within urban areas (Iqbal et al., 2013). Besides, they have high level of customer satisfaction due to low cost and high comfort. Apart from these, battery bike is an ideal example of green transport due to low air pollution, economic and social importance. In spite of these advantages, battery bikes become the main causes of traffic congestion in Khulna city. Because this types of three wheelers stop/park suddenly here and there for boarding or alighting passengers which hampers other vehicle's movement.

Therefore, it's out most important to identify the factors affecting battery bike's dwell time.
This research attempts to find out the relationship between the number of passenger boarding and battery bike dwell time through linear regression model. From a preliminary reconnaissance survey and literature review, a list of factor that might affect the dwell time of battery bike is identified. The list wise data collection is mentioned in the following section

3. METHODOLOGY

There are five main Battery bike routes in Khulna City, Bangladesh. These are*: Rupsha-Shibbari*, *Shibbari-Shonadanga, Gollamari-Powerhouse, Gollamari-Notunrasta, Dakbangla-Notunrasta* (Figure 1). This routes are not declared by any authorities. Most of the times it is fixed by the drivers and the demand of the passengers. The data of this study were collected from two intermediate stoppage (*Nirala More* and *Moilapota More*) due to limited time and manpower. This stoppage are located on *Gollamari- Power house* route. The length of this route is approximately 4 km (*Gollamary to Power house*) consisting 4 battery bike stoppage. This stoppages are selected based on the location at the intersection with high passenger demand and ease of access. The data on the dwell time were collected from 120 battery bikes on Monday at peak and off peak hour (7-8 pm and 11-12 am) due to different traffic dynamics. The data has been collected on the following variables for conducting multiple regression model –

1. Dwell time (Dt)
2. Negotiation time (Nt)
3. Boarding Time (Bt)
4. Alighting Time (At)
5. No of passenger boarding (Nb)
6. No of passenger alighting (Na)
7. Payment duration (Pd)
8. Waiting time (intentional wait, crowded stop, passenger behavior) (Wt)
9. Passenger with load (children, lagudge) (Pl)
10. Gender of the passenger (Gp)

The data extraction has been done manually. For example, to record the time of different variables in SPSS software by observing the video.

Figure 1: Battery bike Route in Khulna City.

4. ANALYSIS AND FINDINGS

4.1 Dynamics of the Dwell Time Factors in Different Time of a Day

For this analysis descriptive statistics has been performed to see the variation in dwell time factors in different time of a day. The number of total battery bikes are more or less the same in all the time even though the passenger's travel behavior varies with the time of a day (peak hour and off peak hour) (Figure 2, 3, 4, 5). Every day, approximately 1200/h battery bikes are found in both direction during peak and off peak hour at each stoppage. From the table 1, it is found that the longest dwell time took place during off peak hour with 20s due to large number of boarding passengers with long boarding time and also the lengthy payment duration. From the visual observation, it is found that this long boarding time also depends on passengers' behavior. For example, sometimes passengers come from the opposite side of the road to board on, especially female passengers sometimes board in with their children.

Sometimes, passengers take time for closing their umbrella in a hot or rainy day.

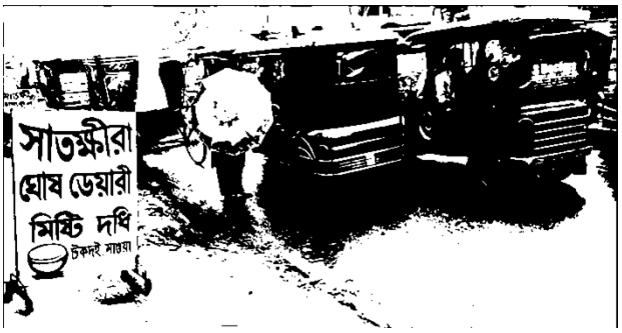

Figure 2: Passenger Closing Umbrella before Boarding

Figure 3: Women with children

Figure 4: Passenger Relocation

Figure 5: Presence of Police at Peak

Besides , during the off peak hour it took long waiting time due to the intension of new passengers, sometimes due to the crowded stoppage and sometimes for passengers relocation. However, it was during the evening period when the most number of passengers alighted with a long time. In this period, most of the passengers basically return to their origin. Sometimes, they meet their friends at the stoppage. Therefore, they alight with a relax mode which extends the time. On the other hand, in the peak hour, payment duration and waiting time is relatively low based on off peak hour because the presence of traffic police force the drivers to leave the stoppage as soon as possible.

Table 1: Mean Value of Variables Affecting Dwell Time

Variables	Peak hour	Off peak hour
Dwell time (s)	15.20	20.27
Negotiation time (s)	.98	.78
Boarding time (s)	1.91	3.08
No of Passenger Boarding (person)	.45	2.56
Alighting time (s)	1.90	.58
No of passenger alighting (person)	.93	.81
Waiting time (s)	2.21	4.50
Payment duration (s)	8.18	8.38

4.2 Factors Affecting Battery Bike Dwell Time

For estimating the factors influencing Battery bike dwell time, regression model has been performed based on the peak hour and off peak hour at 95% confidence level. Here, Dwell

time is a dependent variable and rest are independent variable. It can be expressed in the following way: Dt = f (Nt, Bt, At, Nb, Na, Pd, Wt, Pl, Gp).

From the result, it is found that gender of the passengers (sig. peak = .776, off peak =.482) and the passengers with load (sig. peak= .769; off peak =.097) do not affect the battery bike dwell time. But during the morning hour no of passenger alighting (sig .778) and during the evening hour (peak hour) no of passenger boarding (sig .441) does not have significant influence on dwell time. Therefore, the models of this two period are following –

Table 2: Dwell Time Regression Model

Time Period	Regression Model	R^2	ANOVA	
			F	P
Peak Period	Dt= 1.05Nt + .96Bt + .97At + .26Na + .98Pd + 1.02 Wt	.99	5717.13	.00
Off period	Dt= .66Nt +.72Bt + 3.74Nb +1.05At + 1.01Pd + 1.046 Wt	.96	175.29	.00

The results based on the R^2 value that are 99% and 96% showed that the Dt models were adequate and could explain relatively high percentages of the variations in the data. And the results also showed the most prominent independent variables that predicts the battery bike dwell time. From the model equation (table-2) it is also understood that all the influencing factors are positively correlated with the dwell time.

4.3 Sugession and Recommended Dwell Time

It was assumed that to improve reliability, the battery bike dwell time should not exceed the maximum time at each stoppage and by time of the day. To achieve this, the maximum and minimum average of the significant variables at each period was used to obtain the minimum and maximum dwell time. For this, upper limit and lower limit of the 95% confidence interval of variables was taken as maximum average and minimum average respectively.

The summary of the minimum and maximum dwell time is presented in Table3. The maximum suggested dwell time in the off peak period for each battery bike stoppage should be no more than 25s (Table-3). On the other hand, the maximum dwell time during the peak period for each stops should not exceed 5s (Table-3).

Table 3: Minimum and Maximum Dwell Time at the Time of a Day

Peak Hour		Off Peak Hour	
Max	Min	Max	Min
5s	4s	25s	10s

5. DISCUSSION AND CONCLUSIONS

The target of this study was to find out the relationship between dwell time and numbers of passenger boarding. To find the dominant variables, data has been collected on 10 variable s from the two different points during different time of a day. These variables have been selected based on the secondary literature and visual observation. The study shows that battery bike dwell time and the influencing factors vary based on time period. It is also found that dwell time depends on payment duration, waiting time, boarding and alighting time instead of number of boarding and alighting passengers. But during off peak hour no of boarding passenger plays an important role in the dwell time. Besides, passenger behavior has an impact on boarding and alighting time.

However, the concept of dwell time prediction will enable the decision-makers to the improvement of overall reliability. Because, the models can be adequately used, at 95%

confidence interval, to predict the dwell time by the time of the day and it is recommended that during the peak hour and off peak hour battery bike should not spend more than 5s and 25s at each stoppage respectively. It should be noted that the models are based on data collected in Khulna city corporation area, therefore it would not be applicable in other jurisdiction. Besides, as travel pattern and density are subject to change, model updating is required in every 5 or 10 years.

Apart from these, this research has some limitations. Firstly, this study has dealt with limited no of variables, for example, it has not considered the weather condition, age of the passengers, engine problem and so forth which might have impact on the dwell time. Secondly, when boarding and alighting of the passengers happened simultaneously, boarding time was not considered because payment activities and boarding occurred at a time. Finally, presence of police force the battery bike to pass away during the peak hour. In the absence of them, there is a possibility to get extended dwell time.

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ROAD ACCIDENTS AND SAFETY STUDY OF RAJSHAHI CITY IN BANGLADESH

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ABSTRACT

Road accident is an exquisite problem in highway transportation system which consistently related to a lot of deaths, injuries and property damages. Approximately 1.3 million individuals die in road fatalities each year, every day around 3,287 deaths occur all over the world. Further, even 20-50 million are injured or disabled. Low and middle-income countries are the main victim of this problem. The rate of an accident in Bangladesh is 13.6 per 100,000 people. With respect to road accidents Rajshahi, a northern city of Bangladesh is in very severe condition. In last 7 years, about 200 people died, and more than 100 People injured very utterly. This research work presents an overview of the accident rates, involved vehicles, type of collisions, time of the accident, and age of the victims' of the accidents in the highways, regional roads and city roads of Rajshahi city. The detail of the accident data was collected from, a popular local newspaper (Sonali Sangbad).Some additional data was collected from the metropolitan police station. The analysis shows that Natore-Rajshahi-Nawabganj highway (N6) is the most hazardous road in Rajshahi city and head on collision is the leading reason for accident in this road. The rate of death is also very high on city roads. About 46% of the total victims were between ages 21 to 30 years old. In more than one third of the total analyzed accidents pedestrians are the victims including deaths and fatalities. About 50 % of the total casualties occurred, either motorcycle or truck are involved.

Keywords: *Traffic, road accident rate, head on collision, pedestrian, death.*

1. INTRODUCTION

The problem of road accidents is an alarming issue which is internationally recognized. Road traffic accident occurs when a vehicle is moving along a roadway collides with another vehicle or object. Traffic collisions often result in injury, property damage and even death. Road traffic accidents and injuries are global problem and safety situation is severe in developing countries like Bangladesh. Road traffic injuries are the top reason for death among middle-income people. Also, road crashes lead to the global economic losses as estimated in road traffic injury costs of US$518 billion per year. In developing countries, the costs are expected to be US$100 billion, twice the annual amount of development aid to developing countries (Saha,2007). In a research study, WHO has identified that road accidents would be the third leading cause of death in the world by 2020. Accident death rates in developed countries are much lower (at least 50 times) than in developing countries. Even 90% of the world's fatalities on the road occur in low and middle-income countries.

In Bangladesh average, eight people die every day. According to the record of police (2015), in last 21 years 84000 road accidents occurred, 56000 died and 63000 injured (Paul, 2007). But the actual number is more significant than that because all the harmed people don't make a general diary in the police station. It is not possible for the police to keep records of all road accidents. The Same case happens in other countries also. Official results and information from other sources do not match. For example, in the Philippines, only one out of five medically reported road deaths are included in police statistics. In Indonesia, insurance companies report almost 40 percent more deaths than the police (Banik, 2011). With the increase in population, the rate of road accidents is increasing day by day.

Transport is an essential part of Bangladesh economy. But unfortunately, the authority can't pay proper attention to traffic and transportation due to the higher growth rate of the population as well as increasing transport problems. Traffic roads are expanded dynamically without any planning and control due to the rapid socioeconomic changes and to fulfill the demand of growing population.

Although traffic safety has improved in the recent years, the number of road fatalities is still unsatisfactorily high. In fact, the road safety problem in Bangladesh may be much worse than the official statistics. Main causes of the accident should be identified, to develop safety condition. Effective strategies and well-prepared design should be applied to minimise those causes. The Accident Research Centre (ARC) was launched in the Bangladesh University of Engineering and Technology in 2002 with the aim to research accidents and their remedies. There is a scope of training for the professionals in ARC. Lack of safety awareness is one of the major causes of a road accident. Driver fatigue, the absence of additional road facilities like dividers, bus bays, hard shoulders, helpful signals markings, etc. are also responsible for this problem(Ogden,1996).

Rajshahi is an important divisional city of Bangladesh. The internal communication system in this town is well organized. Vehicle entering into Rajshahi increases the possibility of accident occurrence. Traffic engineering and proper transport planning methods are required to reduce accident occurrences together with related records by technical studies. Widespread research works about traffic accidents in Rajshahi city has not been carried out except studies on some particular intersections (Mamun, 2015). Therefore, the aim of this study is to make a detail study on road accidents and losses of life and assets.

2. METHODOLOGY

2.1 Selection of Study Area

National, regional and city highways in Rajshahi zone especially Rajshahi district connected with Rajshahi city are studied in this research (Table 1). Internal roads of the city are also considered in this study although these roads are not incorporated in RHD Rajshahi zone. But the rate of accidents on city roads is very high, so these are taken into consideration.

Table 1: Road network under study

Road no.	Name of the road	Length (km)
N6	Kashinathpur-Dasuria-Natore-Rajshahi-Nawabganj-Kansat-Sona Masjid-Baliadighi Border Road	76
N603	Rajshahi Town By-Pass Road	21
N605	Rajshahi Greater Road	3
R685	Rajshahi (Bindur More)-Nawhata-Chowmasia Road	66
R682	Rajshahi-Nawabganj Road Old Section	1

Including the City roads

2.1.1 Study Area

A partial portion of the roads (mentioned in Table 1) which are within the city are observed with respect to road accidents. Most other parts of the country are connected to Rajshahi via the N6 national highway.Rajshahi Town By-Pass Road and Rajshahi Greater Road are two major road sections of the city. R685 is the connecting road from Rajshahi to Naogaon. other City roads also play important role in the transportation system of Rajshahi.

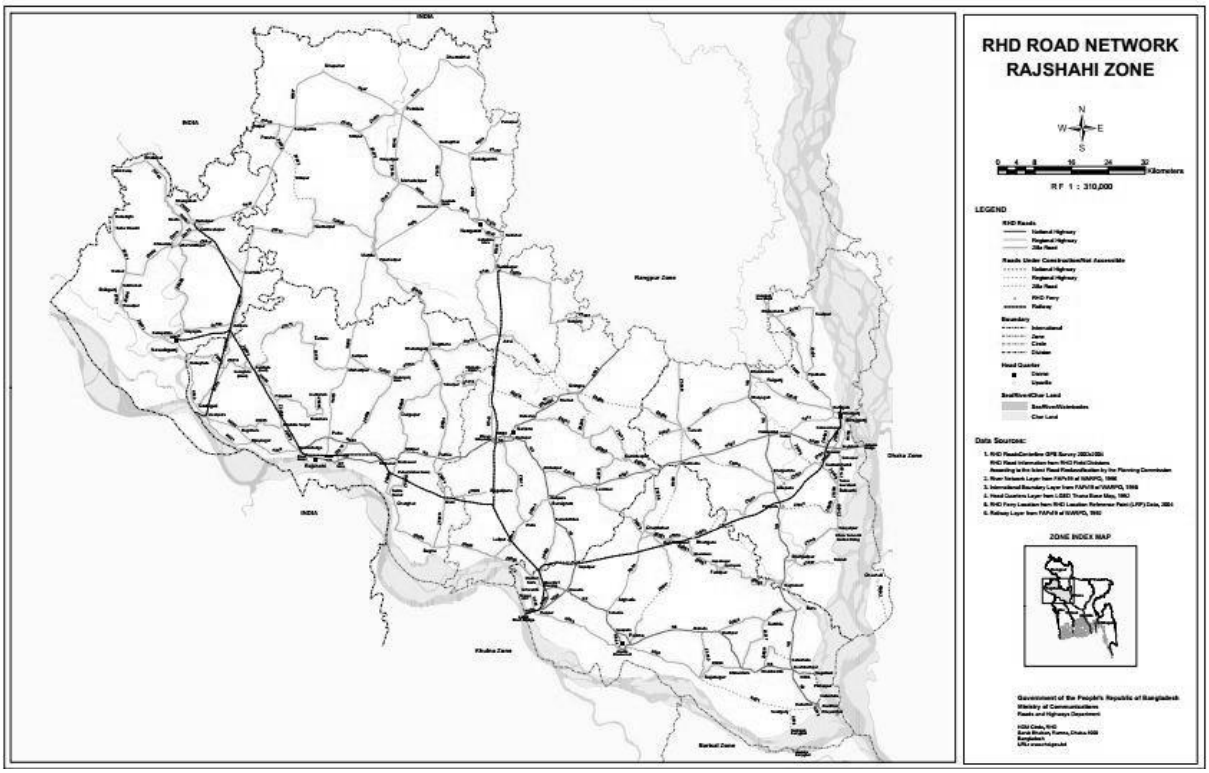

Figure 1. Map of Study Area.
(Source: Roads & Highway Department, Rajshahi, Bangladesh)

2.2 Data Collection

Proper and sufficient data is needed for accurate analysis. Essential road geometric data is collected from the official website of Roads and Highway Department (R&HD).The accident information was obtained from a reliable and popular divisional newspaper the daily “Sonali Sangbad”. The time duration of recorded data is from January 2017 to June 2017. The daily newspaper has been chosen rather than other sources for the following reasons:

1. Insufficient data about road accident from the police station.
2. Victims of spot death accident and the simple injured patient never go to the hospital.
3. Inactivity of related non-government Organizations in this region.
4. The newspaper is the mirror of society, so it represents social aspects of a country.

3. DATA ANALYSIS AND RESULTS

The collected data is analyzed for the age of victims, type of vehicles involved, accident-related collisions of different roads and the roads subjected to a higher frequency of casualties.

3.1 Accident Causalities in Six Successive Months

Different types of accident cases such as casualty, severity, single type crash and corresponding no. of accidents are investigated in Rajshahi city under this research work that is shown in Figure 2. It is evident from the figure that a large number of crashes occurred between April and May. It means in hot weather rate of accident is comparatively large than in cold weather.

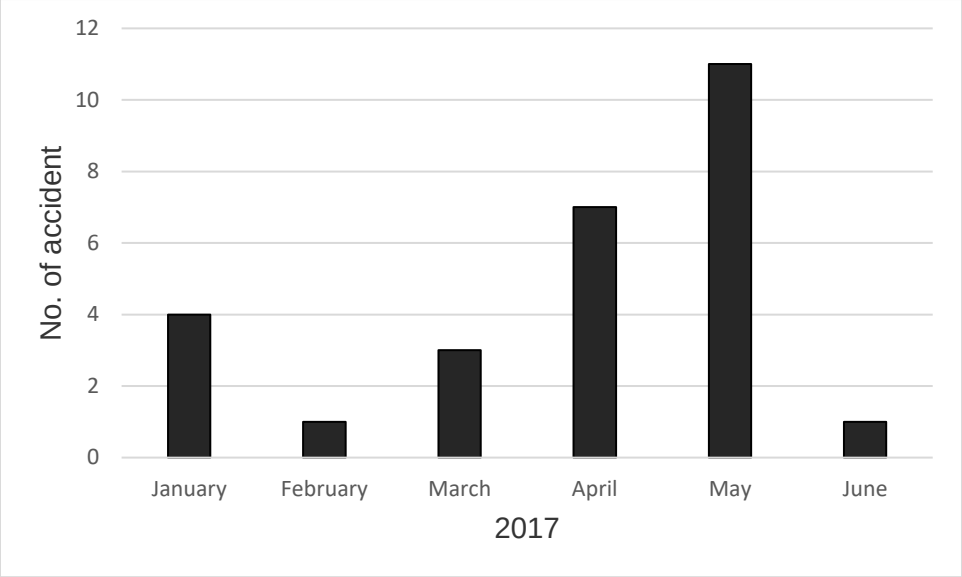

Figure 2: Accidents in different months of 2017

3.2 Age Range of Victims

In Figure 3, a variation of the age of the victims is presented as abscissa concerning the percentage of death and injuries due to the accidents. It is shown that most of the suffered people are within 21 to 30 year old. Death rate between 11 to 20 years old is also high(33%). It means young generation is the ultimate victim of a road accident. Here evidence shows that a large no. of middle-aged people also suffer much.

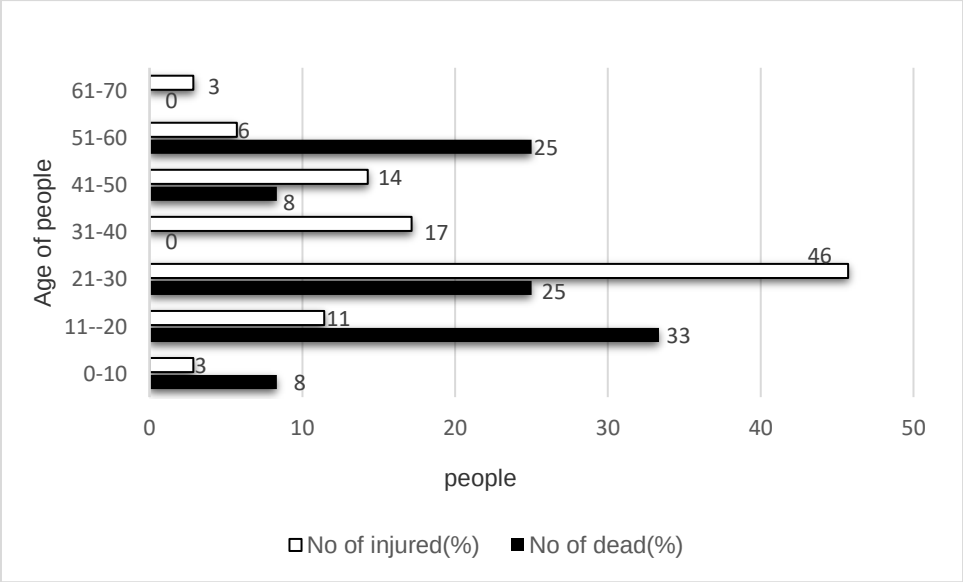

Figure 3: Accident Fatalities of different age people

3.3 Accident Fatalities on Different Roads of the city

Figure 4 represents the percentage of accidents and fatalities in different roads of Rajshahi city. The Natore-Rajshahi national highway (N6) is at high risk according to this statistics. About 38% of total investigated accidents (January 2017 to June 2017) occurred on this road. It is also the busiest road of Rajshahi city. The condition of internal city roads is also not so well. Summation of the deaths in these streets is equal to the no. of death in N6. Accident fatalities on other national highways and regional roads are comparatively less than N6.

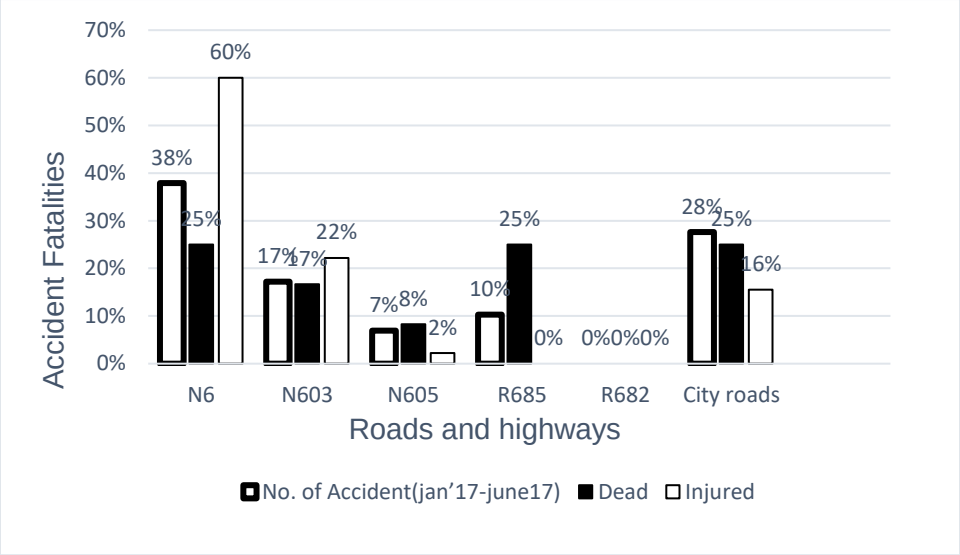

Figure 4: Accident Fatalities on different roads

3.4 Major Causes of Road Accident

Significant causes of road accident are a head-on collision, carelessness of pedestrians during the crossing, fatigue of driver, damaging of the road due to weather effect, expired vehicles, etc. we discussed earlier that Rajshahi is not a planned city. So widening roads and installing divider to reduce head-on collision is not easy. Further, the actual road facilities cannot be experienced by the road users because of illegal interposition. Even in many places almost half of the road width is blocked by roadside trading, kitchen market and parking of vehicles illegally. It is also necessary to mention that adequate footpath is not introduced in many roads. The small pathway may be the reason behind the sufferings of pedestrians. Other causes are lack of proper training of drivers, erosion of pavement, lack of maintenance of roads, small shoulder; heavy vehicles of additional loading, etc.

3.4.1 Type of Collision

Analysis of Collision type shown in Figure. 5, showed 'head-on collision' as the dominant accident type both in the city, about 45 percent accidents are account for this type involvement in fatal accidents. Head on means head to head collision.Pedestrians suffer due to 31 percent accidents.pedestrian involvement happens during unaware road crossing or during walking outside the footpath. Other type of collisions are obstacle(3%),rear end(10%),side collision(7%),overtaking(3%). Anobstacle collision is a type of single-vehicle accidentthat occurs when a vehicle clashes with any roadside object. Whereas Rear end means collision of the rear end of a slow moving vehicle withthe front of other relatively fast movingvehicle.

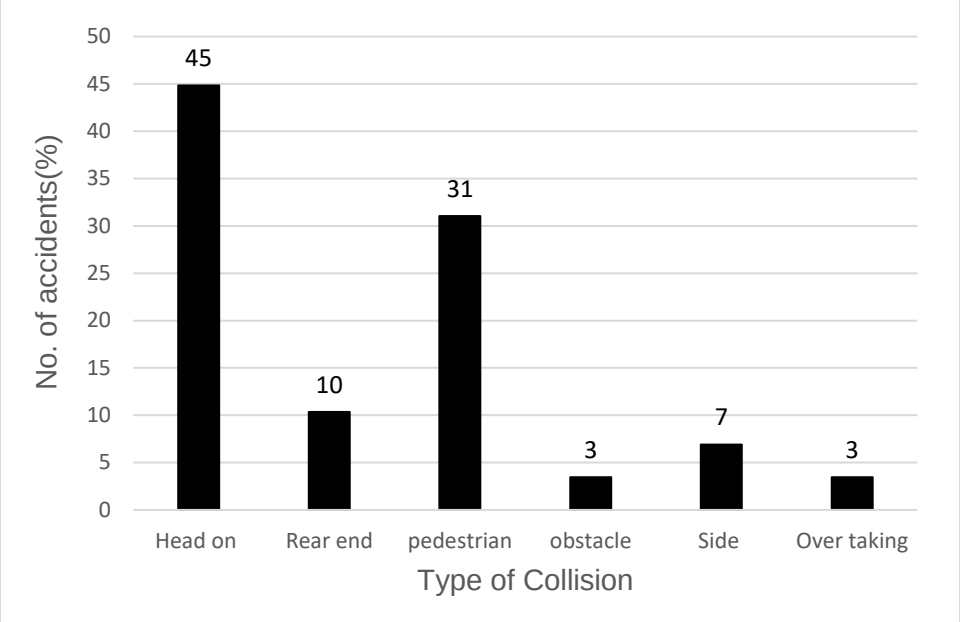

Figure 5: Type of accident in different accident

3.4.2 Involved Vehicles

The chart in figure 6 represents that motorcycle is involved in most of the roadway accidents (26%). Truck is a responsible vehicle for about 24 percent of total accidents occurred during the observation period. On the other hand, auto-rickshaw, cycle-rickshaw, bicycle are at risky zone for fatality and property damage due to a road accident.

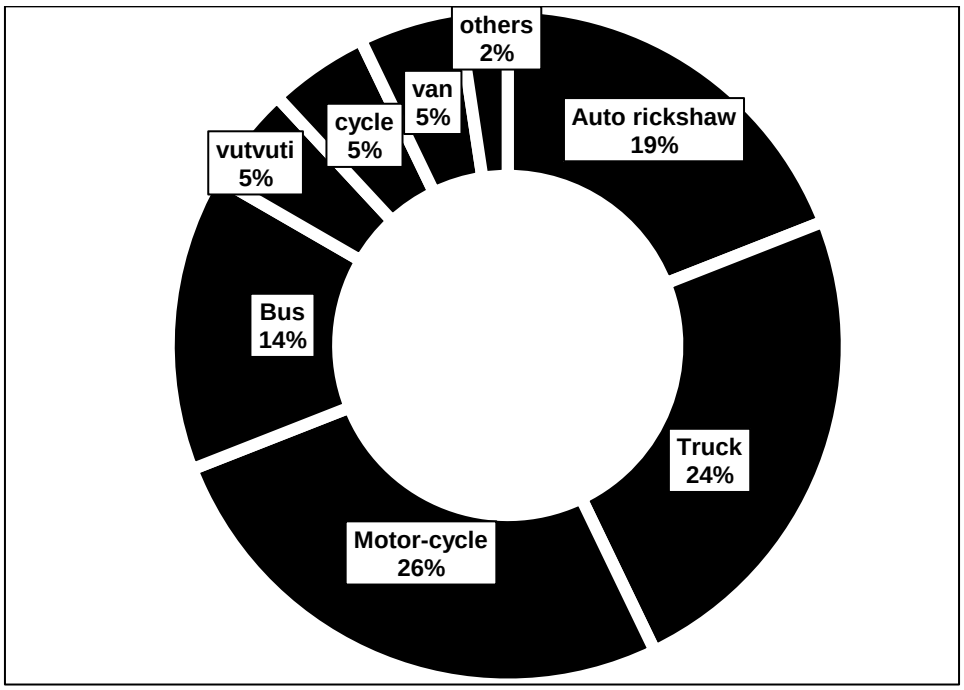

Figure 6: Involved vehicles in road accidents

4. CONCLUSIONS

Following suggestions have come out after the completion of the study:

1. Head on collision is the main reason for road accident, so divider should be introduced in hazardous roads and adequate width should be provided.
2. Awareness of the ordinary people can reduce the sufferings of pedestrians. Electronic media can be used for this purpose.
3. Strict laws of punishment should be made for the convict of the accident, and its application should be ensured. The mobile court can be installed on every road to check the rules and regulations.
4. Particular medical service can reduce the death rate due to a road accident. To implement this idea, primary treatment service can be installed beside the road.
5. Overloaded vehicles damage pavement layer. So these should be avoided. There is a proverb, “a stitch in time saves nine”. So checking at regular intervals and proper maintenance will save time and cost of road repair.
6. Adequate numbers of speed breakers, footpath, traffic signals, Zebra crossings, light posts with streetlights are to be constructed.
7. More research and in-depth analysis should be carried out regarding the situation of road accidents of Rajshahi city with the exertion of government. Then more ideas will be found out to confirm safety for the road users.

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ASSESSING SOCIAL AND ENVIRONMENTAL SUSTAINABILITY OF SONADANGA BUS TERMINAL, KHULNA

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ABSTRACT

For more livable urban places, it is urgently required to change the direction of urban transport development toward a more sustainable future. But sustainability is such a term that can hardly be measured. Properly planned bus transit station would be a better solution for the public transports in cities. In conformity with that perspective; the most common and major topics of the social and environmental sectors can be taken into consideration. This paper focuses on the assessment of sustainability of Sonadanga bus terminal from social and environmental aspects. Based on the secondary and field surveyed data necessary calculations have been performed by using different indices. The result of the analysis indicates moderate sustainability of the terminal from social perspective considering livability, safety, security and accessibility. From the standpoint of HASTA framework, Sonadanga bus terminal is quite sustainable (67.95%). Environmental sustainability has been assessed considering CO_2 emission rate (based on fuel consumption), waste generation and sanitation. All the buses use diesel and it is generating 0.195 mpg/year CO_2 which is greater than the standard value of 0.0264 mpg/year. Dally index shows a poor performance of the bus terminal weighing waste production/year against disposal/year. Regular disposal of waste, proper accommodation of sanitation facilities along with making it comfortable and easily accessible are among the major requirements to be met.

Keywords: *Assessment, Social, Environmental, Bus-terminal, Sustainability*

1. INTRODUCTION

A bus terminal is a facility for passenger boarding and departure and serves as a control point for buses (PIPAF, 2006). It also facilitates ticket counter, waiting room etc. for serving the customers. A properly planned transit station can maximize sustainability of the Transit Oriented Development (TOD).

Khulna is the third largest city of Bangladesh having 15687759 population (Hannan, 2013) and Sonadanga bus terminal is one of the most important transportation nodes of the city. Bus service provided by it connects the city to the whole country. Due to presence of this terminal, bus transit oriented development has been taking place around it. Sonadanga area is flourishing day by day and still has much scope of development. Which means, Sonadanga bus terminal might be able to play a vital role in it from the social and environmental aspects. After the construction of Padma Bridge, vehicular pressure will increase in Khulna city and Sonadanga Bus terminal is going to have to facilitate more services eventually. Evaluation of current social and environmental sustainability can help to identify the lacking and problems of Sonadanga Bus Terminal. Policies can be recommended to overcome the weakness and suggestions for additional improvement can be provided as well. Thus, BTOD can be ensured with maximum level of affectivity and sustainability in terms of social and environmental factors. Recommendations can be made for increasing sustainability of this terminal. Unless assessed, the present condition cannot be identified which will leave no scope for future development. That is the reason behind this project.

2. LITERATURE REVIEW

The term “Sustainability” can be defined as the living process where limited resources are used in a way so that living system can be embedded to thrive. It became a common language at the World’s first Earth Summit in Rio in 1992. Besides, Sustainable developments refers to the development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). As the perspective of a sustainable urban transport system (i.e. Bus terminal) it requires strengthening various features of that system. It deals with the social, economic and environmental compatibilities in that specific system. The success of bus terminal sustainability depends on how it balance the needs of environmental, social and economic aspects effectively for a long term period with flexibility. So, it may be concluded that sustainable development stand by three important pillars which are economic, social and environmental development.

Different social and environmental indices are used to measure the effectiveness of bus terminal. Among them Customer Satisfaction Index (CSI) measures the social sustainability based on satisfaction score and relative importance score of the attributes (Eboli & Mazzulla, 2009). When the value is closer to 10, it means extreme level of socially sustainability. Environmental sustainability can be calculated through Dally index (comparing demand against supply) and TIGGER sustainability equation (Zhang & Vanasupa, 2009). When demand is greater than supply, it denotes unsustainability.

Through TIGGER (Transit Investments in Greenhouse Gas and Energy Reduction) Sustainability calculation, CO_2 emission rate can be calculated and comparison can be made with standard value of emission rate (Linnertz, 2009). Another weighted average index has been formulated applying the benchmark value of sustainability index. This is used for defining sustainability based on some social and environmental indicators such as CO_2 intensity, waste disposal etc. (Bosello et. al, 2011).

In 1993, Calthorpe shows that “Urban TOD” associated with rail stations and a “Neighborhood TOD” associated with bus stations (Calthorpe, 1993). So it can be said that bus terminal can be an effective way to gain sustainability to the zone. Creating economical activities, a bus terminal can create the economic growth and strengthen the economy. It may be added that, a well-functioning bus terminal can attract the community, institutions and industry nearby it. So the pressure on CBD is reduced and employment is decentralized which is important to gain sustainability. For example: 22% of workers in the 100 largest U. S. regions worked within three miles of their respective city centers. But the employment pressure has highly reduced from the CBD by introducing the Bus Transit Oriented Development (BTOD) (Guthrie, 2016).

In Surabaya city, Indonesia the growth rate of vehicles is quite high. To mitigate Green House Gas Effects (GHG) on climate change they used to TOD concept that integrating land use and transportation by creating area around the station. It is found that, trip characteristic in Surabaya was dominated by the private transports (Handayeni, 2014). After the shifting of station, travel behavior change to mode transit and non-motorized usage reduced the number of travel. Policy, institutional and legal aspect support is needed to make TOD successful in Surabaya.

In Italy, a new Customer Satisfaction Index is used for evaluating transit service quality which is based on customers’ perspective (Eboli & Mazzulla, 2009). The methodology adopted in this research aims to obtain a concise indicator by considering different service aspects. The indicators can be calculated on the basis of judgments expressed by a numerical scale from 1 to 10. From the CSI calculation, it is found that services are about

73% successful in satisfying its customers. The attributes with the highest average satisfaction scores are because of ease of purchasing ticket, security against crime and personnel appearance.

3. METHODOLOGY

This section initially briefs the present condition of Sonadanga Bus Terminal. Next the study procedure is explained in detail.

3.1 Study Area

Sonadanga bus terminal is located in Sonadanga, Khulna. The area of this terminal is 12.5 Acres. It is 3.7 kilometers far from Dakbangla More. The terminal is accessible via three streets- M.A Bari Street, Masjid Saroni Road and Sonadanga Bypass Road. These roads crosses by Sonadanga Bus Terminal. Surrounding lands are mainly residential in type. Mixed land use (residential and commercial) characteristics and natural water body exist surrounding the terminal.

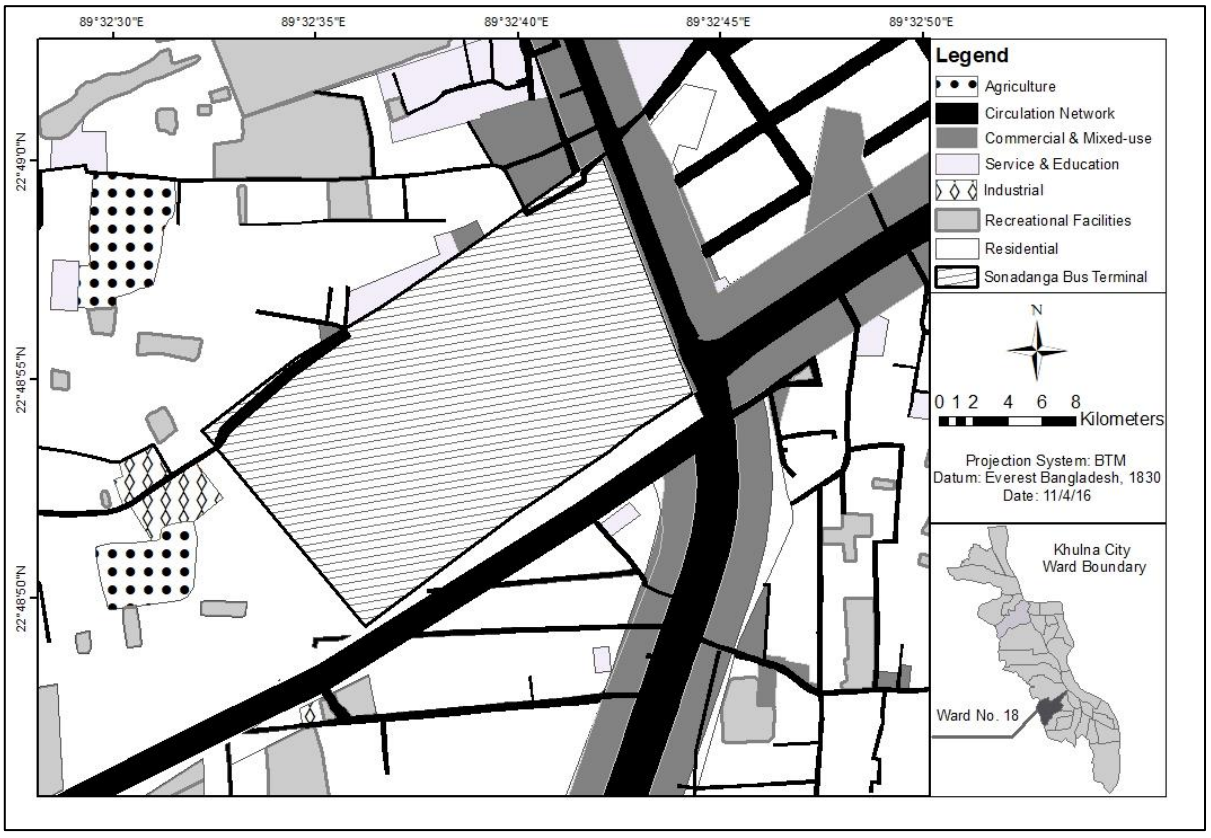

Figure 1: Land-use map of Study Area; the map has been prepared by author (2017)

3.2 Survey Method

The study has been conducted by a group of seven members and focused group of discussions. At first after gathering the conceptual knowledge it had been conducted by means of questionnaire survey and field observation. Probabilistic random sampling has been atopted as sampling method. Sample size for the study has been 117 which has been determined with a z value 1.96 at confidence interval (c) 9.8% by the formula (1) where p is "%" of picking a choice (Freedman et. al, 1997).

$$SS = (z^2 \times p \times (1-p)) \div c^2 \quad (1)$$

Secondary data have been collected using satellite image and GIS software. The collected data have been manipulated and necessary cross tabulation also been done for making the relationships among them and finding the index's values.

Table 1: Benchmark Value for Sustainibility

Value	Indicator	Value	Indicator
0	Extremely unsustainable situation	0.50	a discrete level of sustainability, but still far from target
0.25	indicator is still not sustainable but not as severely as in the previous case	0.75	satisfactory level in the sustainability, yet not on target
		1	target level, fully sustainable

Source: Bosello et. al, 2011

To determine social sustainability, customer satisfaction index has been calculated through the formula (2) (Eboli & Mazzulla, 2009),

$$CSI = \sum_{k=1}^{n} [s_{\bar{k}.} w_k] \quad (2)$$

Here, $s_{\bar{k}}$ the mean of the satisfaction rate of user k attribute and w_k is a weight of k attribute calculated on the basis of the importance rates expressed by users. If the positive response for the taken attributes are greater than 50% in HASTA Indicator Framework, it indicates social sustainability. Environmental Sustainability has been calculated through demand against supply perspective, the score has been derived from the following formula (3) (Zhang & Vanasupa, 2009)-

{(Demand/year) ≤ (Available supply/year)} (3)

Fuel consumption, produced garbage, existing sanitations facilities etc. have been used as demand side indicators.

Table 2: Evaluations and Weighted Transformation

Social		Environment		Weighted transformation
Sub indicators Value		Sub indicator Value		
Worst (0)	Worst (0)	Worst (0)	Worst (0)	Extremely unsustainable situation (0)
Worst (0)	Best (1)	Moderate (0.5)	Sustainable but not on target (0.75)	discrete level of sustainability (0.5<0.56>0.75)

Source: Bosello et. al, 2011

Through TIGGER Sustainability Calculation, diesel consumption (mpg) has been calculated by the following equation-

$$\textit{Diesel used annually} = \frac{\textit{Annual Shuttle Miles}}{\textit{mile per gallon}} \quad (3)$$

The unit here is gallon per year. Only diesel consumption has been considered as all buses use it as for fuel. Produced tons of CO_2 emissions has been compared with standard value 0.0264 mpg (Carbon Independent, 2015). Applying FSI index, social and environmental sub-indicators have been converted into a common benchmark value (Table 1). Finally through evaluations and Mobius transformation method, result is simplified (Table 2).

4. ANALYSIS AND INTERPRETATION

The analysis has been concluded based on the data of the survey conveyed upon 117 user and field observations where 13% are female and most of the respondents are working age people. Among the survey people, 37% has an age ranging between 30 and 44. Around 47% of the respondents have an income below 10000 BDT.

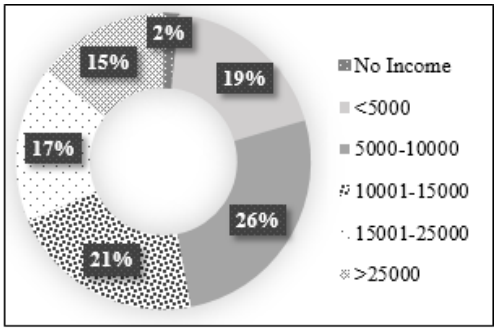

Figure 2: Income distribution
(Field Survey,2017)

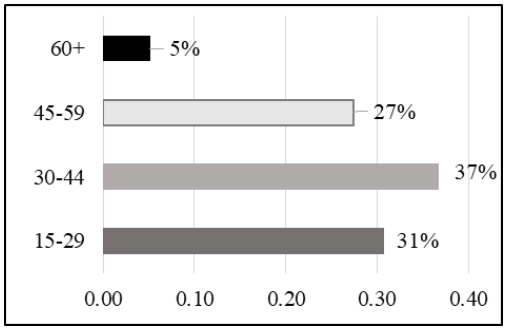

Figure 3: Age distribution
(Field Survey,2017)

4.1 Social Condition

Social sustainability has been assessed in terms of accessibility, safety, security, availability of facilities etc.

4.1.1 Congestion

Due to parking of buses on the roadway for boarding purpose, on an average 3.1m (Arasana & Arkatkar, 2011) effective road width reduces. It gives rise to congestion adjacent to the intersection which hampers social sustainability.

4.1.2 Washroom Facility

Generally, 420 passengers are to be accommodated by the terminal each hour. It is required to have 5 washrooms per 1000 female, 4 washroom and urinals per 1000 male (CED24, 2010). Sonadanga Bus Terminal has two for women and two for men only which are unhygienic as well. 82% of the users are dissatisfied with sanitation facility. This inefficiency to facilitate indicated lack of social sustainability.

4.1.3 User Satisfaction

It can be observed from Figure 2 that above 80% users feel satisfied the availability and ticket price. However, most user are dissatisfied with the existing toilet facility. Their opinion expressed moderate satisfaction for the other facilities.

Figure 3 suggests that most users feel safe in the terminal and most have never faced an accident in the arena and neither harassment. The matter of concern is, though six security guards are being appointed, they are not found to be actively maintaining their duty. So, most of the respondents considers the security level is moderate (59%). When the waiting room is not sufficient for the passengers, they are bound to wait outside which makes them more prone to harassment. This idea has been adopted as the working hypothesis and it has been accepted with 0.014 significance level from the chi-square test

4.1.4 Unpleasant Situations

Often unpleasant situation occurs in the bus terminal and quarrel between passenger and driver or helper breaks out. Such has an occurrence rate of 79% which hampers social sustainability.

4.1.5 Customer Satisfaction Index (CSI)

For assessing customer satisfaction index, ten major attributes are considered. The lowest satisfaction score has been derived for air pollution (2.41) and the attribute (Harassment) with the highest satisfaction score is 9.06 which contributes to the overall weighted score. Waiting room has been rated as the most important attribute (9.5) followed by air pollution

(9). Finally the value of CSI has been determined as 5.33 out of 10 and so, it can be interpreted that Sondanga Bus Terminal is 53.3% successful for being socially sustainable (Eboli & Mazzulla, 2009).

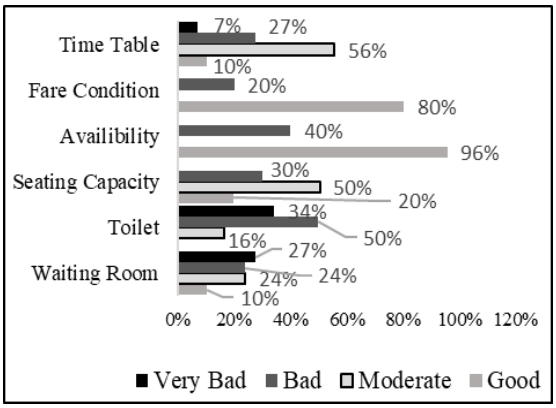

Figure 4: User Satisfaction about Facilities (Survey, 2017)

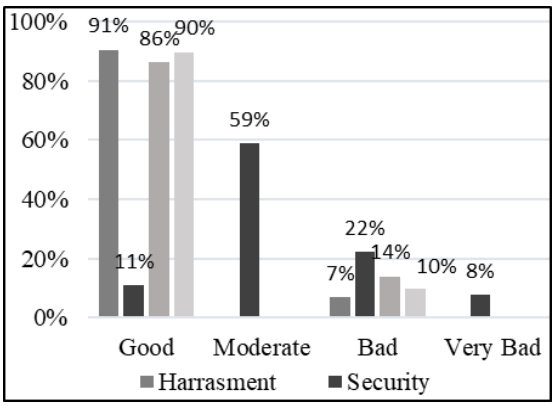

Figure 5: User Opinion about Safety and Security (Survey, 2017)

Table 3: Customer Satisfaction Index for Different attributes

Attributes	Satisfaction Score	Importance Score	Importance Weight	Weighted Score (CSI)
Air pollution	2.41	9	0.11	0.26
Harassment	9.06	8	0.1	0.88
Waiting room	3.92	9.5	0.12	0.45
ATM Service	2.07	7.5	0.09	0.19
Restaurant	5.45	7.5	0.09	0.5
Parking	6.74	8	0.1	0.66
Luggage carrying	6.53	8	0.1	0.64
Control system	3.92	8	0.1	0.38
Purchase ticket	6.91	8.5	0.1	0.72
Accessibility	6.65	8	0.1	0.65
Total		82		5.33

Source: (Field Survey , 2017)

4.1.6 HASTA Indicator Framework

The percentage of positive responds of relevant indicators have been used in this index. With respect to livability, safety and security and accessibility, social sustainability score has been determined to be 67.95%. This indicates that the terminal is moderately sustainable. However, it is unsustainable to a noticeable degree in terms of livability (39.03%) (Olofsson *et. al.*, 2011).

4.2 Environmental Condition

The environmental sustainability of Sonadanga bus terminal has been identified using air pollution, waste disposal, fuel consumption indicators.

4.2.1 Waste Disposal

Only 18% of the user finds the environment of Sonadanga Bus Terminal tolerable. A majority of 78% user identified it as an unhealthy spot. This represents that most of the respondents

find the environment hazardous. A great amount of waste (33%) generates from food particles and percentage of polythene waste is high too. These indicate environmental unsustainability.
The following table shows that most of the respondents are used to throwing wastes anywhere in the terminal. Huge amount of wastes of all types are disposed on the open ground (44%). Uncovered dustbin turns out to be the next obvious choice. Polythene, food wastes and rotten stuff are never get thrown in the planned dustbin. With increase in waste generation, more waste is dumped on the site clumsily.

Table 4: Waste Disposal according to Waste Types

Types of waste	Open Dustbin	Planned Dustbin	Anywhere	Bucket Dustbin	Total
Others	7%	9%	20%	1%	36%
Polythene	9%	0%	9%	3%	21%
Food Particles	12%	0%	13%	8%	32%
Rotten Particles	5%	0%	3%	2%	10%
Total	33%	9%	44%	14%	100%

Source: (Field Survey , 2017)

4.2.2 TIGGER Sustainability Calculations

Using the index it has been determined that 0.195 mpg CO_2 is emitted annually which is greater than the standard 0.0264 mpg. Hence it can be said that Sonadanga bus terminal is not sustainable environmentally according to CO_2 emission standard (Carbon Independent, 2015).

4.2.3 Dally Index

The average no. of buses departing from the terminal is 130 (6 am- 12pm) and diesel used per day is 60 liters (Field Survey, 2017). From the supply-demand relationship of the sustainability law, 2847 metric tons per year are demanded per year but the supply is short by 547 metric tons per year. It is the result of low amount of buying oil of the filling stations. It is often seen that there is a scarcity of oil if any congestion or hazard occur in supply chain. Besides the filling stations do not reserve any extra amount of oil. They just purchase just to meet the need. So it can be said that there is a fuel unsustainability in the region.
Khulna Development Authority (KDA) has provided 3 vans for waste management which works at once daily. But this can not solve the problem as waste remains in the study area. Assuming 1 kg of waste in 1 square feet, total dumping area, waste per day and cleaning capacity has been calculated as 450 sq. ft., 450kg and 180kg respectively. This implies that the demand is greater than the supply ($\frac{164.5}{1} \not\leq \frac{65}{1}$) which indicates lack of environmental sustainability (Zhang & Vanasupa, 2009).

The terminal has a total number of 4 toilets while it has to serve 420 passengers per hour. As per CEDA standard, 1 toilet can serve 222 people the demand for washrooms while supply permits 250 of them to use one (CED24, 2010). So it can be concluded the sanitary condition is nearly meet the demand. But in future when the population will increase it will be unsustainable.

4.3 Overall Social and Environmental Condition

4.3.1 FSI Transformation

Using all the mentioned indices through FSI transformation the social and environmental sustainability score has been derived 0.58 and 0.13 respectively. In comparison to the benchmark values, finally it can be concluded that Sonadanga bus terminal is

environmentally unsustainable though the condition is not very severe. However the terminal is socially sustainable a moderate condition.

5. RECOMMENDATION

On the basis of analysis, some recommendations have been made which would be effective from social and environmental concerns.

1. KDA can install waste bins beside the waiting room, entrances and canteen is essential for keeping the environment cleaner. This would prevent the users from throwing wastes anywhere.
2. Providing one more toilet for both male and female can ensure supply-demand equivalence. Regular toilet cleansing and supplying water in toilets all day is complusury.
3. To make the terminal environmentally compatible, it is required to ban the buses from the terminal physical life of which have expired. Buses which are not used any longer should be removed from the terminal parking lot to increase the parking capacity for other vehicles. They can be recycled for other purposed or shifted to a salvage yard.
4. Security cameras and emergency call boxes are recommended in the main terminal office for monitoring the role and performance of the terminal continuously.
5. Plan of the terminal should be incorporated with the provision of adequate arrangement for drainage of all sewage and waste water to ensure rapid drainage, even during peak rainfall events.

Naturally, all of these proposed changes and improvements will result in heavy expenditures. The bus terminal improvement plan organizes a budget based on the proposed improvements and amenity changes. In order to implement these changes, formulating a plan is necessary. By following the implementation guidelines and utilizing the proposed funding strategies, it is possible to accomplish the required improvements as per Bus Terminal Improvement Plan in reality. As a result, Sonadanga bus terminal would serve as a safe, accessible, and identifiable transit facility.

6. CONCLUSIONS

The study result shows moderate level of social sustainability and environmental unsustainability for the Sonadanga bus terminal. Sanitary condition, waste management and drainage system are needed to be modified significantly. If these sectors are not properly maintained, it would be a great threat for the terminal to achieve sustainability. Moreover terminal authority allows old and poor conditioned buses to access in it which generates huge amount of CO_2. The terminal also has some operational and maintaining drawbacks which must be modified. Finally, it can be concluded that the terminal has some major environmental drawbacks that should be resolved as soon as possible. Otherwise the terminal will lose its acceptability and will become a threat for surrounding environment. In that respect this study can serve as a guideline for the concerning authorities and people associated with it.

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APPENDIX

Table 1: HASTA Indicator Framework

Category	Indicators	Sub- Indicators	Positive Response	Score	Interpretation
Social	Livability	Waiting Room	30.77%	39.03%	The terminal is not sustainable in terms of livability
		Toilet	16.24%		
		Sitting Capacity	70.09%		
	Safety & Security	Harassment	90.60%	84.19%	The terminal is sustainable in terms of safety and security
		Security	70.09%		
		Accidents	86.32%		
		Safety	90%		
	Accessibility	Availability	95.73%	80.63%	The terminal is sustainable in terms of accessibility
		Fare Condition	80.34%		
		Time Table	65.81%		

Source: (Field Survey , 2017)

Table 2: Filling Stations Data Near Sonadanga Bus Terminal

Station	Capacity (L)	Supply Frequency (/day)	Supply Amount (L)	Availability for bus (L)
Maniktala	27000	3	6000	2400
Religate	20000	3	4000	1500
New Road	30000	3	8000	4000
Boikali	25000	3	6000	3000
Joragate	25000	3	6000	2500
Powerhouse	20000	3	4000	1500
Gollamari	27000	3	6000	3000
City Bipass	15000	3	3000	1000
Total				18900

Source: (Field Survey , 2017)

Table 3: Waste Management Scenario in Sonadanga Bus terminal

Total Dumping area (formal & Informal)	Garbage waste (daily) (assume 1 sq.ft = 1kg)	Total cleaning capacity per day
450 sq. ft.	450 kg	3 van of 50 kg per =180 kg

Source: (Field Survey , 2017)

Table 4: Evaluations and Mobius transformation

Environmental Indicator	Benchmark value for Sub-indicator	CO2 Emission	Not Sustainable (0)	
		Fuel Management	Fuel unsustainability (0)	
		Sanitary Condition	just meet the demand (0.5)	
		Waste management	opposite to sustainability (0)	
	Decision	(0+0+0.5+0)/4	= 0<0.13<0.25	Environment is not very sustainable, but not severely unsustainable
Social Indicator	FSI Benchmark value for Sub-indicator	CSI Index	0.53	
		HASTA Indicator	0.67	
	Decision	(0.5+0.67)/2	=0.58	A discrete level of sustainability, but still far from target

Source: (Bosello et. al, 2011)

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ANALYZE THE EFFECT OF DRIVER BEHAVIOR AND SOCIOECONOMIC CONDITION ON TRAFFIC FlOW: A CASE STUDY OF PABNA MUNICIPALITY IN BANGLADESH

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ABSTRACT

The numbers of "Three-wheeler" (locally known as "Auto") are increasing quickly and has turned into the most prevailing urban transport mode in the districts and developing town focal point of Bangladesh. In any case, an excess of import of this vehicle represents a huge weight on the power supply and urban traffic management system of this country. The purpose of this study is to investigate the interaction of socioeconomic condition and driving behavior of Auto drivers toward the design of a safe and efficient traffic and transportation management system. The main objective of this study is to to present the effect of different driving behaviors and socioeconomic condition of Auto drivers on traffic flow system for the town center of Pabna municipality. To achieve the objectives of this study, a direct interview survey was conducted from 50 Auto drivers to determine how individual differences and individual responses to driving conditions cheap driving behavior. This study reveals that in this municipality the number (3500) of Auto vehicles is increasing day by day for low price, less noise, and safety.62% driver response that the competition between them in making more trips to support their family are the main causes of traffic rules violation and traffic congestion. Finally, it was shown through correlation analysis between the socioeconomic condition and with the different driving behaviors of Auto drivers. The results of correlation analysis are in good agreement with the general views of respondents and it shows that the socio-economic condition and driving behaviors of Auto drivers are interdependent to ensure safe and efficient traffic flow for an urban area.

Keywords: *Auto, Traffic congestion, Passenger attraction, Correlation, Driving behaviors*

1. INTRODUCTION

Traffic congestion is a typical event and occurs almost in all the cities of Bangladesh. Among the major urban areas like Dhaka, Chittagong, Khulna, Rajshahi and some district town like Pabna, Jessore, Bagura and so on are additionally confronting this issue (Shamsher & Abdullah, 2013). Shamsher and Abdullah (2013), likewise contend that traffic research still can't completely anticipate under which conditions a "traffic congestion" suddenly occur. Traffic congestion happen when the street limit is doused inferable from a high number of vehicles passing a similar point in the meantime and due to road works, accidents, extreme climate conditions, and so on (Matin et al., 2012; Remi et al., 2009; Salman & Qureshi, 2009). On the other hand (Parker & Senserrick, 2017; Parker & Senserrick, 2012) carry out that emotions, moods, driving experience, are perceived as powerful factors in their driving behaviour, and importantly as compelling variables in their road safety outcomes, congestion, and a mediation. Parker and Senserrick (2017), likewise contended that the emotions which emerge from driver-particular or context specific triggers which result in changes in their driving decision-making (intentionally or unknowingly) and at last changes in their driving behavior. In addition, the quality of traffic roads and behaviors of drivers are additionally critical components causing traffic congestion (Araina et al., 2017). Aggressive driving behavior is one of the aggressive behavior forms which is regularly found right now

(Lajunen & Parker, 2004; Shinar & Compton, 2004; Galovski et ai., 2005; Hohn, 2006). It might cause different issues in the public arena, for example, traffic congestion, a mishap that influences the properties and life of individuals, sickness and demise (Chomeya, 2010). As per (Shamsher & Abdullah, 2013; and Mamun 2015) Rickshaws and Auto are regularly blamed for the traffic bedlam in Bangladesh. The rickshaw and Auto driver stopped their vehicles at the road side by ignoring traffic rules and regulation resulting traffic congestion and road accident are common in our country. Subsequently, to reduce car influx Bangladesh Government has effectively prohibited rickshaws utilizing on the primary streets of Dhaka city (capital) because of huge weight on movement (Shamsher and Abdullah, 2013). But in other urban and municipal areas rickshaw and Auto or three electric wheels banning procedure has not yet implemented. And these vehicles are increasing with jumping up (see in figure 1). This situation can be easily observed in the few urban territories where vehicles growing faster and exceed the capacity of the transportation system.

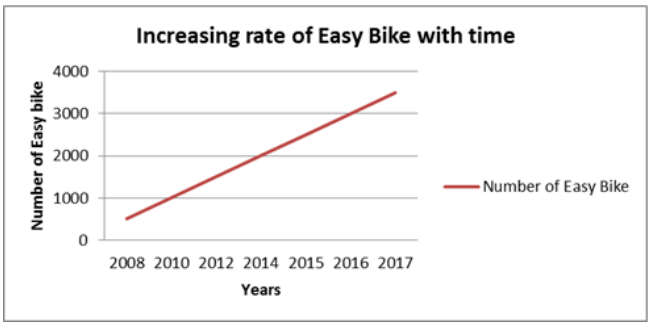

Figure 1: Increasing rate of Auto in the study area

In resultant, slow traffic creates issues for people and leave an antagonistic effect on the business economy in light of the fact that the reaction rate of people towards their allot assignment turn out to be low (Matin et al., 2012). Concerning this issue, it is very important to observe the Auto or three electric wheel drivers behavior and socioeconomic condition, to investigate the appropriateness of this vehicle as a local public transport mode in the municipality.

2. STUDY AREA

Absolute location of the Pabna municipality is 24.99^{o} north latitude and 89.23^{o} east longitude, in figure 2 (Mamun, 2015; UGIIP, 2007). Pabna district is described as an imperative economic center point of Bangladesh for its location and simple transportation linkages with different parts of the nation (Chakma & Chakrabartty, 2017; Saha et al., 2013; & Mamun, 2015). Regular individuals from the encompassing country zone, go to the Pabna CBD area for office work, business, treatment and for different purposes by usinging battery operated auto (Saha et al., 2013). Mamun (2015), carry out that about 2637 Autos employ throughout the roads in this municipality and the number is increasing because of its zero contamination (exhaust), less noise and safety. From field survey it was found that nearly 3,500 battery operated auto were running for 181939 people in18.64 sq. km area. The Municipal authority officially claimed that they gave license upto 1200 auto and 530 rickshaws. But there are also so many others battery driven vehicles (auto bike and auto rickshaw) which are roaming around the Pabna municipal area without any license. For this reason, this city is fully jammed packed with these vehicles. From these perspectives, the study tries to investigate the interactions between socio-economic condition and driving behavior of Auto drivers toward the design of a safe and efficient traffic and transportation management plan of the study area. The main objectives of this study are to set up several scenarios in the driving simulator to test the Auto drivers behavior. The scenarios are divided into different categories including the socio- demographic, work load pressure and traffic

rules violation of Auto drivers & to explore how the socio economic condition and driving behaviors of Auto drivers are interdependent to ensure safe and efficient traffic flow in the study area.

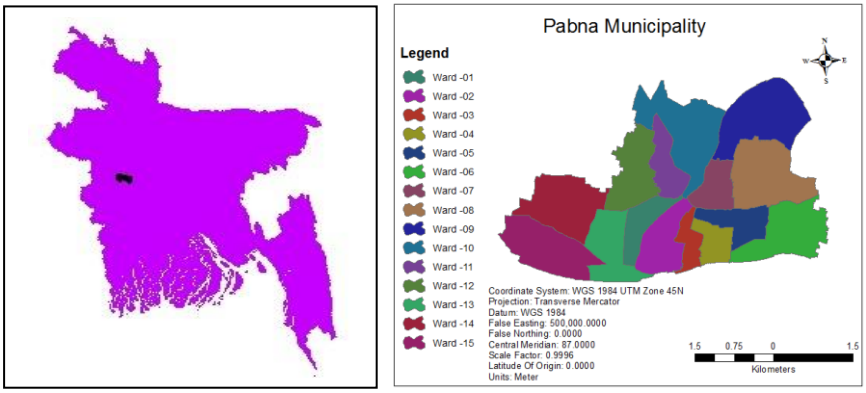

Figure 2: Location of study area with the context of Bangladesh

3. LITERATURE RWVIEW OF THE STUDY

"Three-wheelers" (locally known as "Auto") is a notable travel mode in the urban transportation system in Bangladesh (Mamun, 2015). It is a generally utilized tiny three-wheeled vehicle for transport of individuals, goods and services all over in this country and in numerous Asian countries. Santucci et al (2016), argue that if 10% of car drivers start moving on an electric bike than reduced traffic congestion by 40% in Europe (Brussels). But increase in excess number may create a negative impact on the urban environment. Mandal et al (2015), carry out that Auto vehicles annual growth rate of traffic is about 6.1% in the Rajshahi City Corporation (RCC) area of Bangladesh. Mandal et al (2015), also point out that these batteries cause numerous environmental damages on short scale. Lead batteries in some cases releases hydrogen gas. Gas can cause numerous health issues in terms of long-term exposure. Mamun (2015), in his research paper said that this Auto or Electric three wheelers are responsible for daily 1.53 hours of load shedding per a day in Pabna municipality. Municipal authority said that huge number of illegal Auto is responsible for traffic congestion in CBD area specially bul bul college more and this traffic congestion rate is growing from 2% to 5% in 2016. On the other hand Government republic of Bangladesh has already claimed that the Auto and other battery operated vehicles consume more than 300 Megawatts of electricity every day to recharge their batteries (The Daily Star, 2011).
The introduction of Auto can be indicated as a quiet insurgency in the transport sector of Bangladesh. A huge number of such vehicles are now playing all over the country, largely in the municipalities and suburban area. Some gauge the figures of a million. There are no legitimate insights accessible, as these vehicles are not enlisted with the administrative transport office. These vehicles are advanced in Pabna by some enthusiastic business organization. Around 3500 vehicles ply throughout the streets in this municipality and the number is expanding because of its zero contamination (exhaust), less noise and safety.

Figure 3: Electrict three wheel or Auto

The picture (Table 1) demonstrates the gigantic pressure of Auto on municipal traffic and transportation management system. The investigation assumed that traveler's appreciation for this vehicle is the main reason behind the increasing of Auto and substitution of human hauler.

Table 1: Average number of Easy bike at 6 main points of CBD area in the Pabna municipality during peak hour (9.30am to 10.30am)

Points	Vehicle Number
Edward College	376
In front of Judge court	602
In front General Hospital	421
Pasmatha more	289
Doyel chottor (toward mental hospital)	172
In front of Pabna Zilla school	613

4. MATERIALS AND METHODS

The study carried out on the Pabna municipality of Bangladesh on the basis of the increasing rate of plying easy bikes, nastiest traffic situation and researcher's own interest. To understand the traffic and transportation problem of the town center as a whole and to arrive at a planning solution to alleviate the problem, the following methods were mainly utilized in completing the case study:

4.1 Secondary data collection

Secondary data were obtained from various government offices and concerned departments. Besides consulting different journals, research reports, internet and some newspapers were also used to extract the required information.

4.2 Reconnaissance Survey

During the collection of primary data, the study area of Pabna Municipality has been visited many times, to know the existing situation; a reconnaissance survey had been done to acquire an overall site. So it was decided to run a questionnaire survey to generate primary data.

4.3 Questionnaire Survey & Interview

Questionnaire survey and interview was conducted with the most numerous (50 drivers) auto drivers or three electric wheel drivers from 27th September to 9th October 2017; with the purpose of collecting information about the volume, composition and pattern movements of traffic entering the Municipal boundary, known as external trips, thereby, counting vehicles and interviewing a sample of drivers at cordon points in their journey into the study area. Several discussions were conducted regarding Traffic congestion issues in CBD area with the pedestrian, Transportation engineer, Urban Planner, professional experts in different sectors, from October 2017 to November 2017. The data obtained was analyzed and shown in the graphs.

4.4 Traffic volume survey

The Traffic volume survey was conducted for Easy bikes at different intersections of CBD area in the Pabna municipality by hiring some assistant and set them some important location in the Pabna municipal CBD area, like- Edward College**;** In front of Judge court; In front General Hospital; Pasmatha more; Doi bazar more; Doyel chottor (toward mental hospital); In front of the Pabna zilla school.

5. RESULT AND DISCUSSION

5.1 Trip Characteristics of Different Auto drivers

The planning, design and management of the road traffic and transportation system greatly depends on the availability of relevant, reliable and recent travel data, and the ability to analyze and interpret these data (Rawas, 1989). To know the trip characteristics of auto driver, road side field interview survey was conducted. The main purpose of this survey was to collect the information of auto driver about their movement (origin and destination) and it is found that most of the auto originated from outside of Central Business District (CBD) area and their destination is a CBD area of the municipality. The commercial and administrative zone of Pabna municipality are mostly covered by ward no 2 and 3 with the area of 341.473 acres land (Rahman et al, 2017). Table 02 shows the distribution of vehicle movements.

Table 2: Trip characteristics of different auto drivers

		Destination in different Zones															**Total Trip Generation**
		Ward 1	Ward 2	Ward 3	Ward 4	Ward 5	Ward 6	Ward 7	Ward 8	Ward 9	Ward 10	Ward 11	Ward 12	Ward 13	Ward 14	Ward 15	
Origin in different Zone	Ward 1	-	15	19	-	-	5	-	3	8	-	2	-	-	5	-	57
	Ward 2	15	-	56	12	28	9	51	15	9	7	45	6	7	6	5	271
	Ward 3	19	56	45	21	33	-	-	9	3	-	15	9	12	8	2	232
	Ward 4	-	12	21	-	15	-	1	3	-	9	-	-	2	-	-	63
	Ward 5	-	28	33	15	5	6	13	4	2	4	3	4	1	4	-	122
	Ward 6	5	9	-	-	6	-	-	2	-	4	-	7	-	-	-	33
	Ward 7	-	51	-	1	13	-	19	5	14	7	15	1	3	5	-	134
	Ward 8	3	15	9	3	4	2	5	-	-	-	14	-	-	-	9	64
	Ward 9	8	9	3	-	2	-	14	-	-	4	-	-	-	2	-	42
	Ward 10	-	7	-	9	4	4	7	-	4	-	16	-	3	-	1	55
		2	45	15	-	3	-	15	14	-	16	2	4	1	-	3	120

Ward 11																
Ward 12	-	6	9	-	4	7	1	-	-	-	4	-	-	7	-	38
Ward 13	-	7	12	2	1	-	3	-	-	3	1	-	-	-	3	32
Ward 14	5	6	8	-	4	-	5	-	2	-	-	7	-	1	3	41
Ward 15	-	5	2	-	-	-	-	9	-	1	3	-	3	3	-	26
Total Trips Attraction	57	271	232	63	122	33	134	64	42	55	120	38	32	41	26	

In the survey found that 271 numbers of trips are attracted to the ward no-02, 232 in ward no-03. 134, 122 and 120 trips are attracted into the word no 07, 05 and 11 respectively (Figure 4). The study also tried to find out the reason behind this huge trip attraction on that word. It was found that ward no 02 and 03 are the town center of Pabna municipality, people are congest here for their daily purpose. The other attraction zone are 07,05 and 11 no ward because many institution like- Christian grave yard, Shahid Fazlul Haque Poura High School, Bulbul College and Pabna sadar grave yard in ward no-05; Sadar Thana, Central girls school, Ichamoti Clinic, PTC hospital, Food storehouse, Pathfinder KG school, Blue bird KG school, Jalal Memorial Hospital, Square Company in ward no-07; and DPHE office, BADC office, Petrobangla gas company, District forest office, Power Development Board office, BRDB office in ward no-11.

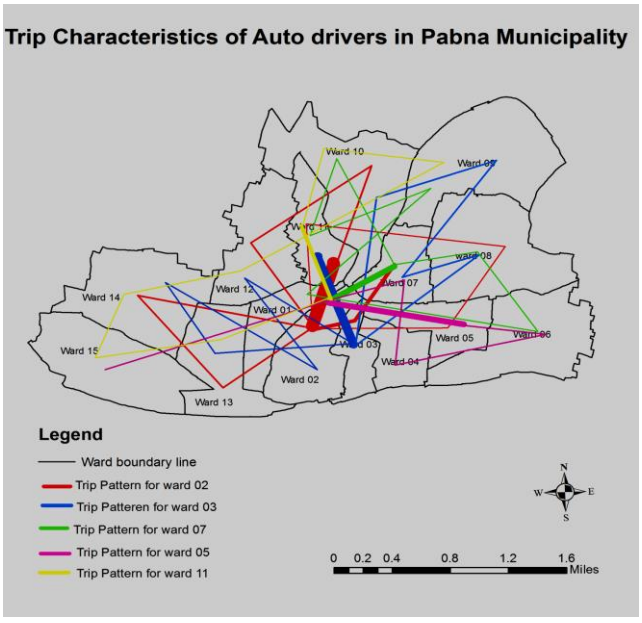

Figure 4: Trip Characteristics of Auto drivers

5.2 Driving Behavior Analysis of Different Auto Drivers

Platten et al (2013), said that besides driving behaviors, operating behavior is an importance secondary task to understand the performance of mechanism while driving. Rauch (2009), was identified hesitations during the secondary task operation occurring in difficult situations. In order to know the best about traffic congestion issues, driving behaviors and quality of roads, we surveyed different regions of the Pabna municipal area. Regarding these issues and based on recommendations from professional and traffic officers a short open-ended questionnaire was designed to get responses from the Auto driver. The collected data were analyzed using ArcGIS 10.3, SPSS software and proper correlation results were obtained. Following questions were asked and responses were obtained to study the driving behavioral effect on traffic flow condition in Pabna municipality.

Table 3: Responses from the respondents about various aspects

Questionnaires	Total Respondents	Frequency (%)
Socio-demographic variables		
Age of the respondent		
1. 18-21	10	20
2. 21-24	7	14
3. 24-30	12	24
4. 30-35	9	18
5. Up to 35	11	22
Education qualification		
1. Read and write	22	44
2. Primary education	13	26
3. Secondary	10	20
4. Higher secondary & Diploma	05	10
What is your marital status?		
1. Single	15	30
2. Married	32	64
3. Divorced	03	6
How many family members do you support?		
1. No family member	05	10
2. 2-3	12	24
3. 3-4	11	22
4. 5 and above	22	44
Who is your vehicle's owner?		
1. Myself	31	62
2. My employer	19	38
Have you got first aid training?		
1. Yes	50	100
2. No	-	
Do you have any driving license?		
1. Yes	08	16
2. No	42	84
Monthly income the owner of the vehicle while driving is around 19000 TK		
Monthly income the employer of the vehicle while driving is around 13000 TK		
The minimum driving experience of the drivers is around 6 months		
Traffic violations		
Reasons of traffic rules (light, speed, no stopping etc.) violation		
1. For short queue	11	22
2. To increase income	23	46
3. Racing with another driver	03	06

4. No fine on violence	02	04
5. Drunk driving	01	02
6. Disregard	05	10
7. Poor traffic management	05	10
8. Others	-	
Safe attitude towards traffic rules violation		
1. Strongly disagree	-	
2. Disagree and	02	04
3. Slightly disagree	-	
4. Neither agree or disagree	06	12
5. Strongly agree	12	24
6. Agree and	29	58
7. Slightly agree	01	02
If your cell phone rang while driving, how you received your call?		
1. Reduce speed and receive calls	07	14
2. Received call at normal speed	39	78
3. Stop driving and receive calls	03	06
4. I disconnect ringing	01	02
Frequency of per day mobile phone usage while driving (general use)		
1. Never use	05	
2. At least 1 or 5 times	19	10
3. At least 5 or 10 times	22	38
4. At least 10 or 15 times	04	44
5. At least 15 or 20 times	-	08
6. More time	-	
Safe attitude towards mobile phone usage		
1. Strongly disagree,	-	
2. Disagree and	03	06
3. Slightly disagree	07	14
4. Neither agree or disagree	10	20
5. Strongly agree,	02	04
6. Agree and	28	56
7. Slightly agree	-	
Do you drive after knowing your Easy bike has a mechanical problem?		
1. Yes	23	46
2. No	27	58
What are the reasons for driving, after having a mechanical problem?		
1. No alternative to support my family	32	64
2. For own income	11	22
3. Foe more income	07	14
4. Others	-	
Causes of driving in the wrong direction		
1. Disregard traffic rules	01	02
2. Time saving	21	42
3. Competition/Racing with another driver	05	10
4. To get more passenger	23	46
Causes of parking violation		
1. Lack of parking place for three electric wheels	25	50
2. Poor traffic management system	07	14

3. Poor parking management system	13	26
4. No parking pricing	05	10
Workload of the driver		
How many hours do you drive per a day?		
a) 5 to 8	15	30
b) 8 to 10	11	22
c) 10 to 15	15	30
d) Above15 hours	09	18
Why you work so long (for 10 to 15 & above 15 hours' work)?		
a) To support my family	31	62
b) For my personal expenses	15	30
c) Others	04	08
Do you do any rough behave with passengers during pressure on work load?		
a) Yes	07	14
b) No	43	86
Do you violence the traffic rules during pressure on work load?		
a) Yes	37	74
b) No	13	26
How many times do you violence the traffic rules?		
a) Always	06	12
b) Sometime	23	46
c) Most of the time	21	42
Have you ever had road traffic accident during the pressure of workload?		
a) Yes	30	60
b) No	20	40
What were the causes of this accident?		
a) Pedestrian carelessness	11	22
b) Failure to follow the right hand rules	10	20
c) Failure to give way for pedestrian	13	26
d) Phone use while driving	08	16
e) Quality of road	01	02
f) Vehicle mechanical problem	04	08
g) Others	02	04
When workload pressures become high?		
a) 8am to 10am	16	32
b) 10am to 12pm	02	04
c) 12pm to 2pm	01	02
d) 2pm to 4pm	04	08
e) 4pm to 6pm	12	26
f) 6pm to 9pm	14	28

*Survey, 2017

5.3 Correlation Analysis of Different Driving behaviors

One of the main objectives of this study is to find the extent to which different driving behaviors are correlated with socioeconomic condition of Auto dirvers. For this, the study introduced four driving behaviors from upper Table 03 as follows:

$Group_1$ (i) Independent variable
X_1 = Age of the drivers

$Group_2$ (j) Dependent variable
X_6 = Reasons of traffic rules violation

X_2 = Education qualification
X_3 = Family member support
X_4 = Cell phone receiving pattern
X_5 = Work hours
X_7 = Driving in the wrong direction
X_8= Parking violation
X_9= Causes of road accident

The coefficient of correlation using the 50 sample responses to see the association between the group1 and group2 may be defined as:

$$rij = \frac{50\sum xixj - \sum xi.\sum xj}{\sqrt{[50\sum xi2 - (\sum xi)2].[50\sum xj2 - (\sum xj)2]}}$$

Where i and j are not same,

Using the upper formula on each possible pair of 50 responses on driving behaviors, the acquired correlation coefficients and significance levels are attested in Table 4.

Table 4: Analysis of different Auto drivers driving behaviors

Case	i	j	R_{ij}	Significance Level	Confidence Level (95%)	
					Lower	Upper
1	X_1	X_6	-o.138	0.340	-.596	.210
	X_1	X_7	-0.101	0.486	-.269	.130
	X_1	X_8	-0.283	0.047	-.342	-.003
	X_1	X_9	0.331	0.019	.067	.709
2	X_2	X_6	0.057	0.695	-.454	.676
	X_2	X_7	0.080	0.580	-.201	.355
	X_2	X_8	-0.129	0.371	-.353	.134
	X_2	X_9	0.284	0.046	.009	.916
3	X_3	X_6	-0.019	0.894	-.592	.518
	X_3	X_7	-0.020	0.892	-.292	.255
	X_3	X_8	0.045	0.758	-.204	.278
	X_3	X_9	-0.070	0.631	-.574	.352
4	X_4	X_6	0.222	0.121	-.179	1.483
	X_4	X_7	0.151	0.296	-.197	.634
	X_4	X_8	0.015	0.917	-.351	.389
	X_4	X_9	0.000	1.000	-.713	.713
5	X_5	X_6	0.016	0.911	-.532	.595
	X_5	X_7	-0.040	0.783	-.316	.240
	X_5	X_8	-0.284	0.046	-.474	-.005
	X_5	X_9	0.035	0.808	-.414	.528

This correlation conducted by using Pearson's correlation. The Pearson's "r" ranges in value from -1 to +1. According to Pearson's ranges we can say; if r≤0. 30 is a weak correlation, if 0.30<r<0.70 moderate correlation and again if r≥0. 70 is a strong correlation between two variables.

Case-1: After the comparison of "age" of the drivers with those who traffic rules violence; who drive on wrong direction; who disregard parking rules shows weak negative correlation with lower confidence level and with the significance level of 38%, 48% and 4.7%, respectively, with this result we can say that the age of the drivers does not effect on traffic rules violation; driving on wrong direction and disregard parking rules. Again, when a comparison of age of the drivers and who make road accident was conducted shows moderate positive correlation with lower significance level of 1.9% and with high level of

confidence 70.9%, with this result, we can say that the age of the drivers is directly affected by making road accident, according to sample data.

Case-2: After the comparison of "education qualification" of the drivers with those who traffic rules violence; who drive on wrong direction; who make road accident shows weak positive correlation with 67.6%, 35.5% and 91.6% confidence and with high level of significance 69.5%, 58.0% and 4.6%, respectively, with this result we can say that lower educated drivers can significantly effect on traffic rules violence; drive on wrong direction; and making road accident. On the other hand, education, quality of the driver does not effect on the parking rules violation, according to sample data.

Case-3: After the comparison of "family member support" of the drivers with those who traffic rules violence; who drive on wrong direction; who make road accident shows weak negative correlation with 51.8%, 25.5% and 35.2% confidence and with high level of significance 89.4%, 89.2% and 63.1%, respectively, with this result we can say that family member support of the drivers does not effect on traffic rules violence; drive on wrong direction; and road accident making. On the other hand a weak positive correlation was found between the number of family member supports of the drivers and who parking violation. In that case we can say that family member supports of the drivers have an effect on who parking rules violence but not significant, according to sample data.

Case-4: After the comparison of "cell phone receiving pattern" of the drivers with those who traffic rules violence; who drive on wrong direction; who parking violation and who make road accident shows weak positive correlation with high level of significance 12.2%, 29.6%, 91. 7% and 100%, respectively, with this result, we can say that, those who received cell phone during driving, he has a significant effect on traffic rules violence; drive on wrong direction; parking violation and occurring road accident, according to sample data.

Case-5: After the comparison of "workload pressure" of the drivers with those who drive on wrong direction; and who disregard parking rules shows weak negative correlation with 78.3% and 4.6% significant level, with this result, we can say that, workload pressure does not effect on driving on wrong direction; and disregard parking rules. On the other hand a weak positive correlation was found with the workload pressure on the drivers and with whom traffic rules violence and who make road accident, with high level of significant 91.1% and 80.8%, respectively, with this result, we can say that those who drive more hour per day he has more potential to make road accident and traffic rules violence, according to sample data.

6. CONCLUSIONS

Pabna is an old town in Bangladesh. There is no "Master plan" for the municipal city as a result the town Centre was developed without concerning expert values. The roads in town Centre are narrow and traffic congestion becomes continuous problems with the increasing numbers of Auto. From past researchers are trying to alleviate traffic congestion problems in the Pabna town center. In this regard 50 Auto drivers were surveyed and their responses to different problems associated with traffic congestion and trip characteristics were discussed. Finally, it was shown through correlation analysis between socioeconomic condition and with the different driving behaviors of Auto drivers. The results of correlation analysis are in good agreement with the general views of respondents and it shows that the socio-economic condition and driving behaviors of Auto drivers are interdependent to ensure safe and efficient traffic flow of the study area. It was found that the competition between them in making more trips to support their family is the main causes of traffic rules violation and traffic congestion. For Town center Pabna, traffic congestion pressure can be improved by launch on various strategies such as improved road infrastructures, road capacity

expansion, building Auto parking space and financial penalty to the traffic law breakers. Most importantly, proper traffic and transportation management system along with the appropriate implementation of traffic rules is necessary to mitigate the problems of traffic congestion in town Centre.

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EVALUATING THE SOCIO-ECONOMIC AND ENVIRONMENTAL IMPACT OF BATTERY OPERATED AUTO RICKSHAW IN KHULNA CITY

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ABSTRACT

This research stands for assessing the social, economic and environmental impacts of battery operated auto rickshaw in Khulna city. For performing that, three core issues are focused i) employment opportunity, ii) environmental hazards and iii) traffic jam and electricity consumption. In this research Khulna City is selected as study area. Because the number of battery operated auto rickshaw is increasing day by day in Khulna City. This research relied on field survey based data collection from the persons who are related to the battery operated auto rickshaw like passengers, drivers, owners etc. The findings of this study suggest that most of the people choose battery operated auto rickshaw for safety and less traveling cost. Battery operated auto rickshaw helps to improve the economic condition of driver and owner both. Another findings shows that battery operated auto rickshaw does not emit any harmful pollutants. It also creates less sound which is tolerable. But generating traffic jam, highly electricity consumption is the main negative aspects of battery operated auto rickshaw.

Key words: *Battery operated auto rickshaw, Employment opportunity, Electricity consumption.*

1. INTRODUCTION

The objective of the research stands for assessing the social, economic and environmental impacts of battery operated auto rickshaw in Khulna city. Khulna is the third largest metropolitan city in Bangladesh. Battery operated auto rickshaw have been becoming more popular in Khulna city because of their low fuel cost and less human effort compared to pulled rickshaws. Battery operated auto rickshaw is the updated form of rickshaw which is locally known as easy bike. It has normally four to six seats for passenger along with the driver(Kabir, Hoque, 2015).The mode is being used as a popular transport mode especially by the lower, lower-middle and even middle income people of urban Bangladesh as the mode involves lower travel cost as well as provides much more safety and convenience to the users during travel than other public transport modes(The Daily Star, 2011). They are being widely accepted as an alternative to petrol/diesel/CNG auto rickshaws.

2. LITERATURE REVIEW

Comprehensive researches have been completed on battery operated auto rickshaw. These researches mainly focused on the socio-economic and environmental aspects of battery operated auto rickshaw.A recent study in Rajshahi city in Bangladesh show that the unemployment problem is reduced about 2% by battery driven auto rickshaw. It consumed about 10 kilo-watt energy at the time of per charging which creates pressure on the local electricity supply(Rahim, Hasan, 2013).

Another study was conducted in 2013 which shows that battery auto rickshaw offers low travel cost than other vehicles (Rana, Mitra, 2013). Bangladesh could save between $200 million and $800 million per year, about 0.7% to 3.0% of its gross national product if air pollution in the countries four major cities were reduced. In these cities around 6.5 million people suffer air pollution related diseases(Mahmood, 2011).

3. STUDY AREA AND METHODOLOGY

3.1 Study Area

Khulna is the 3rd largest city of Bangladesh. The area of Khulna City Corporation is 14.30 square miles and divided into 31 wards. The study area was selected thus a way that it includes all classes of people.

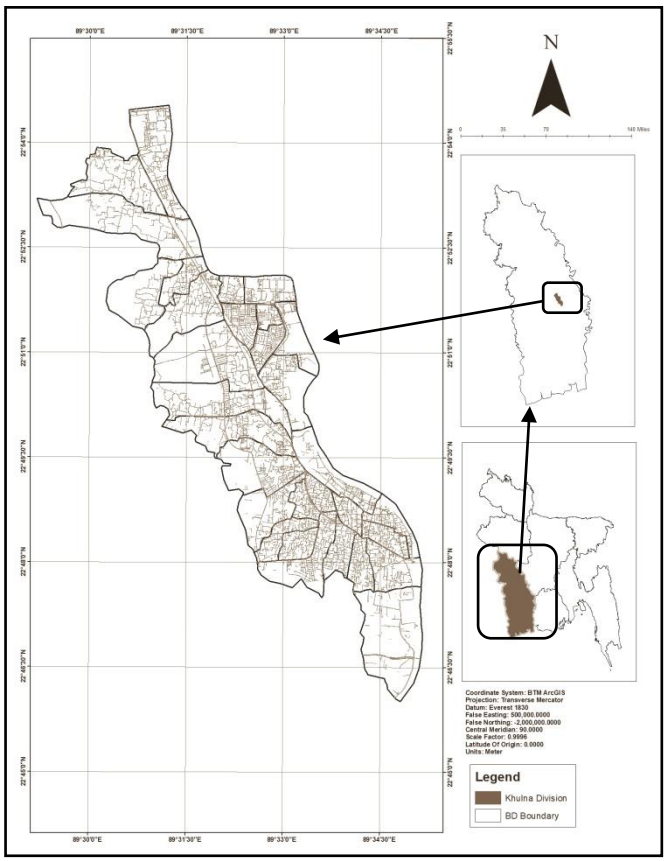

Figure 1: Map of Study Area, Source: Author 2017

Table 1: Study Area at a Glance

City corporation	**1**
Thana	5
Ward	33
population	770498
Population density	18889 (per square kilometer)

Source: KCC

3.2 Methodology

The study was started through reading the available materials in the internet and talking to the people of Khulna city. The study area was selected to assess the social, economic and environmental impacts of battery operated auto rickshaw in Khulna city. This Study relied on field based data, which was collected through the reconnaissance survey & field survey. The preliminary survey helped to collect some initial information about the area. The field survey was done for gathering the required data for social, economic and environmental aspects of

battery operated auto rickshaw in different place of Khulna city like Fulbarigate, Daulatpur, BoyraBazar, Shibbari mor, Royal mor etc. Various types of questions were asked to the passengers, drivers, and owners who are related to the battery operated auto rickshaw of the project area.A user opinion survey was conducted among 100 persons about the fare rate, travel time, safety, travel comfort and quality of service to find out the Performance Index of battery operated auto rickshaw in the area.

The data was stored in Microsoft Excel 2013, from the data different types of analysis was done. GIS based secondary analysis help to know the overall view of the site and the exiting condition. It also helps to make maps for the study.

4. ANALYSIS & INTERPRETATION

4.1 Purposes of Battery Operated Auto Rickshaw

In Khulna City different types of transport mode is used like Mahindra, Bus etc. Battery operated auto rickshaw is used for working purpose, educational purpose, commercial purpose, social working purpose. Almost 53% passengers use battery operated auto rickshaw for their working purpose. Where 25% passenger use it for the educational purpose. The data was collected from Fulbarigate, Daulatpur, BoyraBazar, Shibbari mor, Royal mor.

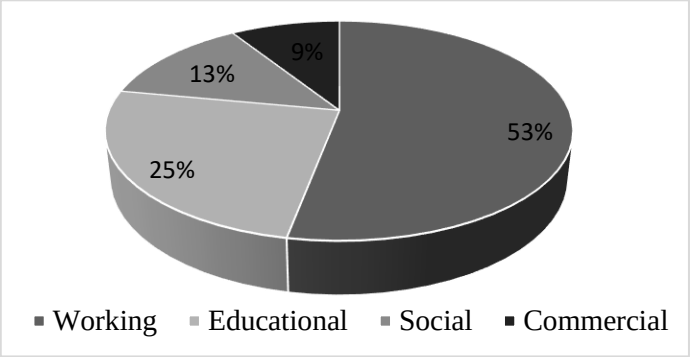

Figure 2: Purpose of Using Battery Operated Auto Rickshaw
Source: Field Survey, 2017

4.2 Positive Aspects

4.2.1 Choice of Auto Rickshaw

People chose transport mode on the basis of road condition, time, availability, financial condition, distance, safety etc. In Khulna city 47% people chose battery operated auto rickshaw as transport mode. Where 42% people use mahindra as transport mode. Most of the people chose battery operated auto rickshaw because of less traveling cost, comfort and safety.

In the battery operated auto rickshaw transportation cost is less than mahindra and paddle rickshaw. In the several place the fare of battery operatedauto rickshaw and mahindra issame.

Table 2*:* Fare of Different Mode

Mode	Distance	Fare/person
Mahindra	Fubarigate to Daulatpur	10 taka
Auto Rickshaw	Fubarigate to Daulatpur	8 taka
Paddle Rickshaw	Fubarigate to Daulatpur	30 taka

Source: Field Survey, 2017

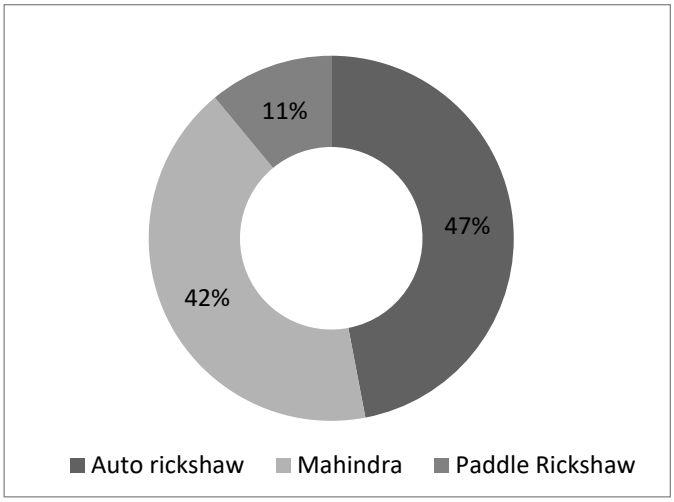

Figure 3: Choice of Auto Rickshaw
Source: Field Survey, 2017

4.2.2 Earning of the Owner

From the auto rickshaw the owner of it get 500 taka per day for each auto rickshaw from the driver. So the one auto rickshaw owner earns 15000 taka per month. Where he spend daily 70-90 taka per day which is 2100-2700 taka in a month for the maintenance and repairing. In the major repairing like replacement of battery, tire, motor the owner has to spend for the long lifecycle.

Table 3*:* Cost of Accessories

Accessories	Cost
Batteries	35000
Tire	1500
Motor	6000

Source: Field Survey, 2017

4.2.3 Earning of the Driver

Most of the drivers, do not have their own auto rickshaw. They hire auto rickshaw from the owner in a daily payment basis. An auto driver earns average 1000-1200 taka per day. They have to pay 500 taka to the owner of auto daily and they have 500-700 taka in their hand. Before starting this occupation most of the drivers are unemployed and some of the drivers are engaged in other occupations like day laborer, industry worker etc. They take this profession to improve their economic condition. From the field survey it is found that 58% drivers strongly agree that this occupation change their social status, where 28% drivers are

disagree. Besides around 74% drivers say that their economic condition have been changed after taking this occupation.

4.2.4 Emit Low Level Pollutants

Auto rickshaws are operated by the battery is called battery operated auto rickshaw. This auto rickshaw does not emit harmful pollutants like CO, CO_2than the other transportation mode like bus, Mahindra. One of the major positive side of this battery operated auto rickshawis that, it makes low sound than other vehicles. It only produces battery water and oil pollutants, which can be controlled by proper management.

4.3 Negative Aspects

4.3.1 Traffic Jam

In Khulna City battery operated auto rickshaws are also responsible for the traffic jam. Because they are commonly parked beside the road. This road side parking creates traffic jam in most the important places in Khulna city.

4.3.2 Electricity Consumption

The auto rickshaws need to recharge the batteries in daily. They charge these batteries from the electric supply line. It takes 7-8 hours for full charging of the batteries. Auto drivers normally charges batteries in 10 pm to 6 am.

It has been estimated that, battery operated auto rickshaw consumes approximately 300 MW electricity every day for recharging their batteries (Field Survey 2017). As Bangladesh is an electric power crisis country and this huge consumption for this purpose creates daily load shedding in the locality.

4.3.3 No License

According to the field survey it is noticed that there is no license or registration number of auto rickshaw and driver. So it is impossible to find out the driver or auto rickshaw after committing any serious action. And it is also difficult to taking action against the owner and driver after committing any crime.

4.4 Performance Index (PI) of Battery Operated Auto Rickshaw

In the user opinion survey respondents are asked to give their opinion on different attributes of battery operated auto rickshaw on a scale of 0 to 5. Where 5 indicates the best excellent and 0 indicate the worst performance(Rana, Mitra, 2013).

User opinions are taken about fare rate, travel time, travel comfort, safety and quality of service of battery operated auto rickshaw.

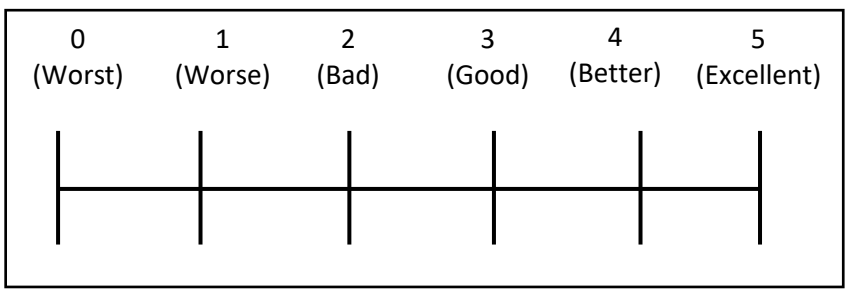

Figure 4: Scale of Satisfaction Level, Source: Author, 2017

Table 4: Value of Different Attributes

Attributes	Scale					
	0	**1**	**2**	**3**	**4**	**5**
Fare Rate	0	0	3	10	25	62
Travel Time	0	0	13	39	35	15
Travel Comfort	0	0	15	9	30	46
Safety	4	9	29	22	19	17
Quality of Service	0	0	6	25	47	22

Source: Field Survey, 2017

$$\text{Performance Index on Fare Rate} = \frac{0*0 + 0*1 + 3*2 + 10*3 + 25*4 + 62*5}{100}$$

$$= 4.46$$

Performance Index of other attributes of battery operated auto rickshaw

Table 5*:* Performance Index of Different Attributes

Attributes	Performance Index
Fare Rate	4.46
Travel Time	3.43
Travel Comfort	4.07
Safety	2.94
Quality of Service	3.85

Source: Field Survey, 2017

From the Table 5,it is seen that the fare rate and travel comfort of battery operated auto rickshaw is nearly excellent to the users. On the other hand travel time and quality of the service from this mode is in the satisfactory level to the users. But in the safety matter, ithas bad performance.

5. CONCLUSIONS

The analysis of socio-economic and environmental impact of battery operated auto rickshaw gives an overview of the positive and negative impacts of it in human life and environment in Khulna city. Most of the people use battery operated auto rickshaw for their working purpose, daily travel. They chose it because the fare is lower than the other transport modes. The results from the analysis represent its positive impact in the social and economic sector of dwellers of the area. By operating the auto rickshaw both the owners and driversare economically benefited. People agree that their economic and social condition is changed after changing their occupation to it. And one of the major positive side of the battery operated auto rickshaw is that, it emits lower level of pollutants than other vehicles. But on the other hand it consumes huge amount of electricity at the time of battery charging and creates traffic jam also. By analyzing the performance index it is found that, the fare rate, travel comfort of battery operated auto rickshaw is excellent. But safety condition is not satisfactory. This study will help to improve the transportation system of Khulna city by usingthe battery operated auto rickshaw in an effective way and to reduce the negative aspects of it.

ACKNOWLEDGEMENT

Special thanks to the local people of Khulna for their participation and coordination at the time of conducting survey. Without their co-operation and help this research could not be up the mark.

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EFFECT OF CEMENT MORTAR USED AS VOID FILLER ON UNIFORM GRADED BINDER COURSE

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ABSTRACT

Flexible pavement, a very common term in the transportation system of Bangladesh can be described to be composed of multiple layers (base and sub base coarse) along with a bituminous sealcoat which primarily acts as the protective shield for the pavements. Generally, sealcoat will provide a layer of protection blocking out the elements like water, oils, and U.V which can deteriorate the binder and expose the aggregate. Though bitumen serves as sealcoat but it has some drawbacks. Presence of water on the bitumen surface displaces the polar molecules and causes stripping and ultimately reaches the under laying layer and breaks the bitumen aggregate bonding. Moreover, it is greatly susceptible to temperature and evolves harmful gases and ultimately reduces the lifespan of pavements. Considering different drawbacks associated with bitumen this study was initiated to check the effectiveness of cement mortar as void filler and additive binder instead of bituminous sealcoat on binder courses and its economic effectiveness. In this research work mortar coating were provided in one face of Marshall Sample and its stability and flow value was determined to compare the result with the bituminous coating sample. The comparison of cost between the two different types was also done based on the per square meter cost of each type of coating.The analysis of the results showed that cement mortar as void filler instead of asphaltic coating gave improvement in the stability as well as flow value and it also proved to be much more cost effective in the primary level of the research.

Keywords: *sealcoat, cement mortar, void filler, binder course, cost effective.*

1. INTRODUCTION

Roads are and have always been, since time immemorial, an indispensable part of our lives and the most crucial element of a civilization. Hence, since remote past, man have always put a continuous effort to ensure the betterment of road making and have tried in every century the use of cutting edge technologies to expose newer and more advanced methods in the construction of roads and highways. And in the present context of Bangladesh Flexible pavement is a very common term. Flexible pavement is composed of a bituminous material surface course and underlying base and sub base courses.

Nowhere in the world is the climatic condition so wet as in the subtropical zones of the Indian subcontinent. The prevalence of heavy rainfall throughout this geographical location makes it an engineering challenge to construct roads and highways here. Though the conventional flexible pavement is consisted of bituminous seal coating to prevent the intrusion of unwanted water that ultimately damages the pavement but it is associated with some problems which reduces the ultimate life span of the pavement e.g. bitumen is highly reactive to water which contributes to the breakage of the bitumen aggregate bonding through chemical reaction or tire pressure etc as well as it evolves poisonous gas like, hydrocarbons and carbon mono-oxide during manufacture. Moreover, asphaltic road construction is hazardous and risky as well as troublesome.

But we need roads and we need roads to exist for a very long time so as to ensure not just maximum efficiency but also maximum effectiveness. The sole purpose of this study or research project is to find an alternate source of sealcoat other than bitumen which is used as the seal coat. Mortar can be used effectively to provide a protection to pavement by replacing the bituminous sealcoat. Mortar may be proved to be more resistant to water in comparison to Bitumen and this research attempts to find out if it truly is so. After the placement of the aggregates in the surface layer, mortar paste is placed to fill the voids in between to give a proper sealing effect. There have not been so many breakthroughs in this field of research and this project of the author is a unique one as the author tries to uncover some exceptionally new information. Whether or not the project manages to provide a solid foundation to the new proposition, a failure too will provide effective approach to further studies in the best interests of science and discovery. That is in actuality the main motivation of the author behind the conduction of this research.

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:

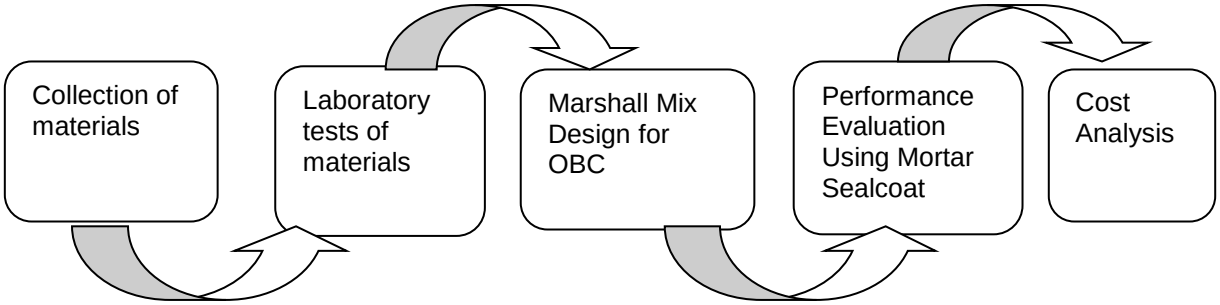

Figure 1: Work Flow Diagram

Thus, it is clear from the above figure that the whole procedure of the study includes collection of materials required and then the laboratory tests for the materials need to be done for checking its feasibility for use in the Marshall Mix Design. Then the optimum bitumen content is need to be determined and using the OBC more samples will be prepared for testing using mortar coating. Last of all the cost analysis is done for economic evaluation.

2.1 Collection of Materials

Material used in the research includes the collection of aggregates and binders as well as cement and sand.

2.1.1 Collection of Aggregate

Uniform graded crushed aggregates (19 mm down) were collected to achieve laboratory investigation and mix design. The aggregate gradation chart and the gradation curve obtained is as follows:

Table 1: Aggregate Gradation Chart

Sieve size (mm)	Sample by wt. retained (gm)	Percent retained (%)	Cumulative percent retained	Percent passing
19	0	0	0	100
12.5	625.1	62.51	62.51	37.5
9.5	152	15.2	77.71	22.3
4.75	105.5	10.6	88.31	11.7
2.36	66.4	6.6	94.91	5.1
1.18	40.4	4.04	98.95	1.05

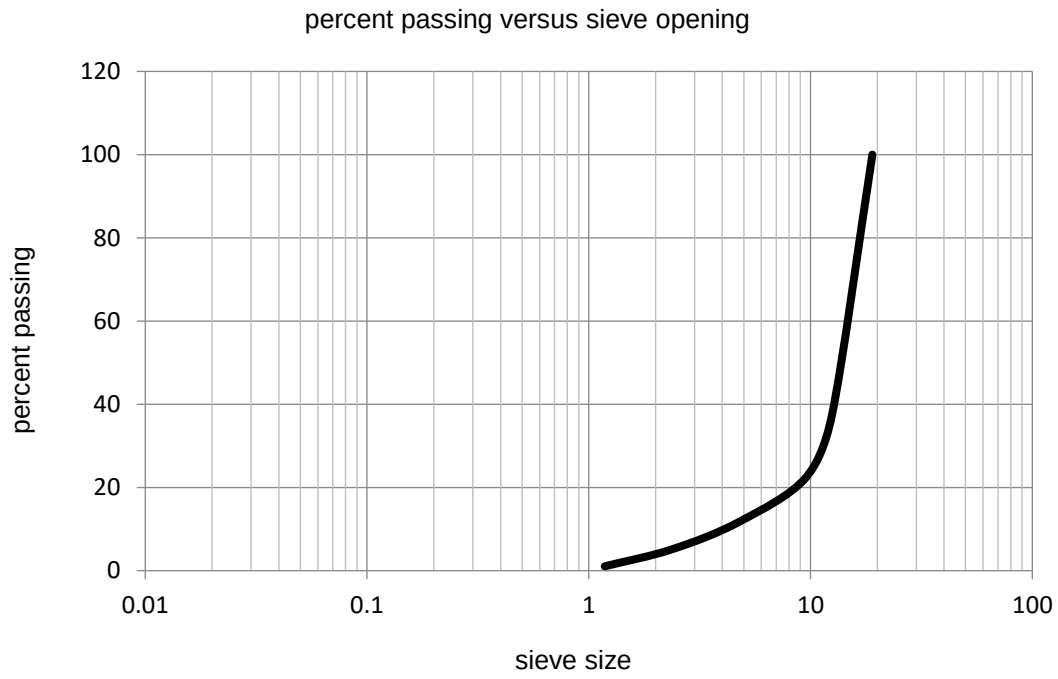

Figure 2: Particle Size Distribution Curve

2.1.2 Collection of Bitumen

Bitumen binder of grade 60/70 has been collected and to investigate the properties of binder, physical characteristics have been evaluated in the transportation laboratory, Department of Civil Engineering, Chittagong University of Engineering & Technology.

2.1.3 Collection of cement & Sand

Portland composite cement was collected for the study available in the laboratory. And the sand collected was Sylhet sand and the fineness modulus data of the sand is as cited below in the following table:

Table 2: Data for Fineness Modulus of Sand

Sieve nos.	Retained (gm)	Cumulative retained (gm)	Cumulative percent retained (%)
8(2.36mm)	14.30	14.30	2.91
16(1.18mm)	84.30	98.60	20.1
30(0.6mm)	103.70	202.30	41.21
50(0.3mm)	234.60	436.90	89
100(0.15mm)	54.00	490.90	100

2.2 Laboratory Tests

For the aggregates property tests have been done and the property tests of binder used were also done in the laboratory. For the aggregates impact test, Los Angeles tests, tests for water absorption, specific gravity, hardness test, sound tests etc. were done and the results were within the specified limit according to IRC limit. Moreover, tests of bitumen were also within limit and can be cited as follows:

Table 3: Bitumen Property Tests

Type of Test	Property values
Penetration Value(mm)	72
Ductility(cm)	100
Softening Point(degree Celsius)	48
Flash Point (degree Celsius)	308
Fire Point (degree Celsius)	320
Loss on Heating	.15%
Specific Gravity	1.031

2.3 Marshall Mix Design

Marshall Mix Design is an important step of this research. For the determination of OBC and suitability of the mortar as coating this design method has been used. The mix design determines the optimum bitumen content. Marshal Mix design is a standard laboratory method which is adopted in a large measure in different parts of the world for determining the strength and flow characteristics of paving mixes prepared. For a given gradation if aggregates and binder quality, the optimum binder content to be used is determined by this method. The method is being routinely used as a tool to evaluate the relative performance of different mixes. The Marshall Stability and flow test provides the performance prediction measure for the Marshal Mix design method. The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute. Load is applied to the specimen till failure and the maximum load is designed as stability. During the loading, an attached dial gauge measures the specimen's plastic flow (deformation) due to the loading. The flow value is recorded in .25 mm (0.01 inch) increments at the same time when the maximum load so recorded.

2.3.1 Problem Identification

During conducting the experiments using 19mm down coarse aggregates some problems were faced which can be summarized as follows: Since there were no filler materials, compaction of only coarse materials led to more voids as a result of which proper binding and compaction was not possible. So the amount of aggregates taken was lessening by 100gm to fit in the mold for proper compaction and binding. Again, due to the presence of coarser material (19 mm down) amount of bitumen content added need to be maintained properly as when bitumen content taken was 2% the sample did not get bonded. Again when the bitumen content was 4.5% then the sample got distorted when placed in the water bath. Due to the absence of filler material the stability and flow value of the samples were comparatively low. Moreover, because of larger voids weight of displaced water was less.

3. LABORATORY INVESTIGATION

The performance test will evaluate the feasibility of mortar as void filler instead of bitumen or asphaltic coating. The performance tests include the stability and flow test of the Marshall Sample with bitumen content as determined giving a mortar coating on it.

3.1 Shortcomings & Decisions

By analyzing the results and data it is obtained that since the samples are made of mainly coarse aggregates and there is absence of filler materials so the amount of displaced of water is comparatively less due to presence of comparatively larger voids and as a result it is not possible to determine the volume of bitumen, VMA, VFA and subsequently the OBC cannot be determined too. As a result, to continue the further research work bitumen content corresponding 4% was decided to use since it showed comparatively better strength and flow value.

3.2 Sample Preparation & Testing

Three Marshall Samples were produced using 4% bitumen content. Then the mortar coating was given in one face. The mortar was made slurry by using more percentage of water so that it attains enough liquidity to fill ups the voids present in the sample and make a firm bonding. The cement sand ratio taken was 1:3. Then the sample was kept for 28 days Air curing for hardening of mortar. After that the stability and flow tests of the three samples were done to compare the value with the samples of only bitumen content. The following table gives the result of the three samples:

Table 4: Marshall Sample Test Results

Serial nos.	Stability (KN)	Flow value (mm)	Average stability (KN)	Average flow value (mm)
1	7.00	1.975		
2	5.75	1.75	6.05	1.75
3	5.40	1.5		

4. RESULTS & OUTCOMES

After testing and calculation it was seen that the stability of the Marshall samples with mortar coating on one face is more than that of the samples those are without coating. The flow value of the samples also improved. The comparison between the results of samples having bituminous coating and mortar coating both having bitumen content corresponding to 4% is as follows

Table 5: comparison between the results for performance evaluation

properties	Asphaltic/bituminous coating	Mortar coating
Stability (KN)	4.89	6.05
Flow value (mm)	1.575	1.75

5. COST ANALYSIS

comparisons have been made and different ideas have been debated over and researched into to see the usability of mortar and bitumen as seal coat.

5.2 Pavement Comparison

The following figure describes the comparison between conventional road on low volume flexible pavement having bituminous sealcoat and the proposed pavement where the cement mortar penetrated through the voids and also acted as an additional binding material to serve the facilities like sealcoat.

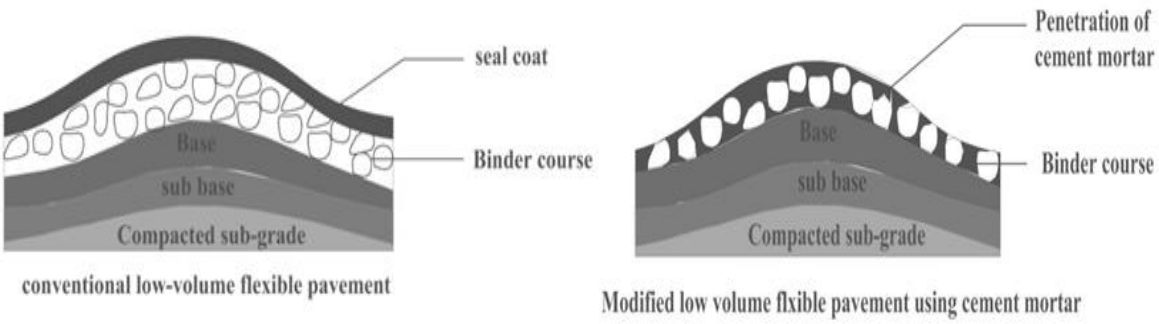

Figure 3: Comparison between Conventional & Modified Low Volume Flexible Pavement

5.3 Price Analysis

As seen from the figure 3 in the new modified road the sealcoat is totally being omitted and cement mortar is being placed as void filler instead thus the price of sealcoat is being saved. Moreover from Market analysis the following price may be assumed:

Table 6: Market Price of Materials

Item	Unit	Price in BDT
Cement	1 bag (1.25 cft)	450 – 470
Sylhet Sand	1cft	22 -25
60/70 grade bitumen	1kg	82.66

According to the schedule proposed on 2008 by Public Works Department (PWD) and Department of Roads and Highway of Bangladesh, the following costs may be assumed

Table 7: Comparison between the Prices of Materials

Item	Unit	Price in BDT
Mortar (6mm) with cement sand ratio 1:3	1 sq m	132
Bitumen (12mm)	1 sq m	215

It can be observed that the price of mortar is less than that of bitumen. However, bitumen also requires maintenance at regular intervals and the intervals are quite short in comparison to mortar. Mortar too requires maintenance but it lasts over a long period of time and does not need to be treated for maintenance as often as bitumen. Again, the labor cost of bituminous works is high as it requires exposure to risks and dangers. Labor cost of mortar works is comparatively low as it is comparatively simpler and workers are less exposed to risks.

6. CONCLUSION

As the sole purpose of the investigation of this research work was to find the acceptability and competence of mortar as a void filler and binder over bitumenous sealcoat, the author has tried various methods to test every possibility that may have borne an outcome to give statistics in affirmation or in negation to the thesis proposal. Whether or not the project work was a grand success is henceforth succeeded over by the fact that this research has opened doors to further investigation by means of which more conclusive results may be obtained.
The analysis of the results showed that cement mortar as void filler and binding material instead of asphaltic coating gave improvement in the stability as well as flow value and it also proved to be much more cost effective in the primary level of the research. To conclude the general section, it can be said that the use of mortar as a seal coat is to some extent, if not huge, more effective and has higher lifespan than bitumen.

7. RECOMMENDATION

To improve the quality as well as to increase the life span of the flexible road following recommendations have been suggested about the problems identified during investigation

- Modified bitumen can be used with the aggregates instead of nit bitumen.
- It would be preferable to use coarse aggregates which are smaller (like 12.5 mm down) than the aggregates used in the research work for improved bonding and compaction.
- For betterment of the strength of the mortar seal coat curing can also be used for further investigation.

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EVALUATING THE USER'S PERCEPTION REGARDING THE ROLE AND PERFORMANCE OF PUBLIC TRANSPORT IN KHULNA-JESSORE HIGHWAY: A CASE STUDY ON AFILGATE TO FULBARIGATE MIDBLOCK

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ABSTRACT

The sustainable growth of a city can greatly be influenced by public transport in developing countries. It can be a prerequisite from social and economic aspects. The study has been conducted to evaluate the user's perception about the role and performance of public transport (i.e. the existing condition of the fixed facilities and control system) of Khulna-Jessore Highway (Afilgate to Fulbarigate) in Khulna. To achieve the objective a user opinion survey has been conducted among the public transport users including drivers and traffic polices. The overall traffic condition of the study area has been evaluated and the satisfaction level of the users has been measured. Moreover, speed and volume survey have been conducted to get an overview of the vehicular flow and the fluctuation of speed on the midblock. Overall satisfaction level of public transport has been obtained through Customer Satisfaction Index (CSI) considering some service performance indicators including availability, reliability, safety and comfort. Users of bus (CSI score = 4.80) are less satisfied blaming availability and reliability of this transportation mode where Mahindra/ Atul (CSI score = 5.84) has got less satisfaction because of the discomfort and high fare cost. Again, analyzing data, this study has found that about 46% respondents have indicated Fulbarigate as the busiest node at peak hours because of high road side commercial activities. However, the people are satisfied with accessibility and availability of the vehicles all over the midblock. During questionnaire survey about 35% of the respondents have suggested to ban road side commercial activities and around 25% has focused on lane separation for abating traffic congestion and irregular flow.

Keywords: *Evaluation, User's Perception, Satisfaction, Performance, Transportation.*

1. INTRODUCTION

Transport is an important component of economic activity in all over the world especially in developing counties (Mahmud, Rahman, & Rabbi, 2006). According to (Shamsher & Abdullah, 2012) the annual country wise wastage due to traffic jam was USD 79 million for the year in 1997. The Asian developing cities are facing the serious traffic congestion, deteriorating public transport service, lack of investment funds and other traffic problems.

Bangladesh is among the top 12 developing countries with a population of over 20 million and 7.1% annual GDP growth (World Bank, 2016). One of the most challenging and complicated issues in city management in the present decade for Bangladesh is the traffic problem as well as the improvement of transportation system (Shamsher & Abdullah, 2012). The safety situation of road transport in Bangladesh is very severe by international standard and traffic accidents are costing the community in the order of US$ 800 million (nearly 2% of GDP) each year (Mahmud et. al, 2006).

In this situation, improvement of traffic and transportation system is one of the main challenge. As becoming industrialized city and divisional town with a port at Mongla, Khulna is the country's third largest city in Bangladesh having a higher transportation demand (Asian City

Development Strategies, 2000). Again, the establishment of Padma Bridge will stimulate the economy of entire south-western region through the well connectivity with rest regions of the country. Thus, the pressure on the transportation system of the city will be much higher than now within 2018 and will play a significant role in national economy. The identification of the existing problems of the highway will help to provide some propositions for the embodiment of transport facilities where it is needed.

Continuous urban growth, environmental issues, competition for limited space, longer commuting distances as well as the need to promote equity and equality in society are the primary reasons that make the use of Public Transport a priority in today's world (Abenoza et al., 2016). Developing public transport facilities is one of the main ways to reduce congestion (Lia, et. al, 2013).

Performance of public transport can be measured by service utilization (ridership), service quality, and accessibility to the service (Hawas et al., 2012). Customer retention and the attraction of new users can be accomplished by increasing customer satisfaction with Public Transport services and improving their public image, which are widely believed to play decisive roles in rising ridership (Abenoza et. al, 2016). Optimum efficiency can be achieved by the creation of balance in supply cost (disutility) and level of service improving the operational features (Daganzo, 2010). The objective of this study is to evaluate the user's perception regarding the role and performance of public transport of a midblock (Afilgate to Fulbarigate) of Khulna-Jessore Highway.

2. METHODOLOGY

2.1 Review of Previous Study

The evaluation index system of public transportation was established based on six aspects like safety, speediness, punctuality, comfort, economy and convenience from the operators and users in China. (Lia, et. Al,2013).

(Abenoza et. al, 2016) Identifies and characterizes current and potential users of public transport in Sweden and identifies the most important determinants of travel satisfaction with Public Transport services for each segment of travelers. It investigates the changes over time of attribute importance among the different segments and the inter-segment geographical variation of overall satisfaction. The cluster analysis results with five segments of Swedish travelers include: (i) inactive travelers; (ii) long distance commuters; (iii) urban motorist commuters; (iv) rural motorist commuters and; (v) students. By contrasting satisfaction with the importance of each quality of service attribute, three key attributes that should be prioritized by stakeholders are identified: customer interface, operation, network and length of trip time.

(Nesheli et al., 2015), Study was undertaken in two-parts: (a) assessment of the effects of delay on PT user's perception and decision to change route or mode; (b) evaluation of user's decision based on various real-time operational tactics. To investigate users' perception and decisions related to various operational tactics, a user-preference survey was conducted at a major terminal in Auckland, New Zealand, and Lyon, France. The survey data was modeled a Multinomial Logistic Regression and a decision-tree-based method.

From the study of different research and secondary sources, User perception regarding the role and performance of public transportation system can be found through the evaluation of operational features based on a user opinion survey. In this paper, the road users are passengers, drivers and traffic staffs. In this study area, maximum trips are commercial based as almost half of the land use is commercial along the highway. The satisfaction level of the road users can perceive the congestion rate and level of service of that midblock.

Traffic volume should be in an optimum number and composition so that the highway can serve the passengers without hazard. Speed is an important transportation consideration because it relates to safety, time, comfort, convenience, and economics determining general speed trends, reasonable speed limits. The actual speed of traffic flow over a given route may fluctuated widely, as because at each time the volume of traffic varies. Accordingly, speeds are generally classified into three main categories; spot speed, journey speed and running speed.

2.2 Study Area

Afilgate to Fulbarigate midblock of Khulna-Jessore Highway has been selected as the study area for this project. Because of the linear shape of Khulna division Khulna-Jessore Highway is the most important transport road way for both intra and inter Khulna city transportation network. The length of the study area segment is 4.8km. About 50% surrounding space is used for government services such as eye hospital, transport authority etc. that reflects high trip attracting characteristics. Besides commercial activities occupy 7% of the space and recreational area occupies almost 8% which is located in Jahanabad. Again, 19% residential and 8% manufacturing industries are mainly the trip generator.

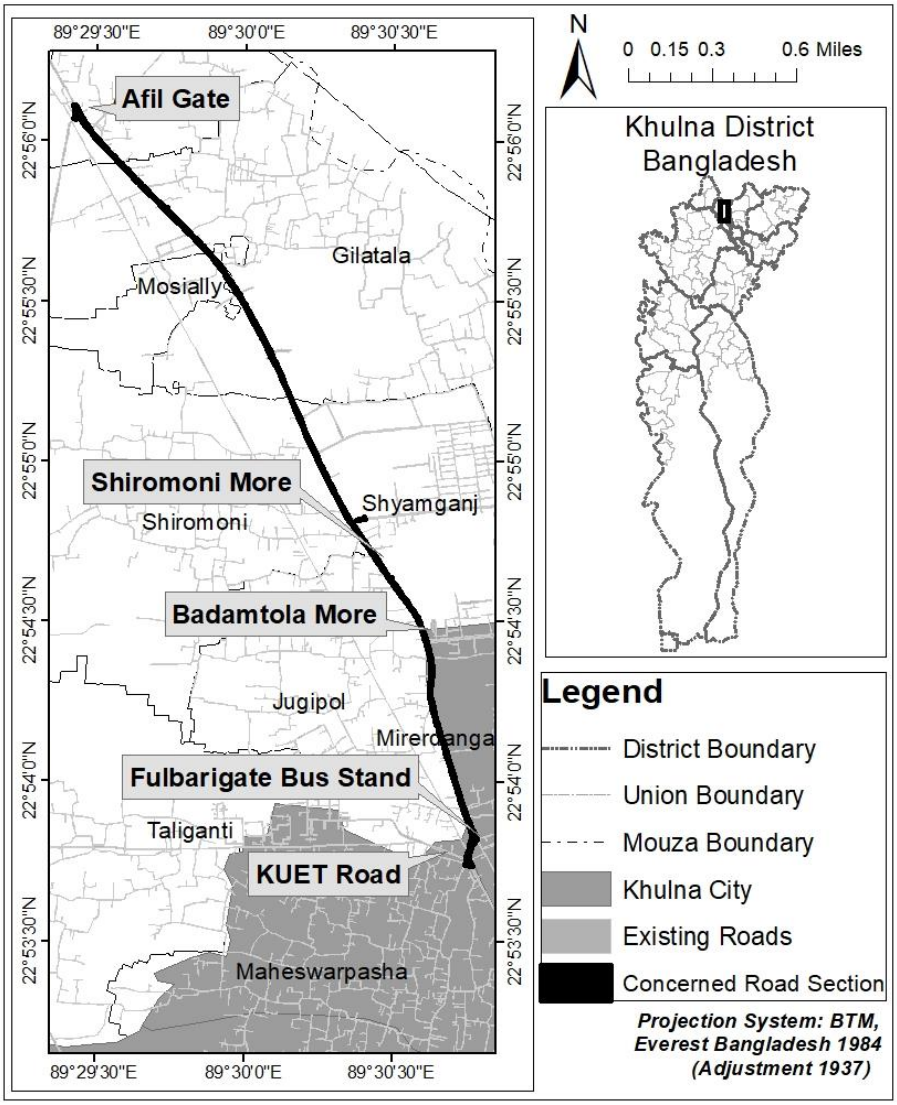


Figure 1: Study area location;

2.3 Survey Design

Data has been collected from a questionnaire survey considering the indicators of measuring performance of the operational features of public transport. The sample size has been estimated 140 (100 road users, 20 vehicle drivers and owners as well as 20 traffic polices) for the survey. The survey has covered the issues necessary to evaluate the performance of existing public transport with different fixed facilities and control system. Again, the survey output is a reflection of satisfaction level of the public transport users. For assistance of the research and reliability issues some other survey has been conducted in the study area; those are physical feature survey, volume survey and speed survey.

Physical feature survey has been done which has reflected the existing condition of fixed facilities of roadway including cross sectional elements, road side land uses and various control systems.

To get an overview of the vehicular flow on the midblock, volume survey has been done at peak and off-peak period of both weekday and weekend. Again, the number of pedestrian passes on the midblock has been counted.

Spot speed of all public transport has been measured at different segments of the midblock. Moving observer method has been used to determine the journey and running speed of two vehicle; viz: town service (public transport) and microbus (private transport).

2.4 Analysis

Analysis has focused on to evaluate travel behavior of public transport users, the major transportation related problems, the satisfaction level on different operational features of public transport and the suggestions to make efficient and convenient public transport facilities.

A data set has been prepared in SPSS regarding the questionnaire survey and different statistical analysis has been completed.

The most congested node of the midblock has been identified based on the user's perspective and this opinion has been validated through volume and speed of the vehicles for each node of the road midblock.

The finding has showed the satisfaction level of road users on operational features. After the analysis, a decision has been taken if the operational features of public transport of the study area are good or bad based on the typical public transport system. A set of recommendation has been provided based on the user's requirement and planning standard.

Customer Satisfaction Index (CSI) measures how satisfied customers currently are with each service provided. 13 performance indicators have been selected based on different secondary sources (Rabby, Hossain, & Rahman, 2016; Transport for NSW, 2015). The indicators have been calculated on the basis of user judgments expressed by a numerical scale. The scale of both satisfaction level and importance score is 1 to 10. Where 10 expresses highest satisfaction and importance level whereas 1 expresses that of the lowest. The following formula has been used:

$$CSI = \sum_{k=1}^{N} MSS * IW \quad (1)$$

Where, $MSS =$ the mean of the satisfaction rates expressed by users on the service quality of k indicator,

$IW(Importance\ Weight) =$ A weight of the k indicator, calculated on the basis of the importance rates expressed by experts and customers. Specifically, it is the ratio between the mean of the importance rates expressed by them on the k indicator and the sum of the average importance rates of all the performance indicator. [$IW = \frac{MIS_k}{\sum_{k=1}^{N} MIS_k}$; I_k= Importance factor of k attribute] (Eboli & Mazzulla, 2009)

CSI score has been interpreted on the basis of following criteria showed in (Table 1).

Table 1: Criteria for customer satisfaction index (CSI)

CSI Value	Criterion of CSI
0.81-1.00	Very satisfied
0.66-0.80	Satisfied
0.51-0.65	Quite satisfied
0.4-0.50	Less satisfied
0.00-0.39	Not satisfied

Source: (Rabby et al., 2016)

3. FINDINGS

After conducting a questionnaire survey, it has been noticed that maximum people travel through Afilgate to Fulbarigate are students. And the second highest number of people travel in the study area are service holder in occupation. But very less surveyed people are found unemployed. The road is mostly used by the teenagers, young adults and adults. Again, maximum time people travels for once in a day. But when it is for business purpose, people travels multiple times a day. There are some people who also travel for once in week too and frequency of those people is 2% (by surveying people). However, the trips are mostly made in Sunday as the opening day of the week which makes it the most critical day for users. Besides, people coming from Fultala is the highest in frequency. The second highest number of people comes from Shiromoni.

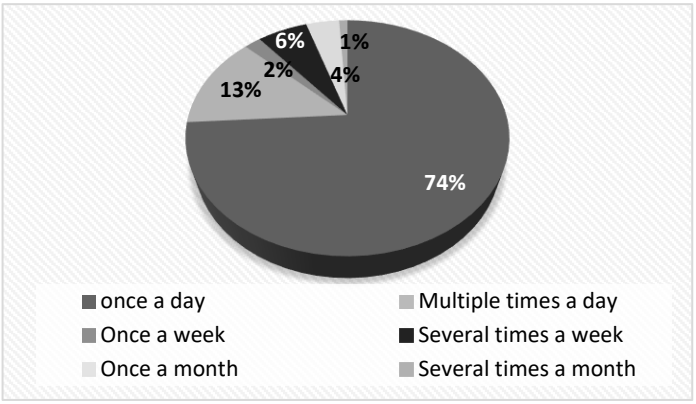


Figure 2: Frequency of Trips (Field Survey, 2016)

3.1 Modal Choice

The utmost number of the people traveling in the study area have an income of less than 5000tk. The people who are businessmen or engaged with trading activities earn 25000TK or more per month. And maximum number of people travels for non-home-based work. The travelers normally prefer Easybike as a mode of transport most of the times. But with the increasing of income, people are shifting to other preferable modes such as Atul or Motorcycles. Easybikes are mainly preferred for low transport fare and high comfort, availability and proximity to origin. But most of the surveyed people such as 25% have responded to availability as the reason. While Atul has been preferred for it's less travel time and has got 20% of total response. People who have a busy day such as travelling multiple times a day like to use Atul for its availability and less travel time. The economic level of the people surveyed has been categorized into five tires. Among them the most people make work purpose trip lied between 5001-10000 income groups that means the people of lower

income are more eager to work rather than shopping. The final tire of the income group more preferred to business trip.

Table 2: Trip Purpose vs. Preferred Vehicle

		Most preferred vehicle						Total
		Bus	Atul	Easybike	Car	Motorcycles	Others	
Trip Purpose	Work	0	9	8	1	9	3	31
	Shopping	0	5	13	0	0	0	11
	Business	1	3	3	0	3	0	10
	Recreation	0	0	4	0	0	0	5
	Education	3	10	11	0	0	0	26
	Others	0	6	8	0	0	0	17
Total		4	33	47	1	12	3	100

Source: Field Survey, 2016

3.2 Problems faced by the Passengers

Most of the respondents have asserted Fulbarigate as the most congested node, followed by Shiromoni as the second and Badamtola as the third. But Afilgate and Jahanabad have not been identified as congested one. Most of the users have suggested that they have to spend less than 5 minutes in traffic jam and have to face congestion during their evening trips.

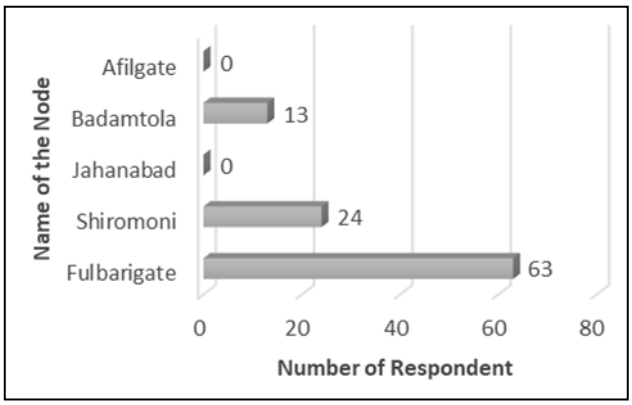


Figure 3: Rank of Congested Node (Field Survey, 2016)

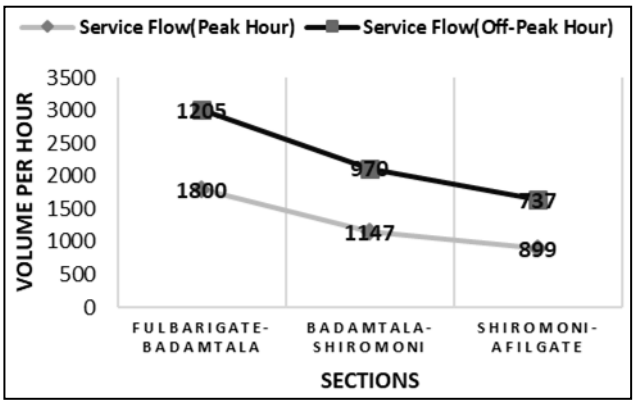


Figure 4: Flow Fluctuation Rate at week days (Field Survey, 2016)

Volume survey has showed that during week days the maximum rate of flow is 1800 vehicles per hour at Fulbarigate to Badamtala and the minimum rate of flow is 899 vehicles per hour at Shiromoni to Afilgate in peak periods which generally indicates that the Fulbarigate to Badamtola segment is more congested than the Shiromoni to Afilgate segment.

Figure 5: Traffic Jam Duration & Time Period (Field Survey, 2016)

On the other hand, Badamtola to Shiromoni road segment has a rate of 1147 vehicles per hour of traffic in peak periods that is less than that of Fulbarigate to Badamtola road segment. But in off-peak periods it is 1205, 970, 737 vehicles per hour in three road segments.

Again, some problems in different nodes on their travel route have been faced by the users. 44% has identified congestion as the biggest problem which is mainly caused by roadside informal parking and 24% has claimed to face problems for informal roadside commercial activities in different nodes. Besides, irregular traffic flow is another reason behind the congestion. And most of these problems are faced in Fulbarigate node. In case of the road-segment between Badamtola and Fulbarigate, a total of 25% respondents often have to go through difficult situations. Fulbarigate has been identified as the intersection with maximum issues. 48% of the respondents have expressed negative opinion about the traffic police which is a serious deal.

Table 3: Reason behind Congestion

Reason behind the congestion	No. of Response
Commercial roadside activity	24
Roadside parking	44
Roadside construction	3
Irregular flow of vehicle	18
Others	11
Total	**100**

Source: Field Survey, 2016

For BRTC service; some users have never experienced BRTC Bus Service while the ones who have do not consider it as a great transport mode. The users have made suggestions for improving the facility. 54% of the respondents have demanded for increasing number of buses. 16% of the users desire the bus to be on schedule and 11% think that avoiding overloading of passengers can help the service get better. The rest consider reducing the fare a better option.

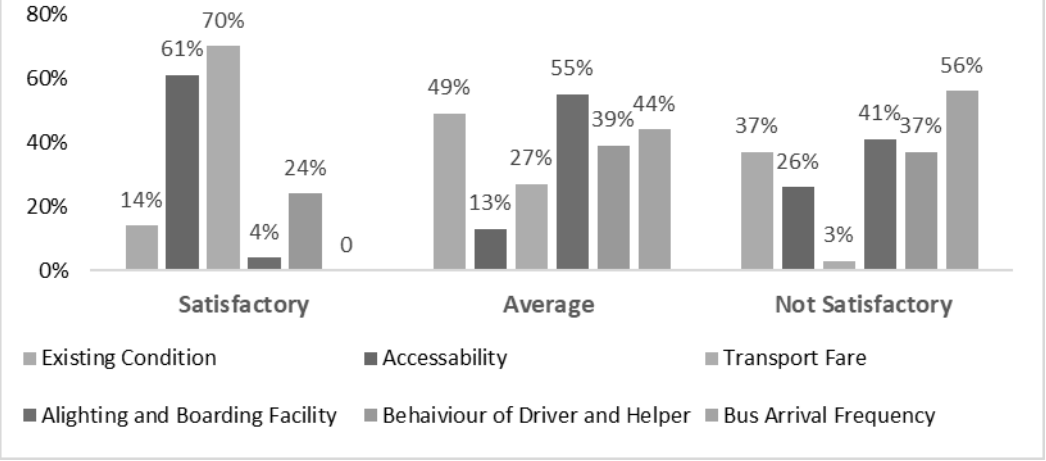


Figure 6. User's Satisfaction about Public Transport (Field survey, 2016)

Most of the users have expressed their satisfaction about the current transport fare while the dissatisfaction in vast amount rises from not having enough local buses running on the street around the clock.

While the speed study shows that the journey speed is less than running speed, it indicates that the journey follows a stop-go condition with enforced acceleration and deceleration (Traffic stream characteristics, n.d.). Both journey and running speed of microbus is higher than that of town service which shows a speed inequality between public and private transport system of the study area.

Table 2: Journey and Running Speed of the Study Area

Features	Town Service (Bus)	Micro Bus
Mean Journey Time (min)	10.67	8.39
Journey Speed (Kmph)	27.00	36.04
Mean Running Time (min)	10.37	8.12
Running Speed (Kmph)	27.77	37.3

Source: Field survey, 2016

3.3 Users' Suggestion:

For improving public transport facility and reducing accidents on the roadway, maximum number of users (43%) think that raising awareness is the best option. Training the drivers properly and putting up signs might help. 31% users suggest that regulatory measures can be applied for different issues, for instants, commercial activities on the footpath can be banned. 16% user desire for better signaling facility and they think auto- signaling can help. Rest of the user said that implementation of different acts is necessary and imposing penalty can be a great tool for reducing the law violation and making road way safer.

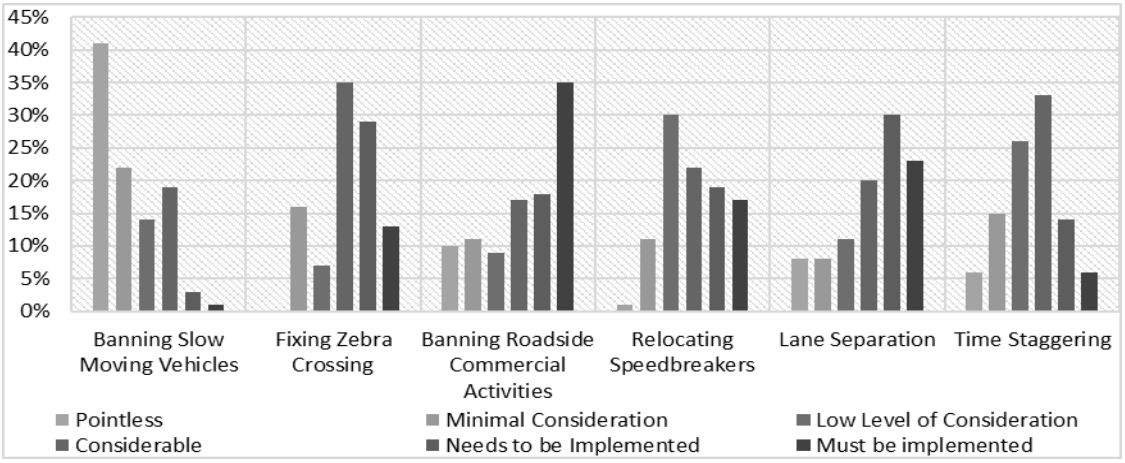


Figure 7. User Opinion for Different Regulatory Measures
(Field survey, 2016)

3.4 Customer Satisfaction Index

Table 3: Calculation of CSI for bus transport (Scale of 1 to 10)

Performance Indicators	Measures of the indicators	MIS	IW	MSS	CSI (IW*MSS)
Availability	Service frequency (number of runs per day) and service time	8.00	0.09	3.8	0.36
Service Reliability	Regularity of the service	6.70	0.08	2.8	0.22
Accessibility	How easily user can get form their houses	7.00	0.08	4.6	0.38
Service coverage	No of stops and distance between stops	6.00	0.07	3.4	0.24
Information	access to information like schedule, ticket cost	5.80	0.07	3.4	0.23
Cleanliness	Internal and external cleanliness of	4.90	0.06	6.1	0.35

Performance Indicators	Measures of the indicators	MIS	IW	MSS	CSI (IW*MSS)
	vehicles				
Comfort on trip	passenger personal comfort while transit is used including seat comfort, ride comfort	5.00	0.06	4.9	0.29
Safety	No of accident and security concerns personal against crimes	7.20	0.08	6.4	0.54
Pollution	Pollution creates by vehicle	7.40	0.09	4.8	0.42
Parking System	No of parking lots and the service quality	8.00	0.09	3.2	0.30
Behavior of driver	One of the services of public transport.	4.50	0.05	6.7	0.35
Efficiency	Travel time and journey speed	6.80	0.08	4.7	0.37
Affordable Fare	affordability of per capita Fare	8.00	0.09	8.0	0.75
	Total CSI				4.80

Source: Author, 2016

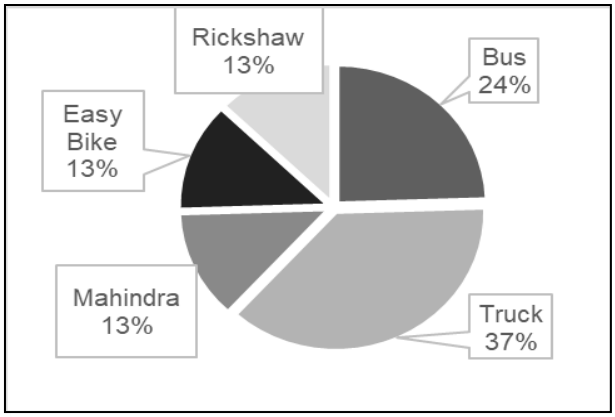
From the above calculation, CSI score has been obtained 4.80 out of 10 (table 6) that expresses the bus transport as a less satisfied (Table 1) and less efficient transportation mode in this midblock. Users raise their voice against low reliability, availability of the mode and bad performance of parking capacity of the midblock. On the contrary, they are highly satisfied with low fare cost.

Again, CSI of Mahindra (preferred by 33% of respondent) has been calculated 5.84 using same importance weight. However, the score is quite satisfied as its less travel time, availability and reliability. At the same time discomfort resulted due to its high speed and congested seating capacity.

3.5 In case of Drivers

Most of the drivers are illiterate and they have received informal training. The truck drivers and some easy-bike drivers have no educational qualification and they have no training either. Equal number of drivers seem to work up to 8 hours and further (12hrs.) 50% of the truck drivers work up to 12 hours a day. 75% of the rickshaw pullers work for minimum time limits a day. 70% of the drivers are satisfied with the repair facility and gas stations. Yet the Atul drivers have complained that since the vehicle has been newly introduced to the city, repair facilities have not been established yet for this vehicle.

60% drivers expressed their satisfaction with the daily amount they have to pay to the owner of the vehicle. Among the unsatisfied group, majority are truck drivers and workers of bus service.



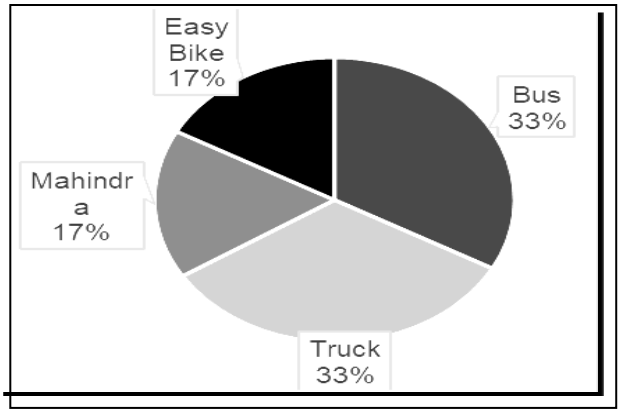


Figure 9: Dissatisfaction of Drivers (Field survey,2016)

Figure 8: Dissatisfaction of Owners (Field survey,2016)

However, Atul drivers calls out for strikes more often due to this problem. As for the owners, bus owners are most satisfied with their income. But the rickshaw owners and truck owners have the maximum complains with the amount they receive against their vehicles daily. The following figures compares the unsatisfied vehicle drivers and owners respectively.

3.6 In case of Traffic Polices:

5 traffic police have been queried and all of them stay on duty for up to hour 8 hours' maximum. They have identified 6-9pm as the most congested hour. 60% of the respondents suggest that motorcycles are more accident prone while the rest have identified easy-bike as so. Motor-cycle is unanimously considered to be the vehicle which is found to be unlicensed in most cases and easy-bike is chosen as the second one. Motorcycle is identified to often use the wrong direction as well, maintaining noticeably high speed.

4. POLICY IMPLICATIONS

Some recommendations may help in improving the existing public transport of Khulna-Jessore highway (Afilgate to Fulbarigate) such as;

- ✓ Formal on-street parallel parking should be introduced at Fulbarigate and Shiromoni intersections. Where the width and length of the parking space should be 2.0m and 6m respectively. Parking price should be levied according to parking duration and parking enforcement should be implemented (Mills, Dillarstone & Tucker, 2016). Very short-term drop off/ pick up places with a time of 3 to maximum 5 minutes. Short-term zones for loading or unloading or quick errands with a time limit of 5 to maximum 8 minutes.
- ✓ Land use should be controlled to single use in a place and temporary road side commercial activities should be banned.
- ✓ No of vehicles should be controlled by reducing slow moving easy bike and increasing the no of fast moving town service. Again, the schedule should be controlled for increasing the arrival frequency.
- ✓ Fulbarigate, Shiromoni and Badamtola intersection should be signalized with traffic polices and markings.
- ✓ Irregular U turn should be banned at congested intersections as like as Fulbarigate more.
- ✓ Variable massage signs should be provided for the convenience of both users and drivers as well as the role of traffic policies should be enhanced.
- ✓ Alighting and Boarding facilities should be widely implemented as the most passenger suggest this.

The transportation system plays a momentous preface for a developing country to achieve a sustainable growth in all aspects such as social, economic and environmental. The present condition of the transportation system of Khulna-Jessore highway has gained people's satisfaction in some cases. Again, in some cases people are dissatisfied. But if the initiatives are taken properly and through some qualitative measures the existing condition can be more exalted. Thus, it can put some positive influences on the users.

5. CONCLUSIONS

This paper has aimed to find out the overall satisfaction level of the operational features of public transport. Questionnaire survey has been accomplished at a week day for finding perception of people travelling for work purpose. Again the sample size is 140 that is low for a satisfactory result. Fulbarigate more has been found as the most congested node due to illegal commercial activities and lack of proper on-site parking system. At the same time, Fulbrigate to

badamtola road segment is the most overflowing section having volume of 1800 vehicle per hour and journey speed of 27 kmph (bus). City bus transport has got lower satisfaction level than that of Easy bike and Mahindra. The availability and reliability is the main problem for this lower satisfaction level where Mahindra serves less travel time with higher availability at higher fare cost. Parking and traffic regulation system is worse here. Signalized road intersection, systematic on-site parking and controlling land use can improve the existing performance of public transport and increase the satisfaction level of the users.

ACKNOWLEDGEMENT

The completion of this study could not have been possible without the participation and assistance of the local people and the traffic management authorities. Besides, drivers and owners of the public as well as private vehicles have contributed respectfully. Suddah Ahmed, Shoaib Md. Shice and Provakor Chowdhury (4th year students, Department of Urban and Regional Planning, KUET) have greatly helped us in conducting the survey. We are thankful to them for their participation and coordination. Their contributions are sincerely appreciated and gratefully acknowledged. Above all, we are always gratified to the Great Almighty, the author of knowledge and wisdom, for his countless support.

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APPENDICES

Table 4 :Calculation of CSI for Mahindra (1-10 scale)

Performance Indicators	Measures of the indicators	MIS	IW	MSS	CSI (IW*MSS)
Availability	Service frequency (number of runs per day) and service time	8.0	0.09	8.7	0.82
Service Reliability	Regularity of the service	6.7	0.08	7.1	0.56
Accessibility	How easily user can get form their houses	7.0	0.08	7.5	0.62
Service coverage	No of stops and distance between stops	6.0	0.07	6.8	0.48
Information	access to information like schedule, ticket cost	5.8	0.07	3.4	0.23
Cleanliness	Internal and external cleanliness of vehicles	4.9	0.06	6.9	0.40
Comfort on trip	passenger personal comfort while transit is used including seat comfort, ride comfort	5.0	0.06	5.0	0.29
Safety	No of accident and security concerns personal against crimes	7.2	0.08	6.4	0.54
Pollution	Pollution creates by vehicle	7.4	0.09	5.8	0.50
Parking System	No of parking lots and the service quality	8.0	0.09	3.2	0.30
Behavior of driver	One of the services of public transport.	4.5	0.05	7.2	0.38
Efficiency	Travel time and journey speed	6.8	0.08	4.7	0.37
Affordable Fare	affordability of per capita Fare	8.0	0.09	3.8	0.36
	Total CSI				5.84

Source: Author, 2016

ASSESSMENT ON VOLUME STUDY OF PUBLIC TRANSPORTATION SYSTEM OF KHULNA- CITY ROAD, BANGLADESH: A CASE STUDY OF BOYRA TO SHIB-BARI MOR MIDBLOCK

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ABSTRACT

Traffic volume is a very important parameter in majority of the transportation planning applications. This paper attempts to gain insights into the traffic volume and its effect on public transport system. For this reason a traffic volume study has been conducted from Boyra to Shib-Bari Mor of Khulna- city road. In this study, volume of the road section has been determined through video analysis method and is represented by Passenger Car Unit (PCU). The collected data is analyzed to identify the congestion phenomenon during peak and off-peak period on weekdays and weekends. The volume to capacity (V/C) ratio identified for the section "Boyra-Joragate" is mor than 0.62, which is found to be the highest comparing with other sections (V/C in between 0.30 to 0.35) during the peak period of weekdays. Finally, the Level of service (LOS) for this road section is also determined along with the formal and informal parking of the road. Proposals like; reduction of conflicting points, provision of off-street parking; would be some potential solutions to increase the efficiency of this section of road.

Keywords: *Volume, Capacity, Level of service, Assessment, Conflict Points*

1. INTRODUCTION

Khulna is one of the divisional cities of Bangladesh with a land area of 45.65 km^2. It has a road network of 1231 km (Hossain et al., 2005) here Khulna- city road is about 106.25km (50 - Roads and Railway Division, 2013). For increasing efficiency of this city road and to provide better means to utilize other roads linked to this city road a traffic volume study was necessary. Morover, a volume study survey can also be helpful in impact analysis of this road and determining need for traffic control system.

The volume study survey was being conducted from Boyra to Shib-bari mor on Khulna-city road in two different spots at 3 peak period and 2 off peak period on both weekday and weekend. It was performed through indirect method in which vehicle movements were captured by camera and counted by categorizing them. It is a permanent method and so the collected data can be used to monitor and evaluate traffic volumes and trends over a long period of time (Traffic Volume Counts). In this study, Passenger Car Unit of different vehicles represents the volume across the road sections and Passenger Car Equivalent Unit represents the road capacity where Dhaka Urban Transport Study is used as standard but in general the design capacity of urban arterial road is 1400 PCU/lane/hour (Sharmeen et al., 2012). Major finding of this study is determining the Level of service (LOS) of the roads through Volume-Capacity ratio (Boarnet et al., 1998). The objective of this study is to assess the existing volume condition of the roads and reducing the number of conflict points and also to increase road life by controlling excessive volume of vehicles.

Due to rapid growth of urbanization there is a major influence on transportation sectors in terms of major traffic characteristics such as increasing volume, city road capacity and level of service etc. Traffic volume is an important measure of magnitude, composition, and time and route distribution of volume. Volume by definition is the total number of vehicles that pass over a given point or section of a lane or roadway during a given time interval (Nuzhat Nueery Haque et al., 2013). One of the main design parameter of road, "average annual daily traffic" can be obtained through dividing summation of daily traffic count in one year by 365 (Roads Department, 2004).

Since roads have certain width with varying lanes, flow is always defined in terms of width, ADT, termed as average daily traffic, implies the road capacity which is considered as a function of traffic and road geometrics. To express city road capacity the Passenger Car Unit (PCU) or Passenger Car Equivalent (PCE) is used which is termed to be the universally adopted unit for measuring traffic volume or capacity (Pothula Sanyasi Naidu, 2015).

Case Study on Development of Passenger Car Unit in NAL STOP, PUNE shows that the PCU value of each vehicle is not a constant but varies with several factors such as proportion of other classes, level of service and volume to capacity (Patil, 2015).

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 manoeuvre, traffic interruptions, and comfort and convenience and six LOS which are defined for each type of facility that has analysis procedures available (Singh et al. 1991).

Percentage Speed Reduction (PSR) from Free Flow Speed (FFS) can be identified as a performance measure for LOS assessment on urban arterials which has been analysed from the Case Study on the Assessment of Level of service on Urban Arterials in Kolkata (Subhadip Biswas, 2016).

2. METHODOLOGY

2.1 Study Area

The study area is located in Khulna-Jossore City road and the surveyed area was Boera to Shibbari mor. The total road is almost 2.2 KM. The study area is about 1.2 KM and 1.3 KM from Dakbanglo mor and Sonadanga mor respectively. The land use along the road is residential use (32%) and commercial use (16%). Common traffic control systems, stopping point, roundabout, speed breaker and signal are introduced in the area. There are three major intersection, Boyra mor, Joragate mor and Shibbari mor.

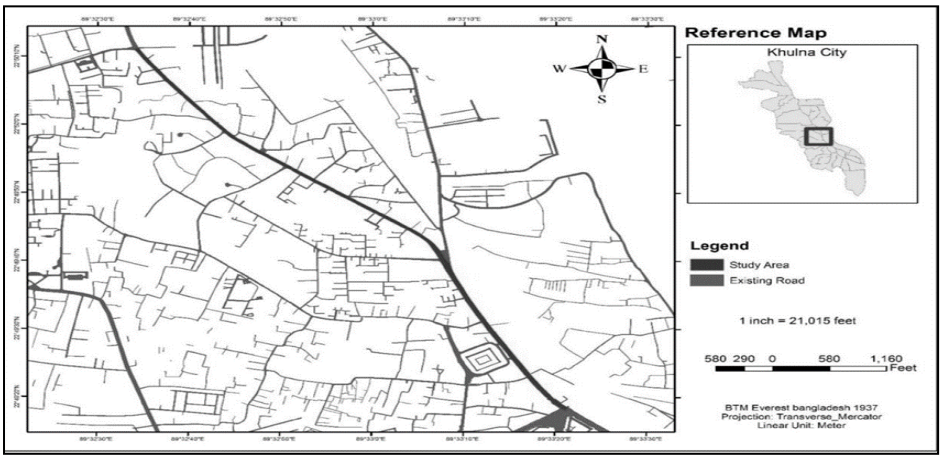

Figure 1: Study Area Map

2.2 Methods

A theoretical framework was developed from the understanding of operational features of the selected study area, relevant volume and speed studies. In the operational features of the study area, considered elements were: right of way, carriage way, median, lane numbers, footpaths, and driveways. Volume, speed and delay studies along with road capacity and LOS have considerable influence on theoretical assessment of public transport.

After conceptualization, the survey strategy was developed. The survey covered questionnaires of different user groups, checklist of existing roadway facilities and user rating survey. Three (3) questioner survey forms were developed addressing general users, drivers and traffic policies.

Additional data was collected from both primary and secondary sources. Primary data focused on physical features of roadway, vehicle speed and volume data. Directional vehicle volume data was collected by using video camera at selected nodes. The selected nodes were in front of Passport Office near Boyra mor and near Joragate mor. Speed data was collected using different test vehicles at a specified roadway segment. Vehicle speed of peak and off-peak hours were calculated and compared. The survey was conducted on two weekdays at 5 different times (3 peak times and 2 off-peak times). Secondary data covered technical sources which were basically the standards of Rajdhani Unnayan Kartripakkha (RAJUK), Khulna Development Authority (KDA), and Khulna City Corporation (KCC).

The primary data was used to calculate LOS which may be helpful to plan to reduce the conflict points and secondary data was used to compare those results with the national standards so that mor facilities can be added to increase road life.

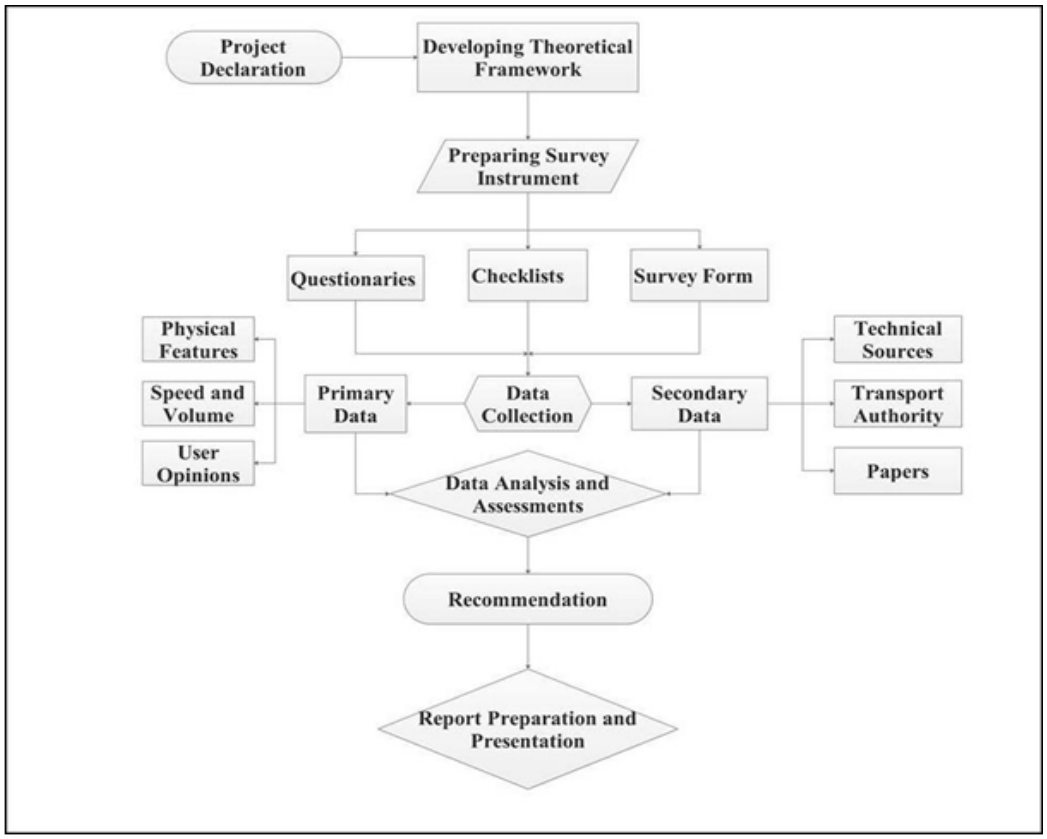

Figure 2: Methodology for Flow Chart

3. ANALYSIS

3.1 Volume:

Table 1: Vehicles according to direction in Weekdays

Vehicles	Baira-Joragate		Joragate-Boyra		Joragate-Shibbari		Shibbari-Joragate	
	Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Truck	4.2	9.3	4.9	9.4	3.2	7.3	6.6	8.7
Bus	5.0	5.2	6.2	4.6	5.5	4.8	4.8	4.1
Mini-Truck	3.1	7.3	3.9	7.4	5.6	8.0	1.3	7.7
Car	8.9	5.0	11.1	3.8	15.1	6.7	17.6	4.1
Mahendra	41.5	24.1	29.6	33.0	24.8	27.6	23.7	27.9
Easy bike	14.6	23.6	20.4	20.5	17.3	24.6	16.1	26.0
CNG	2.5	3.5	3.7	3.0	9.8	3.5	6.1	2.8
Bike	11.1	11.4	8.6	11.2	8.1	7.2	11.1	10.9
Rickshaw	3.1	3.9	5.0	3.1	5.2	3.8	5.9	3.5
Cycle	3.7	3.9	3.5	2.8	2.5	3.2	4.7	2.9
Van	2.2	2.8	3.0	1.1	2.9	3.2	2.1	1.2

Table 1 and Table 2 show that the volume of the study area varied on the weekdays and weekends and even in the day long. The volume study was surveyed in two different spot at 3 peak periods and 2 off peak periods on both weekdays and weekends. In Boyra College Mor to Joragate section, Mahendra occupied 41.5% of volume moving towards Joragate and 29.6% towards Boyra College Mor in peak during weekdays. The number of Motorbike and Easybike were highest after the number of Mahendra. Mahendra had the highest Passenger Car Unit of the particular section in both directions. Percentage of PCU for van was 2.2 % which is the lowest among all type of vehicles. The volume of the area towards Joragate was approximately 1145 PCU/hr and toward Boyra College Mor was almost 1000 PCU/hr.
On the other hand, on off peak period, Mahendra and Easybike generated the highest volume towards Joragate Mor which was 24.1% and 23.6% respectively. The volume of Mahendra was the highest (33%) towards Boyra College Mor. In weekend, the volume was lower compared to weekdays which is clear from the Table 2 below.

Table 2: Vehicles according to direction in Weekends

Vehicles	Baira-Joragate		Joragate-Boyra		Joragate-Shibbari		Shibbari-Joragate	
	Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Truck	7.8	8.9	6.4	7.2	2.6	4.9	2.5	5.5
Bus	4.1	1.7	2.5	2.5	3.4	2.4	4.4	4.7
Mini-Truck	2.4	2.1	1.5	2.9	9.3	6.9	3.1	4.6
Car	6.7	11.0	10.6	6.4	15.5	8.3	19.2	9.5
Mahendra	31.0	26.9	32.5	34.4	29.3	24.7	29.6	26.2
Easy bike	21.1	19.7	21.0	16.5	12.0	26.9	15.5	25.3
CNG	5.8	11.1	3.4	8.2	11.1	3.9	7.4	3.9
Bike	10.2	10.1	9.3	9.7	6.3	10.9	6.8	9.9
Rickshaw	4.3	2.8	6.0	5.1	6.2	5.8	6.1	5.6
Cycle	2.9	2.1	3.0	2.6	2.1	2.0	2.8	2.1
Van	3.6	3.5	3.8	4.4	2.3	3.2	2.7	2.7

In the Joragate-Shibbari section, the nature of occupied volume was the same as the Boyra College mor to Joragate section. In both section, the number and volume of mahendra was highest in both direction. Van and in some cases bicycle occupied the lowest volume of total volume.

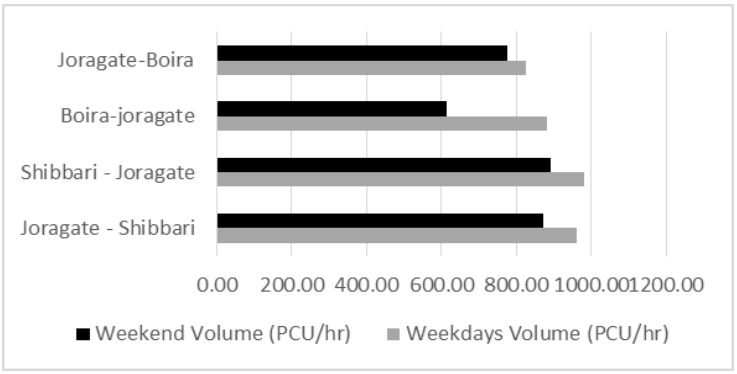

Figure 2: Peak Period Volume Variation in Weekdays and Weekends

Figure 3 implies that peak period volume of vehicles in weekdays was greater than the volume in weekends. There are two residential area near the road within 3 KM which generates the flow of public vehicles.

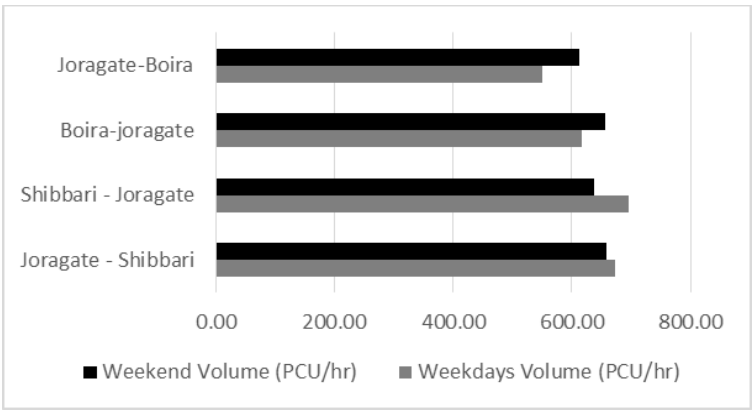

Figure 3: Off Peak Period Volume Variation in Weekdays and Weekends

From figure 4 it is clear that in off peak period, the volume of vehicles in weekend was greater than the volume of weekdays in the Joragate to Boyra College Mor section and the volume of vehicles in weekend is lower than the volume in weekdays in the Shibbari to Joragate section. The volume from two residential area added with the volume in Joragate intersection.

3.2 Volume Capacity Ratio

To identify the level of service it was needed to calculate the volume capacity ratio. Figure 5 refers that in peak period the volume capacity ratio of Boyra College Mor to Joragate direction is 0.63 in weekdays. All the directions having the ratio lower than 0.60 indicated LOS A as LOS can be measured through speed range or volume capacity ratio. Such as if the speed is >=80kph or the volume capacity ratio is <=.60 then the required LOS will be LOAS A. These road had free flow in both direction.

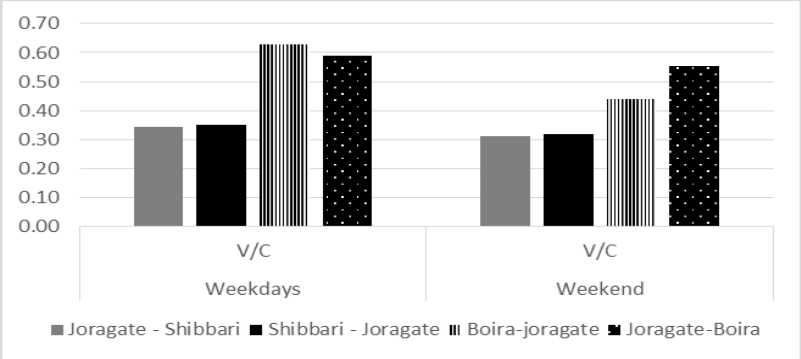

Figure 4: Peak Period Volume Capacity Ratio in Different Section.

The Level of service in Boyra College Mor to Joragate direction in weekdays was LOS B and reasonably free flow in that specific direction.

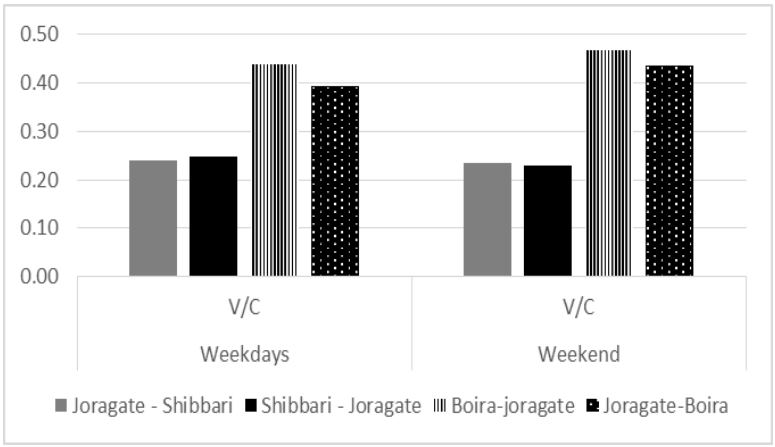

Figure 5: Off Peak Period Volume Capacity Ratio in Different Section.

Figure 6 shows that in off peak period the result shows that the Volume Capacity Ratio is less than 0.60 which indicates that the section had LOS A and they had free flow in all directions. Volume capacity ratio and spot speed ratio was used to determine the level of service of the road section.

3.3 Capacity and Level of service

It is observed that Shibbari mor to Joragate and Boyra College mor to Joragate respectively consist of two lane and one lane. The capacity of each lane is 1400 PCU/hr/lane according to Dhaka Integrated Transport Study, 1994.

Table 3: Volume and Level of service according to direction in Peak Period

Direction	Weekdays				Weekend			
	Volume (PCU/hr)	Capacity (PCU/hr/lane)	V/C	LOS	Volume (PCU/hr)	Capacity (PCU/hr/lane)	V/C	LOS
Joragate - Shibbari	959.58	2800	0.34	A	870.23	2800	0.31	A
Shibbari - Joragate	979.63	2800	0.35	A	890.70	2800	0.32	A
Boyra-joragate	881.82	1400	0.63	B	613.73	1400	0.44	A
Joragate-Boyra	824.75	1400	0.59	A	774.47	1400	0.55	A

The volume capacity ratio of all direction except the Boyra College mor to Joragate mor direction are lower than 0.60. This indicates that all the directional flow have level of service A which represents free flow conditions. Only the geometric design features of the city road may limit the speed of the car. Comfort and convenience levels for road users are very high as vehicles have almost complete freedom to maneuver. Only the Boyra College mor to Joragate direction have level of service B. This represents reasonable free-flow conditions. Comfort and convenience levels for road users are still relatively high as vehicles have only slightly reduced freedom to maneuver.

Table 4: Volume and Level of service according to direction in Off-Peak Period

Direction	**Weekdays**				**Weekend**			
	Volume (PCU/hr)	Capacity (PCU/hr/lane)	V/C	LOS	Volume (PCU/hr)	Capacity (PCU/hr/lane)	V/C	LOS
Joragate - Shibbari	673.33	2800	0.24	A	657.60	2800	0.23	A
Shibbari - Joragate	695.60	2800	0.25	A	638.40	2800	0.23	A
Boyra-joragate	615.87	1400	0.44	A	656.40	1400	0.47	A
Joragate-Boyra	550.97	1400	0.39	A	611.83	1400	0.44	A

In off-peak period, all the directional flow shows that the level of service is A. This represents free flow conditions where traffic flow is virtually zero. Only the geometric design features of the city road may limit the speed of the car. Comfort and convenience levels for road users are very high as vehicles have almost complete freedom to maneuver.

3.4 Parking

The informal on street parking are seen in various places of the study area. The left of the starting of the boyar bazar road is informally used for Easybike parking. Morover there is a driveway in front of Newmarket where car, Rickshaw and various other vehicles are being parked. At Shib-bari mor the opposite road lane of KDA Building is used as on street parking space in some extent.

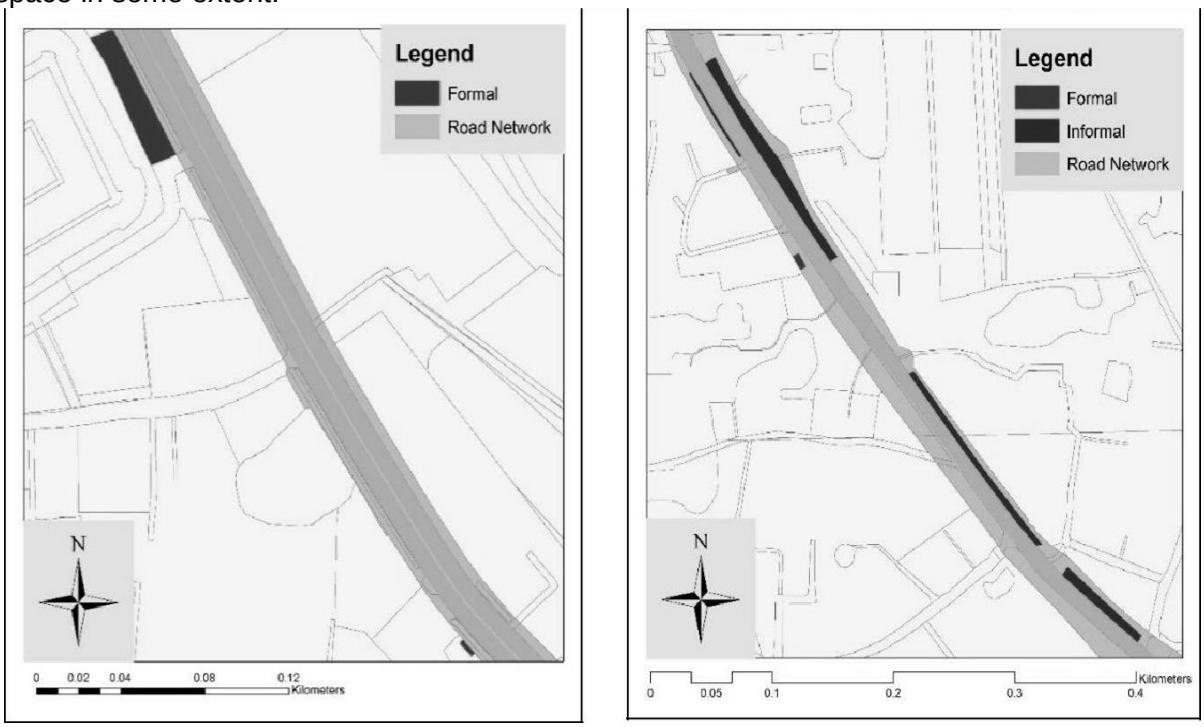

Figure 6: Parking facilities in Khulna Jessore City road

3.4.1 Conflicts point at intersection

The road intersections are a most significant component of a road where different type of vehicles merge into or diverge from the major road to minor road. This merging and diverging causes conflict at the intersections and sometimes it causes accidents. So it is a vital issue to maintain the traffic movement at these intersection points manually or in a signalized way.

There is three major intersection in study area (Boyra to Shibbari mor) which are:

- A T shape intersection at Boyra which connects another major road heading towards Boyra to Shonadanga.
- A Y shape or skewed intersection at Joragate which connects Khalishpur residential are road to this major area.
- Intersection at Shibbari mor links 3 road which is connected to Moylapota, Shonadanga and Dakbanglo road.

Here, all three are very important intersection where a huge no. of vehicles diverges and merges into the Khulna-city road and affect the traffic behavior of this road.

3.4.1.1 Conflict points at Boyra road intersection and Joragate road intersection

Boyra intersection is the lowest merge diverging point overall. Basically mahendra and easy bikes are observed mosty in this point. There are 9 conflicting points overall among them 3 are merging and 3 are diverging points which describes the accident potential for this intersection.

Next is Joragate Road intersection which is a skewed intersection and a very complex intersection point. There is a fuel station which causes frequent divergence in vehicular movement which is directed to south. Among 9 conflicting points 3 are diverging and 3 are merging points. Accident potential is similar to Boyra point in respect of the number of conflict points. As it is not signalized intersection “Inappropriate intersection traffic control, vehicle conflicts with non-motorists, misjudgement of gaps in traffics” occur daily.

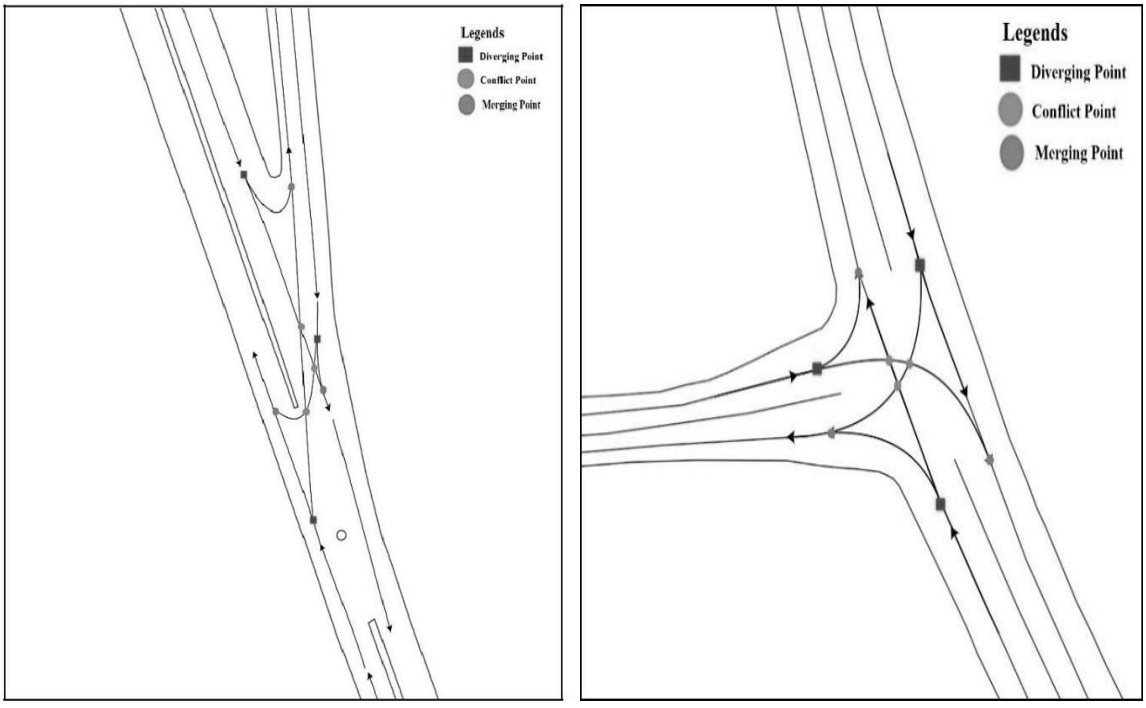

Figure 8: Conflict points at Joragate and Boyra intersection

3.4.1.2 Conflict points at Shibbari mor Intersection

Due to the location of many commercial, institutional activities and road pattern it can be categorized complex intersection. Highest number of vehicle among all these three intersections runs through this section. There are 7 diverging points and 8 merging points whereas total conflict points are 31. These large number of conflict points provide drivers complicated driving situation which lead to make them mor mistakes and even to accidents. Morover Lack of signal system, informal parking increases the congestion risk, provides inadequate guidance for motorist, lead to poor operational performance.

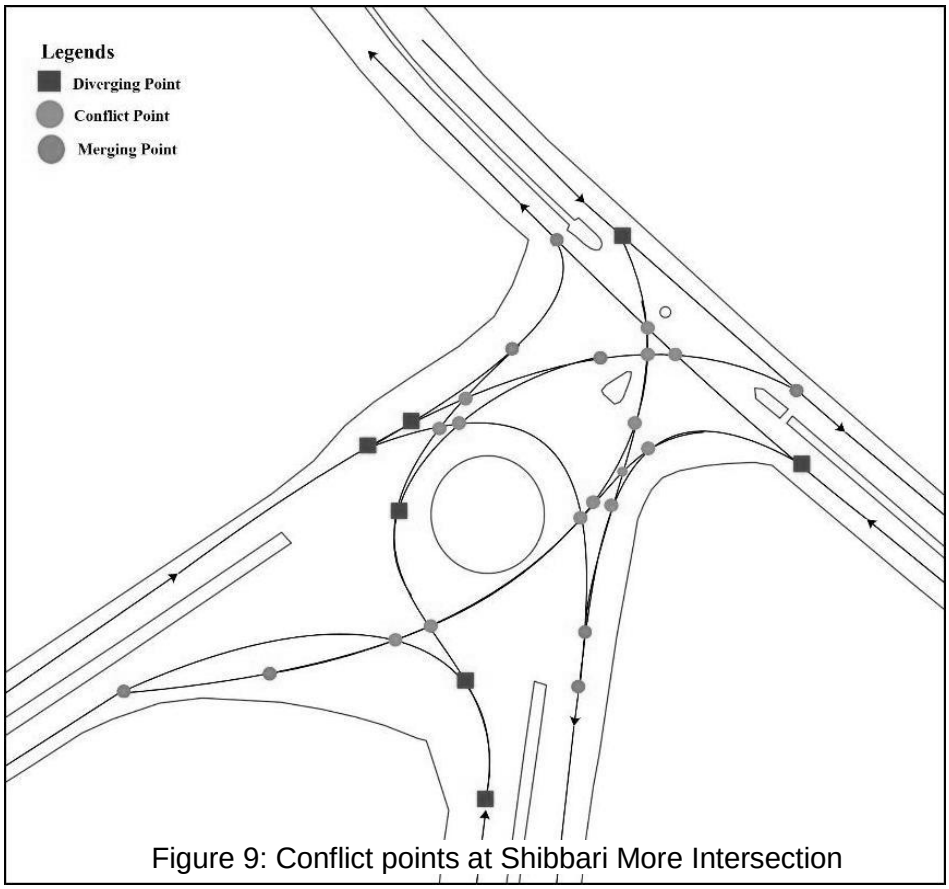

Figure 9: Conflict points at Shibbari More Intersection

3.5 Recommendation

All the solution and proposals will be provided through this section.

3.5.1 Reduction of conflict points at Boyra mor Intersection

In the Boyra College mor, the intersection was a three-leg intersection. From the field survey it was observed that through vehicles and right turning vehicles were not high in that Intersection. If it is required in the future to reduce the right turn conflicts, two U-turn can be constructed along the Boyra-Newmarket road. From field survey, space required to do so was found available. All the vehicles coming from Daulatpur can take a U-turn at 450 feet ahead from the intersection. The vehicles from Boyra direction will also be forced to go through and after 450 feet there will be a U-turn for the vehicles taking right turns to Khulna. On the both U-turn, yield sign should be used to reduce the speed of vehicles to diverge and merge the vehicles with upstream and downstream flow.

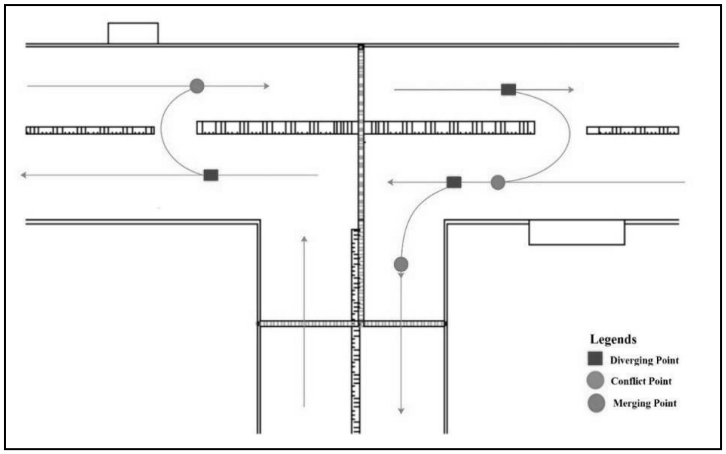

Figure 10: Reduction of Conflict Points at Boyra Mor

3.5.2 Reduction of conflict points at Joragate mor Intersection

In Joragete, the intersection is skewed Y shape. The vehicles from Shibbari mor toward Khalishpur will take a U-turn at 450 feet ahead from the intersection. There will be a channelized island which separate the flow from Boyra College Mor into two different direction. A median is proposed to prevent the vehicles to take right turn in the intersection. Number of conflict points has been reduced from 9 to 4 which is very effective to reduce accident rate in this intersection and to ensure safety.

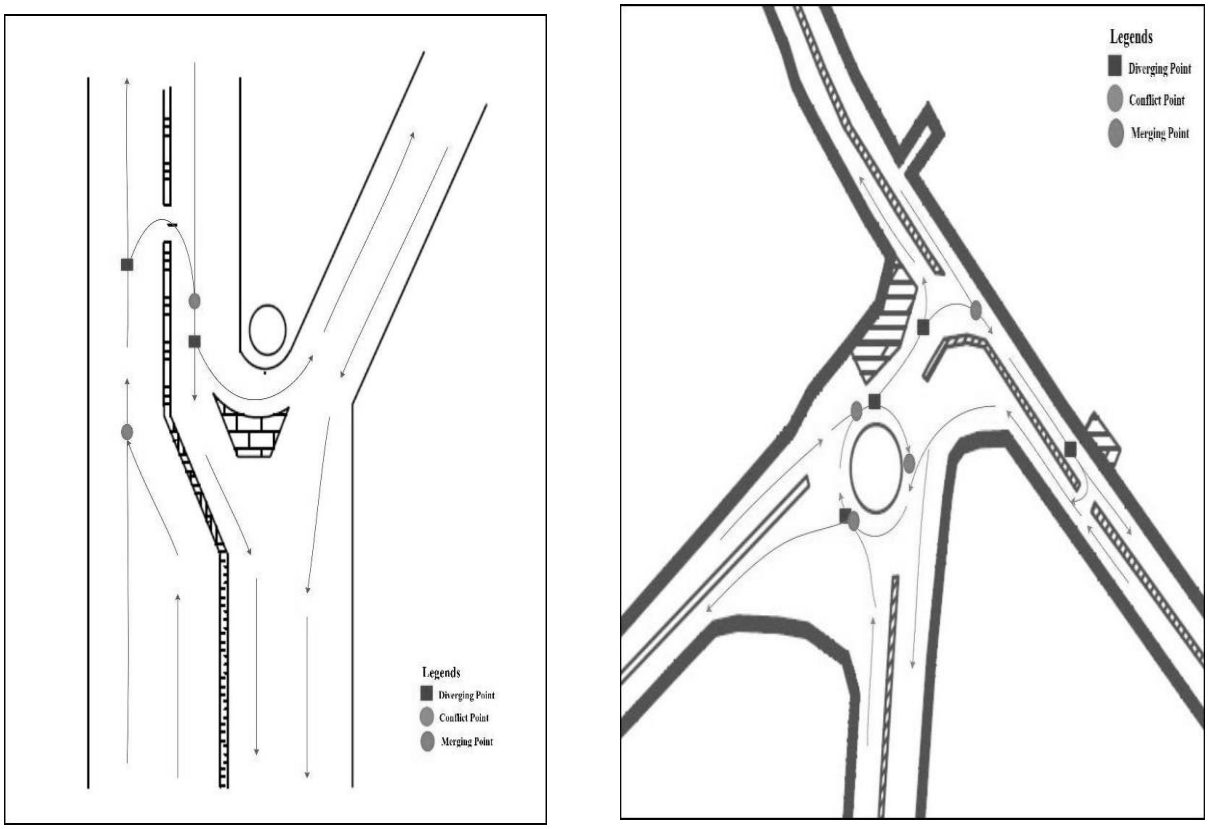

Figure 11: Reduction of Conflict Points at Joragate Mor and Shib-Bari Mor

3.5.3 Reduction of conflict points at Shibbari mor Intersection

Shibbari mor is required as the most congested junction of the study area due to informal parking. To reduce conflict points at this mor traffic flow has been channelized directed towards roundabout coming from Dakbanglo mor through extending the median which is clear from the image below. Furthermor a “U” turn is provided to avoid confliction between the flows coming from Moylapota to Dakbanglo and flows coming from Dakbanglo to moylapota. Previously number of conflict points were 31 which has been reduced to points through changing the pattern of median and providing median.

3.5.4 Providing median between two way roads

In the study area from Boyra to Joragate intersection there are no medians. In most of the cases accidents occur due to head to head collision. So in order to reduce the accidents medians should be provided in the area

3.5.5 Introducing digital traffic signals

The major intersection in this road are free flow driveways. The overall traffic management system is informal in type. To start a formal traffic management system signalized traffic system is needed. Though some signalized traffic are seen at the town side but most of them are not operational. So two way auto signalized traffic system needs to be installed at every intersection. Improving the quality of road markings. In the study area very few road markings were found. Among the present road markings most of the road markings were not visible clearly.

3.5.6 Establishing mor road signs

In the study area the amount of road sings were insufficient. For the convenience of both drivers and pedestrians the road sings should be newly established at necessary intervals.

3.5.7 Providing off street parking

Off-street parking bays must be introduced specially for the public transports in order to reduce the amount of on-street parking and thus reduce the congestion of the road.

3.5.8 Separating lanes for motorized and non-motorized vehicles

In order to increase the regular speed of motorized vehicles in the study area the lanes for motorized and non-motorized vehicles should be separated.

3.5.9 Providing regular monitoring

Regular monitoring includes, checking driving license regularly, banning wrong way traffic flow and assigning traffic police in regular intervals.

4. CONCLUSIONS

The main objective of the paper was to assess the operational features of public transport and volume study of different types of vehicles in Khulna-city road. The paper contains different information’s about volume study of the study area from Boyra to Shibbari mor. The main finding of the paper was that the volume capacity ratio of all direction except the Boira College mor to Joragate mor direction are lower than 0.60. This indicates that all the directional flow have level of service A which represents free flow conditions. From the analysis of the data and information it was found that the present condition was not satisfactory. The number of conflicting points were mor and as a result of which the free flowing movement of vehicles were hampered. Some important recommendations were mentioned in order to solve the current problems and provide the pedestrians and drivers with improved facilities.

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USE OF CRUMB RUBBER IN FLEXIBLE PAVEMENTS

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ABSTRACT

In the modern era, nationwide connectivity is a precondition for the economic and social development. In Bangladesh, flexible pavements count about 98% of paved roads. But these conventional bituminous pavements are highly susceptible to moisture damage, temperature variation and need routine maintenance. So, conventional bitumen modification is a crying need. Bangladesh generates about 90000 tons of non-biodegradable waste tires annually which creates a huge environmental problem. But this waste tires can effectively be incorporated with neat bitumen to make bituminous roads durable, less susceptible to temperature variation and highly resistant to moisture induced damage. Marshall mix design method was used to evaluate the performance of neat bitumen and crumb rubber modified bitumen (CRMB) mixtures whether they meet mix design requirements or not. Water sensitivity analysis was done for both bituminous sample. Loss of stability due to waterlogging was investigated by retained stability test. Resistance to lower temperature cracking and rutting was investigated by indirect tensile strength test. Stripping due to frost and thawing action was investigated by moisture induced damage test. After conducting all tests, it can be concluded that CRMB showed higher softening point and lower stripping value. Water sensitivity tests indicate modified bituminous mixes showed higher resistance to moisture induced damage, lower temperature cracking and rutting which in turn alludes less maintenance work is needed for CRMB road. So, it can be said that CRMB is a sustainable solution for durable and efficient road construction in Bangladesh considering economically and environmentally.

Keywords:*Flexible pavement, Water sensitivity, Temperature variation, Waste tire, Sustainable Development*

1. INTRODUCTION

Approximately 1.5 billion tires are produced globally in each year which will normally enter the stream of waste representing a major potential waste and environmental problem (Williams, 2013). In Bangladesh waste tire generation of each year is about 90000 tons (BBS, 28 edition, 2008).One common way for disposal of these waste tires is land filling or dumping it in the waterbody. Tires are bulky and more than 75% of the space a tire occupies is void, so the land filling by waste tires has several major problems. Tires tend to rise in landfill and come to the surface of ground. Under the ground waste tires capture various types of gases such as methane which has natural tendency to burn suddenly with a vast explosion. If the waste tire is scattered on land in vain then it comes with rain water and may be a good place for breeding mosquitos or otherpathogenic bacteria. This causes harmful diseases to human beings and animals. Bangladesh is a country with vast variation in temperature and the amount of rain is not uniform over the year. About 98% paved roads in Bangladesh are bituminous flexible pavementand these roads get easily deteriorated due to high temperature susceptibility of the conventional bitumen used in Bangladesh. Water logging is an ever-increasing problem for Chittagong city and during waterlogging the roads get deteriorated due to lower resistance to moisture induced damage of the conventional bitumen used. Although road maintenance cost in Bangladesh is high but sufficient fund is not allotted for maintenance in the national budget. With an economic development rate of 6.5 % or more of GDP on average the number and capacity of vehicle is increasing very rapidly for increased import export activity within the country. Vehicles with ever increasing

carrying capacity require improvedheavy-duty roadsbut cannot be achieved with conventional bitumen. So, modification of conventional bitumen in a cost-effective manner is a crying need for Bangladesh. This problem can easily be solved by incorporating crumb rubber with bitumen to have the desired properties for flexible pavements of Bangladesh.

1.1 History of Using Crumb Rubber as a Modifier in Bituminous Pavement

Incorporation of crumb rubber with conventional bitumen has been practiced for more than a century. The first attempt was taken in early 1840s, which involved mixing of natural rubber with bitumen to improve the desired engineering properties. Modification process of bitumen by natural and synthetic rubber was introduced at early 1843 (Thompson, 1979). The modification process both by natural and synthetic got further improvement in 1923 (Isacsson and Lu 1999; Yildrim, 2007). Yildrim stated that the development of rubber-bitumenmaterials being used as joint sealers and patches began in the late 1930s. According to the study of Hanson, in 1950 the use of scrap tire in asphalt pavement was reported (Hanson,Foo, Brown& Denson 1994).

In 1960, Charlie Mac Donald reported successfull use of scrap tyre rubber asan additive in bitumen binder modification. He concluded that after mixing of crumb rubber with the neat bitumen and allowing it to blend for mixduration of 45 to 60 min, there were new materialproperties produced, which resulted in swelling in the sizeof the rubber particles at higher temperatures allowing forhigher concentrations of liquid bitumen contents in pavement mixes (Huffman,1980). In the mid-1980s, theEuropeans began the development of different polymers and additives for application in bitumen binder modification (Brule, 1996). In recent years, the use of crumb rubberhas gained interest in pavement modification and hasshown that crumb tyre rubber can improve the bitumenperformance properties (Brown,Jared, Jones& Watson 1997).It is reported that during thebitumen-rubber thermal blending, due to higher stiffness andtensile strength at elevated temperatures, the modified bitumen had decreased rutting capability (Palit,Sudhakar&Pandey, 2004).

2. MATERIALS USED IN INVESTIGATION

Crumb rubber collected from a local tire retreading shop near New market,Chittagong was used to modify 80/100 penetration graded asphalt obtained from Eastern refinery located also in Chittagong. The crumb rubber was generated byscraping old tires of automobiles. Crumb rubber passing ASTM 30 sieve andretained on ASTM 50 sievewas used for bitumen modification. Stone chips collected from local quarry in Chittagong were used as aggregates.Due to local practiceIRC, 81 specifications for aggregate gradation for 50-65 mm thick bituminous surface course was used in this investigation. Stone dust passing 0.075 mm sieve was taken as filler material. Apparent specific gravity of different types of aggregates were determined to use them in Marshall mix design.Physical properties of different types of aggregate are given in Table 1. The aggregate gradation chart is given below by Table 2 and gradation curve is shown in Figure 1.

Table 1: Physical Properties of Aggregates Used

Properties	Coarse aggregate	Fine aggregate	Filler material
Apparent Specific Gravity	2.71	2.64	2.86
Los Angles Abrasion %	21.4	_	_
Aggregate Impact value %	7.16	_	_
Water Absorption %	2	_	_
Combined Elongation and Flakiness index%	24.3	_	_

Table 2: Gradation of Aggregates Used

IS Sieve (mm)	% passing	Individual % retained by wt. of total agg. Passing	Individual retained (gm)
26.5	100	00	00
19.0	79-100	13.3	146
13.2	59-79	18	198
9.50	52-55	7.27	80
4.75	35-55	16.37	180
2.36	28-44	10	110
1.18	20-34	9	99
0.6	15-17	6	66
0.3	10-20	6	66
0.15	5-13	6	66
0.075	2-8	4	44

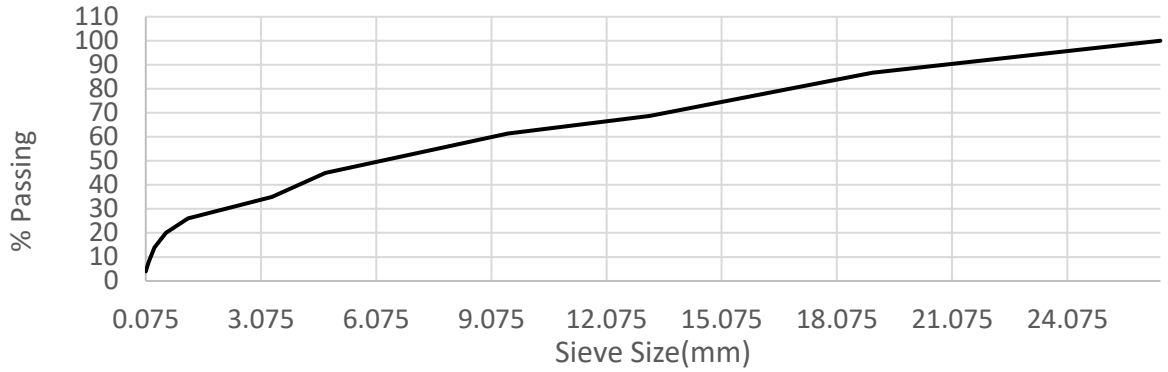

Figure 1: Aggregate Gradation Curve

2.1 Scrap Tire Grinding Process

Crumb rubber was produced by shredding waste tires, which is a material free of fibre and steel. Crumb rubber is normally designated by the mesh screen or sieve size through which it passes during the production process. To produce good quality crumb rubber, it is important to reduce the size of the tire powder to the required degree. There are generally two techniques to produce crumb rubber: ambient grinding and the cryogenic process (Becker, Mendez, Rodriguez,2001). The ambient grinding process can be divided into two methods: granulation and cracker mills. The ambient describes the temperature when the waste tyres rubber as its size is reduced. The scrap tire is loaded inside the crack mill or granulator at ambient temperature. Then the Crack mill reduces the scrap tire to powder. Cryogenic grinding is associated with application of liquid nitrogen to make the scrap tire solid to make it easy to turn it into powder.The cryogenic grinding is a cleaner, slightly faster operation resulting in production of fine mesh size, but the high cost of this process is a disadvantage due tothe added cost of liquid nitrogen. The process is also dangerous as it is related with the handling of liquid nitrogen. Ambient grinding is more popular in the crumb rubber production industry.

3. METHODOLGY

3.1 Preparation of Crumb Rubber Modified Bitumen

There are different methods for blending crumb rubber with bitumen. Among the different specification developed the specifications developed by Palit 2001 were used for blending crumb rubber with asphalt. In this process, 80/100 penetrationgrade asphalt was heated to 160°C in the mixing machine before crumb rubber was added andwas mixed at low speed

for about 5 min. Then 0.5 kg crumb rubber was added with 5 kg neat bitumen to get the optimum result (Issa, 2016). The mixture was heated to 170°C to 175°C and agitated vigorously for about 40 to 45 minute using a mechanical stirrer operated at 2,000 rpm.After 40 to 45 minute the developed modified bitumen was removed from the mixing machine and kept in a sealed container after cooling to room temperature.

3.2 Determination of Optimum Binder Content

Marshall mix design method was used for both neat and modified bitumen to determine optimum binder content (OBC) and to check whether bituminous mixtures meet Marshall mix design requirements at OBC or not. Test results of Density-Void analysis and Stability-Flow analysis of Marshall mix design method are presented below by Figure 2and 3

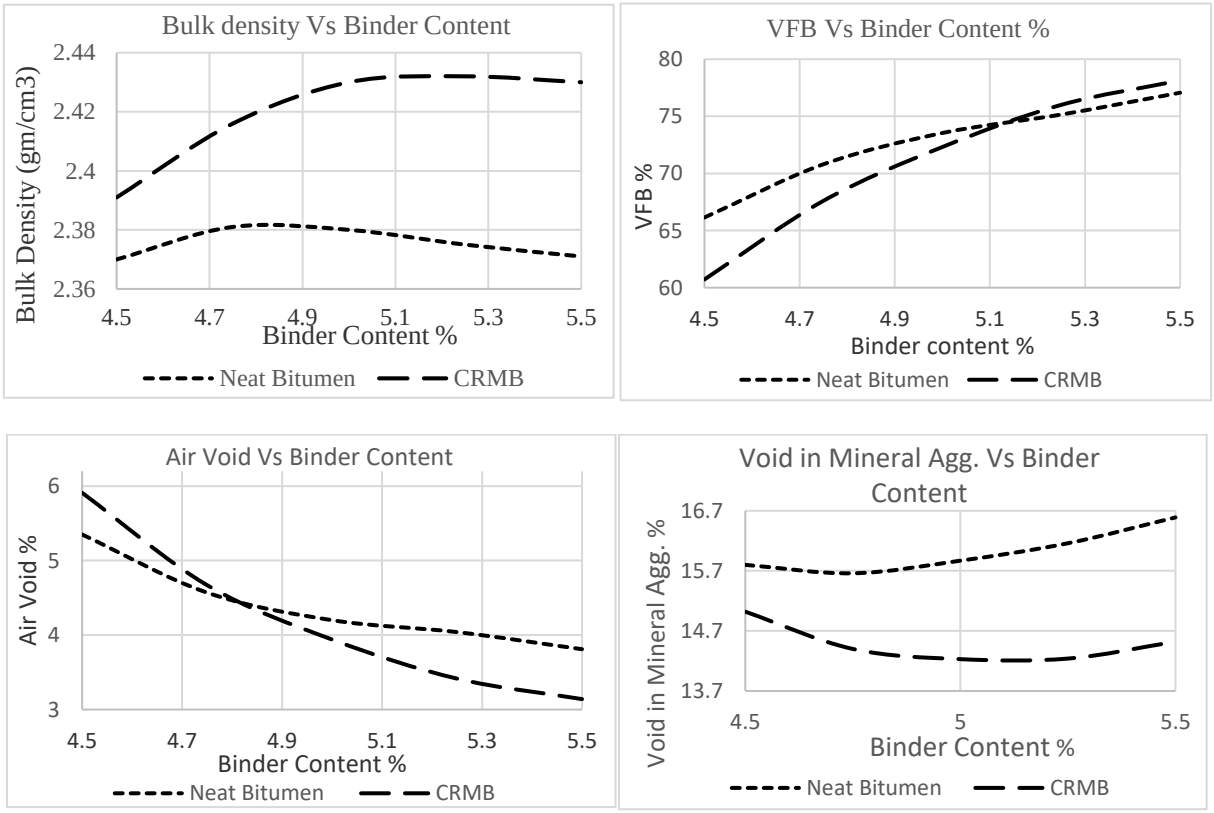

Figure 2: Density- Void Analysis

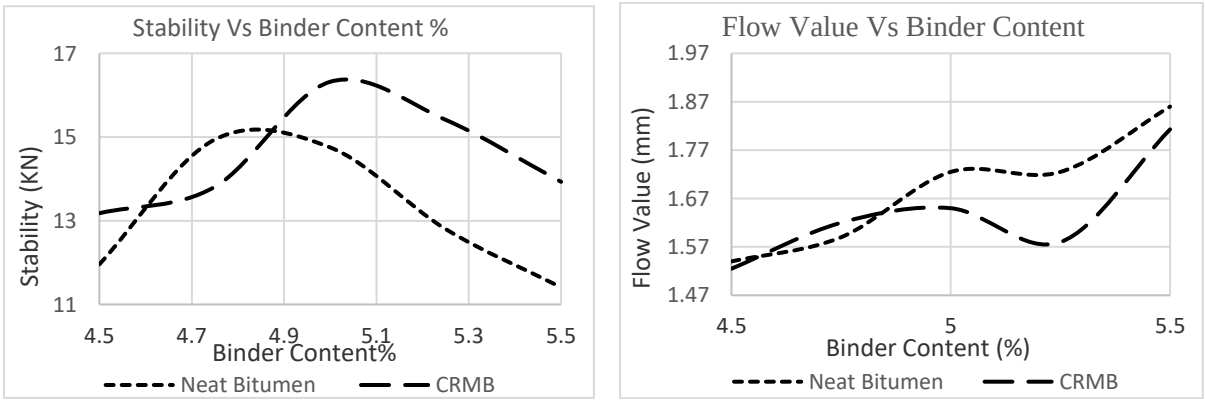

Figure 3: Stability- Flow Analysis

Marshall mix design test results ensured that both neat bitumen and CRMB met Marshall mix design requirements. Optimum binder content was determined 5% and 5.2% for neat bitumen and CRMB respectively. All other tests of sample were conducted at OBC for both types of bitumen.

Indirect Tensile Strength Test (IDT)

Tensile strength of flexible pavement is an indirect measure of resistance to rutting problem and lower temperature cracking. This test was done according to ASTM D 6931 specification. The tensile characteristics of bituminous mixtures were evaluated by loading the Marshall specimen along a diametric plane with a compressive load at a constant rate acting parallel to and along the vertical diametrical plane of the specimen through two opposite loading strips. The compressive load indirectly creates a tensile load in the horizontal direction of the sample. The peak load was recorded, and it was divided by appropriate geometrical factors to obtain the split tensile strength using the following equation(1)

$$S_t = [\frac{2000p}{\pi tD}]$$
(1)

Where,
S_t = IDT strength, kPa
p = maximum load, N
t = specimen height immediately before test, mm
D = specimen diameter, mm

The results can also be used to determine the resistance to field moisture of flexible pavement when results are obtained on both water conditioned and unconditioned specimens.A total of 06 specimenswere prepared. The first group (3 specimens) was immersed in a water bath at 60˚C, for a period of 24 hours (conditioned samples). The samples were then removed from the water bath and kept at a temperature of 25˚C for a period of 2 hours. Other set (3 specimens) of samples (unconditioned samples) were kept at a temperature of 25˚C for a period of 2 hours without soaking. These specimens were then mounted on the conventional Marshall testing apparatus and loaded at a deformation rate of 51mm/min and the load at failure was recorded at each case. The tensile strength(St) of water conditioned as well as unconditioned specimen was determined. Finally, tensile strength ratio(TSR)was calculated for both neat and modified bitumen by equation (2). Bitumen having higher TSR value is more resistant to damage due to moisture. The higher the tensile strength of a bitumen, the more it is resistant to rutting and lower temperature cracking.

$$TSR = [\frac{St(conditioned)}{St(unconditioned)}] \quad ` \quad (2)$$

3.4 Retained Marshall Stability Test

Loss of stability due to immersion of flexible pavement under water was determined by ASTM D 1075.At least six Marshall compacted specimens, three for conditioned and three for unconditioned sample of both neat and modified bitumen were required. The specimens were at the optimum binder content and designed gradation.Density and air voids of each specimen was determined. Three samples were set at room temperature and three samples in a water bath at 60°C for 24 hours. Normal stability tests were run on each sample and the average results for each set was taken. The three standard specimens were conditioned at the end of a 24hour waiting period. Retained stability was calculated by the equation (3). Bitumen having higher retained stability value is more resistant to damage of road stability due to immersion under water.

$$Retained\ Stability\ \% = [\frac{Conditioned\ Stability}{Unconditioned\ Stability}]\text{x}100 \quad (3)$$

3.5 Moisture Induced Damage Test

Damage of flexible pavement due to freezing-thawing action was determined by moisture induced damage test according to AASHTO T 283 Specification. The test was carried on two sets of Marshall samples having air void between 6% and 8%. The samples were divided into two sets: the first setwas the control group, or "unconditioned", while the second set, or "conditioned", was vacuum saturated by 70-80 percent (AASHTO T283-03) with water and then placed in a freezer at 0º F for 16 to 18 hours. The conditioned specimens were then placed in a water bath at 140º F for 24 hours. After the freeze-thaw conditioning was done, the indirect tensile strength (S_t) was measured. The tensile strength of "conditioned" sample S_t(Conditioned) was compared to the tensile strength of "unconditioned" sample S_t(unconditioned) to determine tensile strength ratio (TSR) similar to equation (2). Bitumen having more TSR value is more resistant to moisture induced damage including freezing-thawing condition.

4. RESULTS

The different physical properties testsof both the neat and modified bitumen were conducted according to ASTM specifications. Theproperty testresults of both neat and modified bitumen are shown below by table 3

Table 3: Physical Properties of Bitumen Used

Name of Property Test	Neat Bitumen	Crumb Rubber Modified Bitumen
Specific Gravity	1.02	1.018
Penetration (1/10 th of mm)	91	73
Ductility(cm)	75	56
Softening point (°C)	43	46
Flash point and Fire point (°C)	321 and 342	320 and 340
Stripping Value (%)	01	00

The Marshall mix design test results at OBC for both neat and modified bitumen are shown below by table 4

Table 4: Comparison of Marshall Test Result at OBC

Bitumen type	Stability (KN)	Bulk Density (gm/cm^3)	% air void	Flow Value (mm)	Volume of Bitumen %	Void In mineral agg%	Void filled with asphalt %
Neat Bitumen	14.80	2.382	4.10	1.6	11.676	15.78	73.98
CRMB	16.60	2.43	3.67	1.5	12.293	15.97	76.97

The indirect tensile test results for both neat and modified bitumen are shown in table 5

Table 5: IDT Test Results of Neat and Modified Bitumen

Bitumen type	S_t Unconditioned (Mpa)	S_t Conditioned (Mpa)	TSR
Neat Bitumen	0.425	0.364	0.86
CRMB	0.45	0.414	0.92

The retained stability test results for both neat and modified bitumen are shown in table 6

Table 6: Retained Stability Test Results of Neat and Modified Bitumen

Bitumen type	Marshall Stability Unconditioned (KN)	Marshall Stability conditioned (KN)	Retained Stability (%)
Neat Bitumen	14.80	13.27	89.66
CRMB	16.60	15.24	91.80

The moisture Induced damage test results for both neat and modified bitumen are shown in table 7

Table 7: Moisture Induced Damage Test Results of Neat and Modified Bitumen

Bitumen type	S_t Unconditioned (Mpa)	S_t Conditioned (Mpa)	TSR
Neat Bitumen	0.425	0.346	0.813
CRMB	0.45	0.407	0.906

From property tests results it was observed that 80/100 penetration graded neat bitumen showed penetration value 91, while modified bitumem showed penetration value of 73 which is similar to 60/70 penetration graded bitumen. The softening point of neat bitumen was 43°C, while 46°C was for modified bitumen. So, modified bitumen is more suitable with respect to global warming. Flash and fire point for both neat and modified bitumen are similar. Neat bitumen showed 1% stripping value while it was 0% for modified bitumen. So,modified bitumen is more resistent to damage due to water contact of flexible pavement. From Marshall test result at optimum binder content it was observed that modified bitumen showed 10.84 % more stability value than neat bitumen. With higher stability value modified bituminous road cancarry heavier traffic than neat bitumen. Modified bituminous Marshall sample showed higher bulk density and less air void than neat bituminous sample. High density and less air void reduces the chance of oxidation and moisture absorption. So, pavement failure for oxidation and moisture absorption is less for modified bituminous road than neat bitumen. From indirect tensile strength test the unconditioned samples of neat and modified bituminous sample showed test value of 0.425 mpa and 0.45 mpa respectively. As indirect tensile strength test is an indirect measure of resistence to damage of flexible pavement due to rutting and lower temperature cracking. So, due to higher indirect tensile strength modified bituminous roadsare more resistent to rutting and lower temperature cracking damage. Tensile strength ratio (TSR) for modified bitumen was6.5% more than neat bituminous sample. Due to higher TSR value modified bituminous roads are more resistent to reduction of tensile strength due to water contact than neat bituminous roads. From retained stability test value is 2.33% more for modified bituminous sample than neat bitumen. So, higher retained stabilty value of modified btumen indicates more resistent to loss of stability of road due to waterlogging of flexible pavements than neat bitumen. Tensile strength ratio(TSR) of modified bituminous sample obtained by moisture induced damage test was 9.3% more than neat bituminous sample. Due to higher TSR value of moisture induced damage test modified bituminous sample is more resistent to damage due to moisture induced damage including freezing- thawing action.

5. CONCLUSIONS

The experimental resultsand related information presented in this research leads to the following conclusions:

Crumb rubber modified (CRM) asphaltic road can carry heavier traffic than the conventional bituminous road. The bleeding problem of bituminous road during summer can be solved to a limited degree by using crumb rubber modified bitumen(CRMB). CRMB has enhanced adhesive characteristics and bonding property which indicates enhanced strength and durability.Crumb rubber modified asphaltic road has less chance of moisture absorptionwhich may lead to stripping of aggregate and subsequent chance of pavement failure. The chance of oxidation of bitumen by entrapped air which makes the bitumen brittle is also less for CRMB. CRM asphaltic road can withstand waterlogging more successfully than the conventional asphaltic road for a certain period. CRM asphaltic road is more resistant to lower temperature cracking than the conventional bituminous road. This means that roads constructed with CRMB will show less crack during winter season. CRM asphaltic roads are less susceptible to damage due to freezing and thawing condition than conventional bituminous road. This suggests that CRM asphaltic road can withstand extreme temperature variation more successfully. We can use CRMB as a replacement of 60/70 penetration graded bitumen as 80/100 penetration graded bitumen modified by crumb rubber shows properties similar to conventional 60/70 penetration graded bitumen. At the end,it can be said that CRMB is a sustainable solution for durable and efficient road construction in Bangladesh considering economically and environmentally.

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EXPLORING THE SIGNIFICANT IMPACTS ON WALKING BEHAVIOR OF THE URBAN POPULATION

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ABSTRACT

Walking is an important diurnal mode of travel and key parts of our urban transport systems. People start and end with a walk from the bus stop or train station to the final destination. Walking sometimes recognized to as active travel or active transport for healthy living. Getting more people in walking results to increase capacity, and reduce congestion, in the overall transport network. Besides, it would reduce environmental impact, improve public health and reduce healthcare costs, improve community well-being as well as social cohesion. The objective of the research was to depict the leading causes, which were responsible for declining the walking behavior of the Dhaka Metropolitan's dwellers. Total 400 survey data were collected from various points of Dhaka Metropolitan. Approximately 89% pedestrians believed that walking environment was unpleasant, nearly 82% thought the surface quality was poor and 86% believed they were unsafe at night. Although 66% preferred walking for short trip up to 1 km for traffic congestion. Traffic congestion could be reduced if authority takes the necessary steps to improve walking environments and safety.

Key Words:*Walking behavior, Traffic congestion, Environment, Safety*

1. INTRODUCTION

None of the world's megacities arises adjacent to Dhaka's population density, nearly 45,000 people are living per square kilometer with worst traffic congestion (Newgeography, 2012.). Being highly dense capital city, Dhaka is one of the slightest motorized cities in the world, only 2,630 vehicles per 100,000 population. The remarkable thing is that Dhaka has just 16.53% motorized vehicle, although it has a vast population(Rahaman, 2006). Dhaka continuing its unplanned growing with 7% roads, while a standard city has the least road requirement is 25%. Nearly 30% of 7.5% road is occupied by the hawkers, salesman, and shopkeepers. A substantial portion is also held by construction materials and waste-containers of the City Corporation which are responsible for the long queue of the vehicles (Habib, 2005).

Walking is a primary mode of transportation used for many purposes like going to work, going to school, recreation for most individuals. Walking is the sole means of conveyance in building interiors, public transit transfer stations, or shopping malls as short trips(National Household Travel Survey, 2009).A travel survey report for the city of Chicago depicts that the walking mode share was about 15% and 26% of total trips, respectively, for North Chicago and Central Chicago in 2008, which represents that walking demand becomes significant, especially in populated communities (Travel Inventory, 2010). Inappropriately designed walking amenities may fail to operate at acceptable levels when pedestrian demand exceeds the walkway capacity and reduce walkability(Zhang, 2012). Urbanites of Dhaka are greatly depended on foot about 60% of the total trips, while almost half of the remaining trips are on non-motorized vehicles(Rahman, 2006). The deficiencies of the significant crossing facility were responsible fornearly 77% of fatal pedestrian accidents in Dhaka Metropolitanin recent years(Pervaz, 2016). The objective of the research is to depict the significant causes, which have noticeable impacts on walking behavior of the Dhaka

Metropolitan's dwellers and suggest possible measures to improve walkability for healthy city livings.

2. METHODOLOGY

The main theme of this study is to find out the impacts of environmental, operational and behavioral deficiencies on walking behavior of the city dwellers. Shahbag the junction of new and old Dhaka, New Market, and Dhanmondihave beenselected as study area.

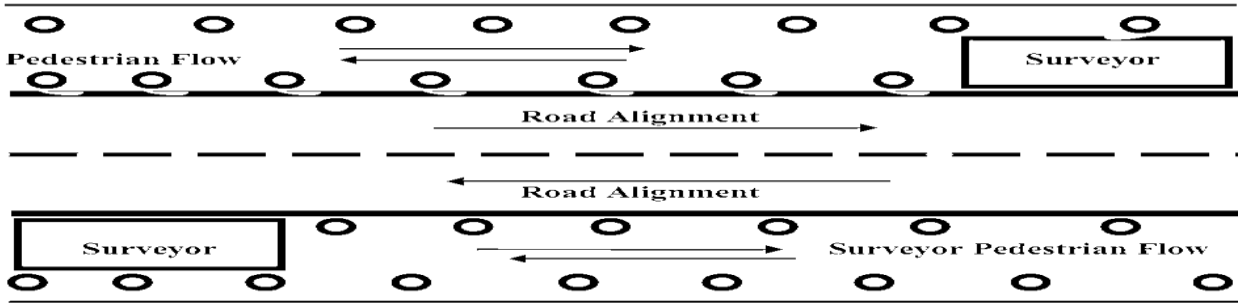

Figure 1: Surveyor location selection for each major roads

In order to conduct this research, necessary data have been collected through face to face questionnaire survey. A questionnaire containing both close-ended and open-ended was prepared to collect data. The questionnaire was pretested before final data collection. Necessary suggestions from transportation experts had also been taken during the preparation of questionnaire. Data were collected at different timetable throughout the month of January 2017 to include various aging groups of the city. The target sample was 600 according to the demography and standard sample size practice. However, random data samples were restricted to 480 due to the unwillingness of the commuters, rush hour office/home movement, and other impending situations. After filtering the anomalies, the remaining final sample size was 400.

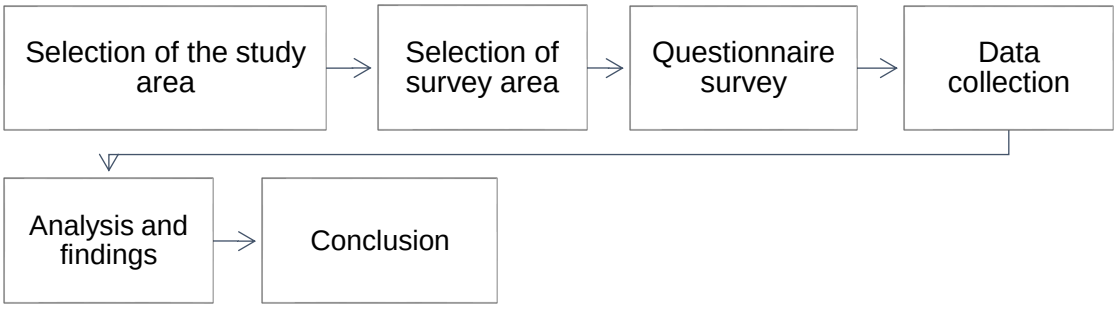

Figure 2: Flow diagram of methodology

3. FINDINGS AND ANALYSIS

Qualitative and graphical analysis imparting the pedestrian behavior was carried out which substantially represented as below amongst at least 400 people.

3.1 Mode of Transport and Purpose of Walking

The gender distribution of pedestrian which takes part during the field survey was about 76% of male and 24% of female. For smaller distance up to 1km traveling people of all ages relevantly like walking about 66%. Nearly 26% people preferred rickshaw as their mode of transport, and 8% favored other options for short distance.

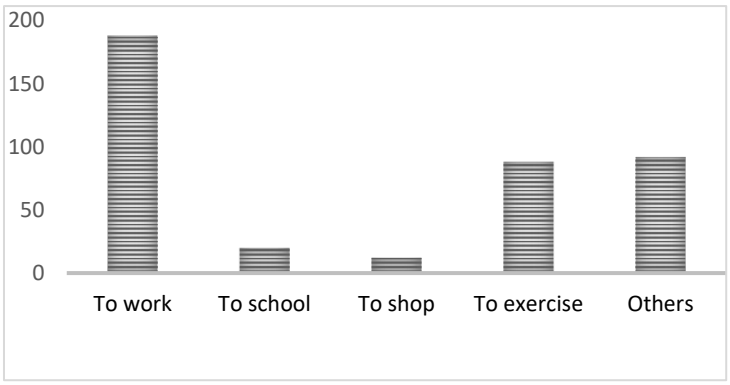

Figure 3: Purpose of walking

Most of the people took walking to go to work about 47% since at that time they inured with extreme traffic congestion and it is a knotty problem to get into public transports as it is overcrowded. In the cases of the vehicular traffic jam, most of the people choose to walk on feet as it is time-saving. In addition to, inadequate traffic regulation also bound people to be pedestrian. Mainly walking is mostly liked by the adult aged people about 22% as they find it a useful exercise. However, 3% and 5% people choose walking in the time of shopping and schooling. Nevertheless, the female pedestrian is on the increase as well as male.

3.2 Surface Quality and Widthof Footpath

People would love to walk when its ambient is good enough. The rough surface of walking lane discourages people to walk which is a typical scenario in Dhaka. According to the survey, 82% pedestrian believed that the surface condition in Dhaka is poor. Undulating surface often leaves pedestrian to get injured during walking.In few areas, there was no pavement on the footpath, covered by debris.

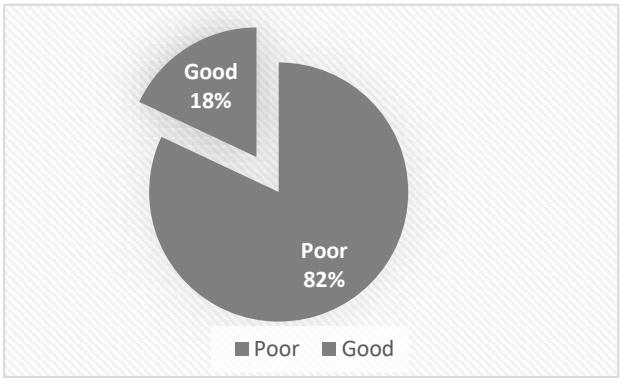

Figure 4: Surface quality of walkway

The width of the footpath is enough to move toward quickly if there is no non-pedestrian activity take place. Nearly 55% width was good enough for footpath users to walk freely. Although in some locations about 10%, the width was narrowed that they need to use the primary carriageway of roads. Surface quality and width of the footpath plays an eminent role to decrease walking habit of the users.

3.3 Support Facility and Lighting Condition

Pedestrian support facilities were in the very worst condition at Shahbag and New Market. Enough sitting is very important especially for aged people so that they can take some rest while they are walking. But such kind of amenities was absent. There were no potable water facilities for a thirsty pedestrian. About 77% people thought that pedestrian support facilities were inferior concerning other developing countries.

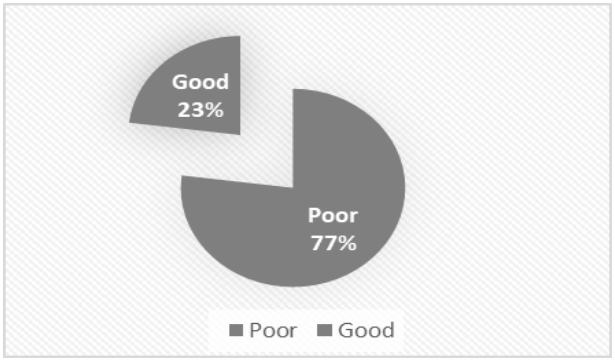

Figure 5: Support facility for pedestrian

Most of the road lamps were not working properly at night. Nearly 79% footpath users said that the lighting system enormously poor to walk safely.Both male and female felt unsafe at night. Larceny was very trite with pedestrians at night because of the deficiencies ofthe proper lighting system. According to their opinion, adequate installment of the lighting system and adequate safety measures is very crucial for users' safety.

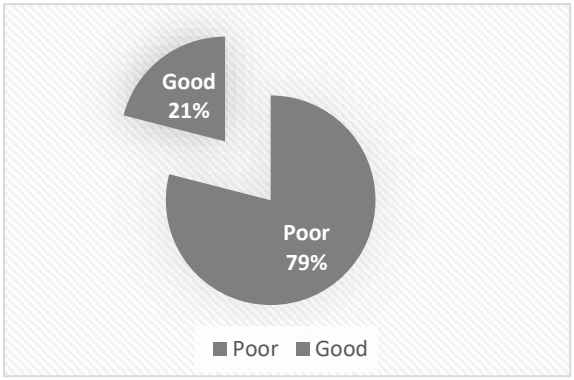

Figure 6: Lighting system of footpath

3.4 Comfortableness During Walking

Most of the footpaths are align with main roads, and the height of the walkways concerning carriage is shallow. Sometimes drivers drive their vehicles over the pathway when they fail to control that makes users' to feel uncomfortable.

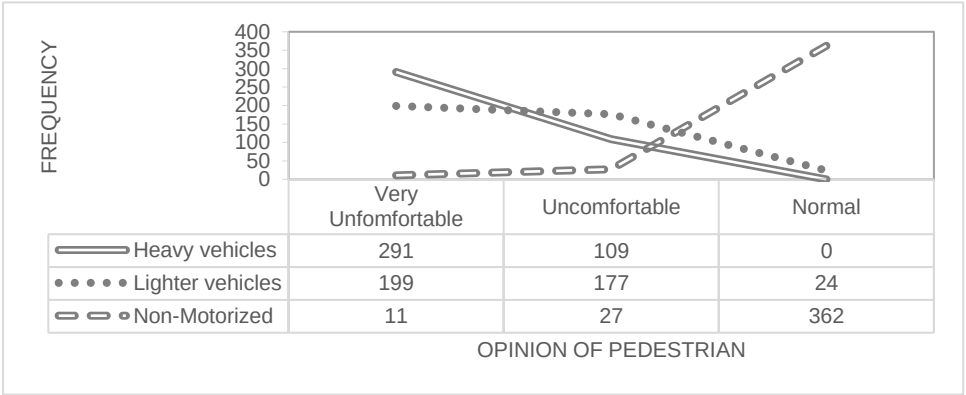

Figure 7: Comfortableness during walking

When heavy vehicles (Bus, Truck, etc.) moves parallel with a pedestrian, nearly 73% felt highly uncomfortable because the conflict between heavy vehicles and the pedestrian was a

typical scenario in Dhaka. Not a single rambler felt comfortable with heavy vehicles. Furthermore, 50% felt also extremely uneasy with lighter cars. On the other hand, 91% pedestrian felt comfortable with non-motorized vehicles because of its less vulnerability. Lane changing mostly occurs in Dhaka city in which people always cannot use the underpass or overpass, especially for time management. Intersections are readily available in Dhaka city where congestion become more responsible for hazardous accident substantially.

3.5 Environment of Footpath

The context of the footpath is very crucial to impress its users. But in Dhaka may present the worst scenario concerning others Megacity. Nearly 89% pedestrian felt that the footpath environment was very unpleasant not only for the deficiency of amenities but also for its milieu. In some locations, authority used footpath as their dumping site. They kept their waste container on the footpath which produces the noxious smell. Children don't prefer those footpaths to walk.Vendors covered the footpath most of the important places at Shahbag and New Market to sell their goods. It created a huge problem on the normal flows of the pedestrians. At winter it is very difficult to walk along with roadway because of the dust on air. Shahbag area has poor cleanliness with the dirty surface. The environmental effect with aesthetic view imparts predominating criteria on the pedestrians generally as dirt roads and surfaces are avoided by the general people of all classes.

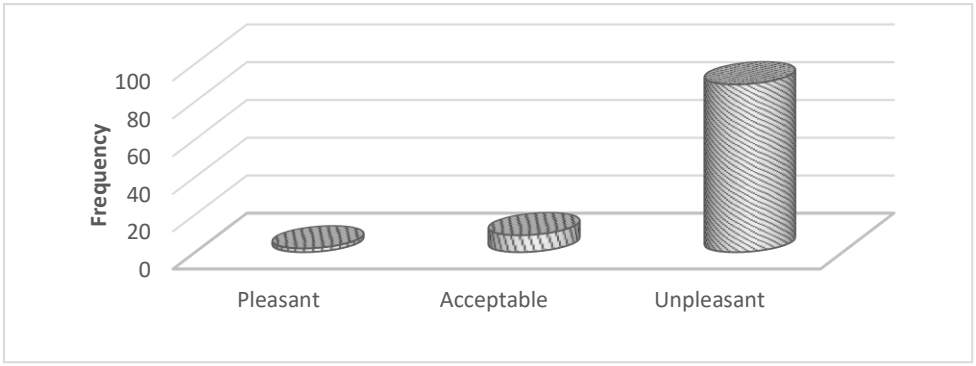

Figure 8: Environment of footpath

3.6 Pedestrian Safety and Security

A large number of traffic accidents, about 62 % occurred in Dhaka with the pedestrian in last few years (Pervaz, 2016). The traffic accident is not the only concern of pedestrian, their personal security is one of the major issue in Dhaka. Then female harassment is another common issue in Dhaka in the recent time. About 89% of female felt uncomfortable when they walk lonely. Nearly 86% pedestrian felt overall safety and security for them extremely poor and acceptable for 11% users. Only 3% pedestrian thought current safety and security level good to use the pathway. Even male didn’t feel comfortable to walk alone at night and in the early morning because of larceny. At that time they prefer another mode of transport as they feel safe to use it. Huge casualties occurred in Dhaka city at the time of road crossing. So the improvement of crossing facility should be taken as a first priority.

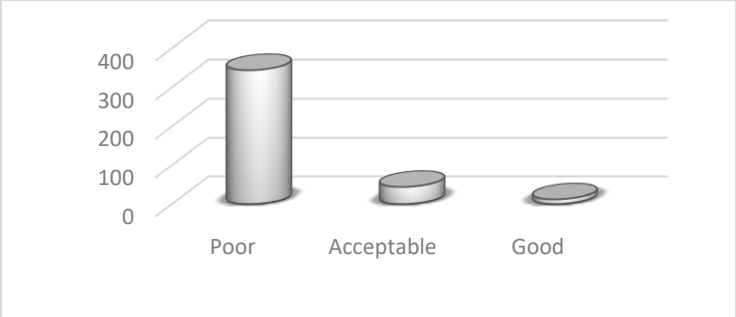

Figure 9: Pedestrian safety and security

4. CONCLUSIONS

This study has made an attempt to find out the major causes that affected the walking behavior of the city dwellers and to find out the reasons behind their perceptions. According to the objective of the study, 86% pedestrian felt unsafe at night because of larceny and poor visibility. Children don't want to walk due to noxious smell from squalor spreading everywhere on the footpath. The surface quality was one of the salient reason to decline the walking habit. Besides, the ambient of the pathway was at an unpleasant level to walk willingly. Unhealthy condition discourages its users to use it. The deficiency of amenities for the pedestrian was another cause to reduce the walking propensity of citizens of Dhaka. Walking is inevitable not only for healthy living but also for an efficient transportation system. Pleasant environment, supportive walking facilities, and safety could increase the predilection toward walking and establish it as an active mode of transport in Dhaka city.

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SAFE SYSYTEM COUNTERMEASURES FOR VULNERABLE ROAD USERS IN DHAKA CITY

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ABSTRACT

In Bangladesh, the vulnerable road users (VRUs) such as pedestrians, bicyclists, motor cyclist, pedal rickshaws and users of various informal motorized and non-motorized modes are victims of massive injury due to heterogeneous traffic practice. In most of the cases, vulnerable road users are ignored from the planning of urban road network system. Nearly 65 percent of road traffic fatalities in Bangladesh are attributed to vulnerable road users. The share of vulnerable road users (VRUs) deaths in urban areas, particularly in Dhaka is much more staggering nearly 60 percent in 2014. Transportation by walking is mostly seen in Bangladesh and is highly vulnerable. Cycle rickshaws too cater quite significant proportion of trips (25% to 40%) in cities. Safe system is required to prevent these deaths and serious injuries occurring which has the objective of eliminating deaths and serious injuries, with the guiding principle that everyone, including planners, share responsibility for creating a safe road system. This paper aims to present VRUs crash factors in Dhaka city with a view to ameliorating in-built crash risk factors by implementing affordable road environmental countermeasures. This paper in particular focuses on the potential application of safe system principles for improving safety of VRUs.

Keywords: *Safe system, Vulnerable road user, crash, Dhaka, countermeasure*

1. INTRODUCTION

Road crash is common in every nation of the world.Each year more than 1.2 million people died in road crashes around the world. About 90 percent of fatalities takes place in low and middle incomecountries,and while these countries occupy 82% of entire people of the world(WHO, 2015).More than 50% of injuries of vulnerable road users claim lives in Southeast Asia, Africa and Europe. As a result, road traffic safety becomes a crucial topic in transportation engineering. The number of crash, in which the major victims are pedestrians, bicyclists, motor bicyclists etc., was not possible to be reduced significantly in past years. The vulnerable road users (VRUs), who are pedestrians, bicyclists, cycle rickshaw occupants and motorcyclists, incorporate the biggest portion (around 80%) of urban trip and they are victim of about 80 percent of road crashes in urban zone of Bangladesh (Hoque et al.). Therefore, it is urgent to introduce safe system to ensure the road safety of VRUs in Dhaka city. This paper focuses to present how safe system could be a proper countermeasure to the magnitude of alarming problem considering significant risk factors of crashes in Dhaka city.

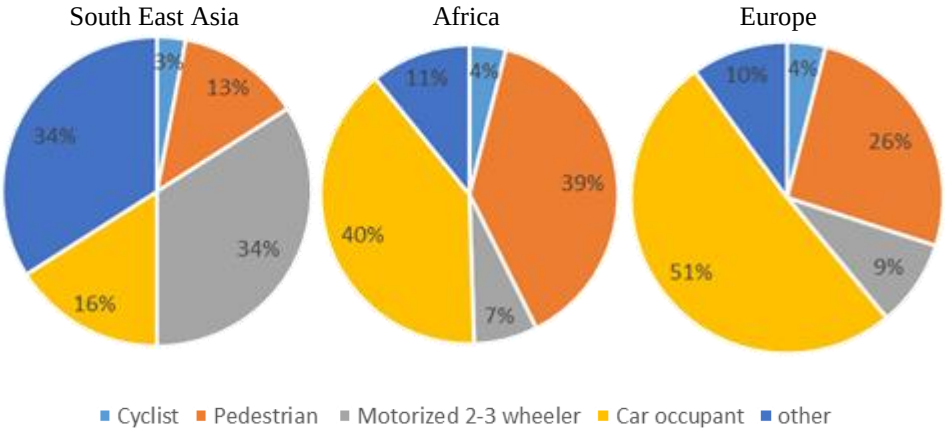

Figure 1: Fatalities of different types of road users around the world (Source: WHO, 2015)

2. SAFE SYSTEM APPROACH

The Safe System concept has the objective of eliminating deaths and serious injuries, with the guiding principle that everyone, including planners, share responsibility for creating a safe road system. Good planning and design sets the foundation for a safe road environment. This approach recognizes that road users inevitably make mistakes that may lead to a crash. In addition, the human body can only withstand certain impact forces before death or serious injury results. Safe system is required to prevent these deaths and serious injuries occurring.

According to the National Road Safety Strategy 2011–2020 (Australian Transport Council 2011),safe system is a road safety approach which holds that people will continue to make mistakes and that roads, vehicles and speeds should be designed to reduce the risk of crashes and to protect people in the event of a crash.

The Safe System comprises five essential components or pillars:

- safe roads and roadsides
- safe speeds
- safe vehicles
- alert and compliant road users (safe road use)
- post-crash care (according to WHO 2011)

Safe roads and road sides that minimize the risk of crashes occurring, and, when crashes do occur, ensure that death or serious injury are minimized. Roads should be predictable, self-explaining and encourage safe travel speeds. Safe speeds that suit the function and environment of the road, so that crash impact forces are managed within human tolerances. All road users should obey limits and drive to conditions. Safe vehicles that incorporate design features and technology that minimize the likelihood of crashes and protect road users (vehicle occupants and other road users, including pedestrians and cyclists) when crashes do occur. Safe road users should be alert, comply with road rules and engage in safe behavior. They are supported through education and information, enforcement of road rules and admittance to the system (e.g. through licensing).

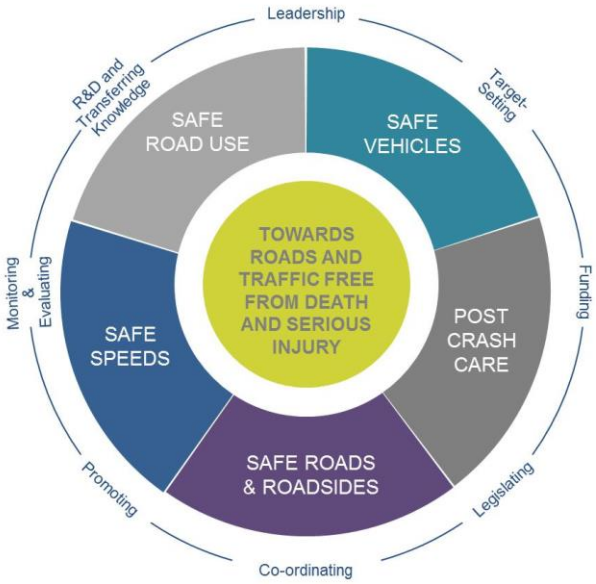

Figure 2: Fundamental elements of Safe system Approach

In order to ensure that safe system elements are considered, or to measure how well a given project (e.g. an intersection, road length, area, treatment type etc.) aligns with safe system principles, a safe system matrix has been produced. The purpose of the matrix is to assess different major vulnerable road users crash considering road users exposure,crash likelihood of it occurring and the severity of the crash should it occur.

Table 1: Safe system assessment matrix for vulnerable road users

	Pedestrian	**Cyclist**	**Motor cyclist**
Road users exposure	AADT; pedestrian numbers; crossing width; length of road segments	AADT; cyclist numbers; pedestrians	AADT; motorcycle numbers; length of road segment
Crash likelihood	Design of facilities; separation; number of conflicting directions; speed	Design of facilities; separation; speed	Design of facilities; separation; speed
Crash severity	Speed	Speed	Speed

3. METHODOLOGY

To find out the situation of vulnerable road users in Dhaka city on the context of their crash problems, some field investigations were performed at various critical areas of intense VRUs movements in Dhaka city. In field investigations photographs, videos and interviews of pedestrian, motor cyclist, pedal cyclist and rickshaw drivers were performed. The historical data from 2001 to 2014 was collected from MAAP (Modular Accident Analysis Program) database of Accident Research Institution (ARI), Bangladesh. From MAAP database, the data was taken in Microsoft excel spread sheet from where different analysis were piled on the research to get risk factors. Moreover, a star rating of iRAP is also executed. Finally, safe system countermeasures are suggested based on crash factors.

4. VRU CRASH DATA ANALYSIS AND RESULTS

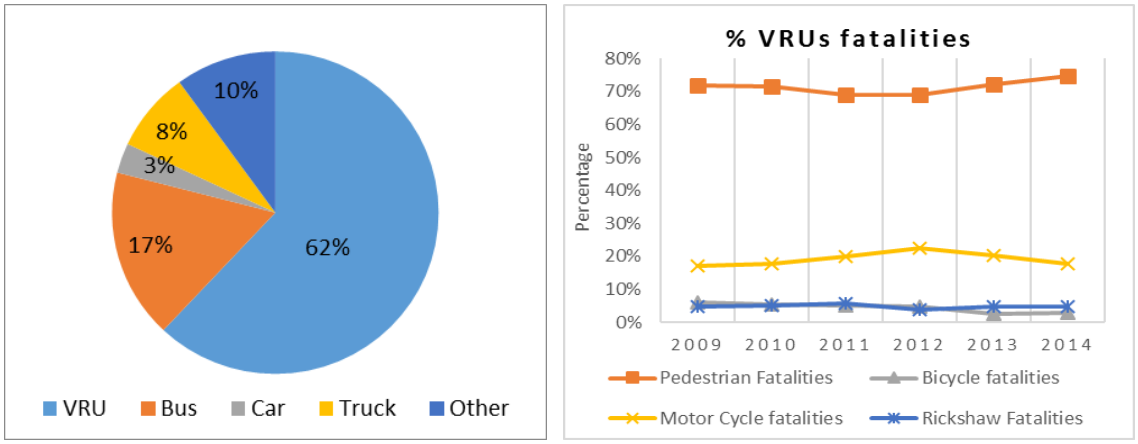

Figure 3: Fatalities of various road users in Bangladesh

Figure 3 shows that the percentage of vulnerable road userfatalities is just above 60% of roadcrash fatalities from 2009 to 2014 in Bangladesh. The right line graph of figure 3depicts percentage of fatalities for each significant member of vulnerable road users. As it is illustrated that in Bangladesh, percentage of pedestrian fatalities (70%) is predominantly higher than rest of the VRUs while motorcyclists about 20%.

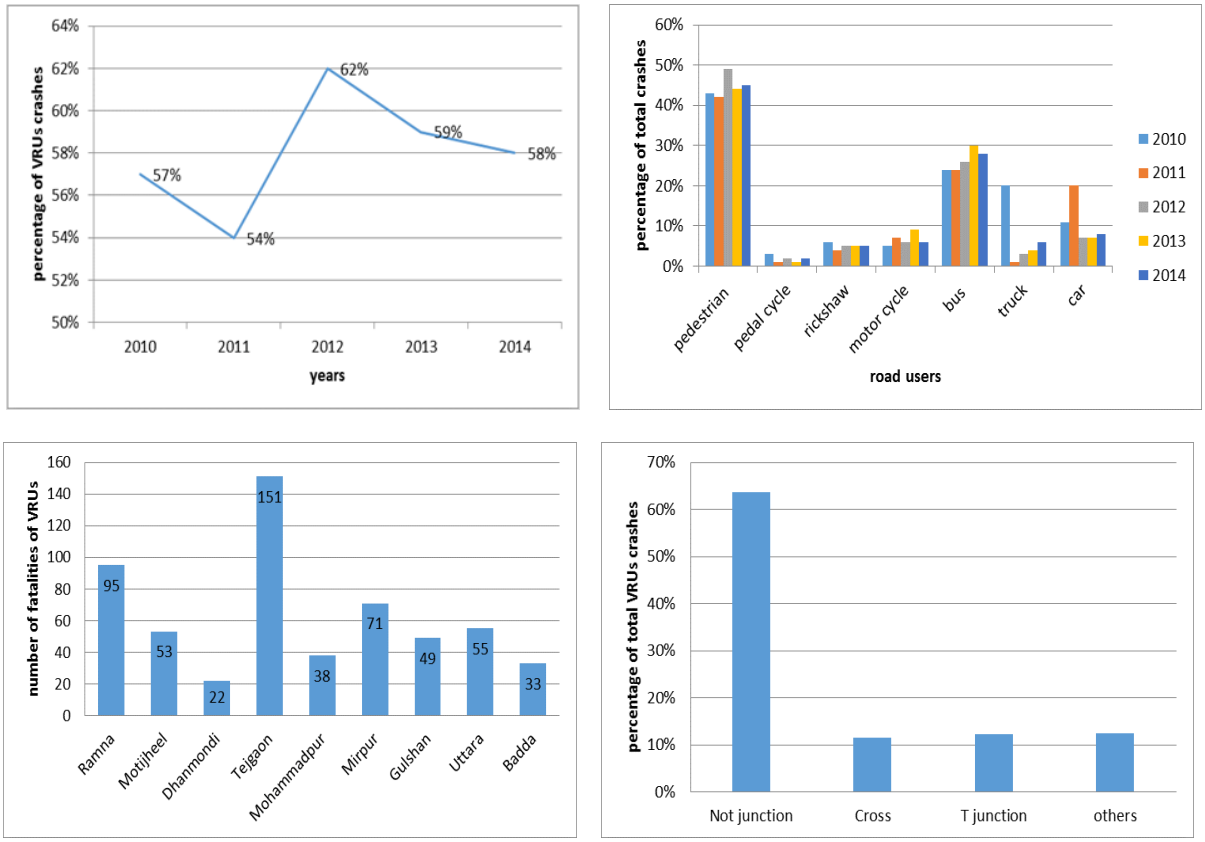

Figure 4: Condition of VRUs fatalities in Dhaka city (2001-2014)

From the left top graph of figure 4,it is obvious that VRUs crash percentage is more than half of total percentage of crashes in Dhaka city of which pedestrian crashes always remain between 40% to 50%,which is the highest one followed by buses and cars as illustrated in

the right-top graph .Tejgaon Thana of Dhaka city had experienced peak number of VRUs fatalities. However locational distribution for individual vulnerable road users crashes during 2001-2014 are as follows

- Nearly 65% of VRUs crashes occurred on the links (not junction) which is dominated by 83% of pedestrian affected with crashes on the links.
- Well above 45% motorcycle crashes occurred at crossing and remaining 22% occurred at straight road and 13% at T-junction.
- Most of the pedal cycle crashes (48%) occurred where there is no junction.
- Nearly 60% pedal rickshaw fatalities occurred at links or mid-blocks and remaining 40% occurred at intersections (T-junction 19%; crossing 10% and others 11%)

Distribution of fatalities for individual vulnerable road users during 2001-2014based on crash type are as follows

- Head on collision is the predominant type of motorcycle crashes (30%) whereas hit pedestrians 28%; rear end 25 %; side swipe 10%
- Among pedal rickshaw crash type, rear-end crash (83%) was the most critical.
- Rear end (58%) and head on (21%) was predominant crashes for pedal cyclists.

5. RISK FACTORS FOR VULNERABLE ROAD USERS

Figure 5: Heterogeneous traffic flow in Mirpur road near bolaka cinema hall.

Figure 6: Foot over bridge occupied by floating shops in Dhaka

5.1 Pedestrian concern

- Incompatible mix of vehicles and pedestrian
- Pedestrians are often exposed to danger during construction work
- Pedestrian facilities are occupied by hawkers and illegal shops
- Inoperative traffic signal and practice of avoiding signal

A star rating score is assigned to pedestrians based on crash likelihood, severity, operating speed, external flow influence and median travers ability using different equations following the iRAP methodology fact sheet #7: Star Rating Bands.

Table 2: iRAP star rating of roads of Dhaka city for pedestrian

Star Rating	Pedestrian Star Rating Score		
	Total	Along	Crossing
5	0 to <5	0 to <0.2	0 to <4.8
4	5 to <15	0.2 to <1	4.8 to <14
3	15 to <40	1 to <7.5	14 to <32.5
2	40 to <90	7.5 to <15	32.5 to <75
1	90+	15+	75+

Pedal Rickshaw and bicycle concern:

- Improper use of segregated lane
- Poor design of road junction and road section

Figure 7: Open drains on footpath in Dhaka city

Figure 8: No head protection while motor cycle riding

5.2 Motor cycle concern:

- Lack of obey stop sign/cross walk/intersection etc.
- Poor monitoring and law enforcement of helmet use
- Wrong perception of vehicle driver in right turn

6. SAFE SYSYTEM COUNTER MEASURES FOR VULNERABLE ROAD USERS

To produce effective road safety for VRUs, good management in all aspects of safety system in roads of Dhaka city is required.

6.1 Safe roads and roadsides elements:

Footway facilities: In Dhaka city hawker-free and attractive footpaths should be provided properly with efficient monitoring. Footway facilities show importance to separate the pedestrians away from the main traffic stream which will ultimately reduce the hit-pedestrian type of accident.

Crossing facilities:About 53% pedestrian casualties occurred while crossing the road in Dhaka city in 2010.So it is very important to provide crossing facilities.Median guard rail, shoulder etc. should be provided properly at midblock or link. Zebra crossing with high visibility should be applied in right place on the road. For school-goers of young ages pedestrian flag facilities can be applied.

Speed hump and pelican crossing facility: At low volume of traffic zone i.e. residential zone, speed hump and pelican crossing facility need to be applied.

Refuge island, dropped kerb, tactile surface:Refuge Island for pedestrian safe crossing the wide road, dropped kerb for road user with physical impairment and tactile surfaces for blind road user should be provided in city areas.

Segregated Lanes:Bicyclists, motor cyclists and pedal rickshaws are legal road users and have the right to use the roadway. Segregated lanes are wished to be used all over the world by such road users. Physical separation for bicyclists, rickshaws and motor cyclists by segregated lanes need to provide in Dhaka city to decrease fatalities of such road users.

6.2 Safe speed

Table 3 depicts that roads with vulnerable road users and motorized vehicle is crash prone when impact speed exceeds 30km/hr. If roadside hazards are protected (with barriers) and intersections are treated to reduce speeds to 50 km/h the travel speeds on the road can be 70 km/h. The addition of median barriers would enable higher operating speeds to be considered as well. Where motorcycles are a large proportion of the traffic, lower speed limits, perhaps 40 km/h, may be necessary. Speed management is at the centre of developing a safe road system. Where infrastructure safety cannot be improved in the foreseeable future and a road has a high crash risk, then reviews of speed limits, supported by appropriate and competent enforcement to support compliance, are a critically important option. Support through targeted infrastructure measures to achieve lower speeds should be considered. The scientific and evidence-based research shows that this will deliver a reduction of up to some 20% in the fatalities occurring on these lengths of roads (e.g. (Sliogeris, 1992). This of course assumes some enforcement support.

Table 3: Survivable impact speeds source: Tingvall& Haworth 1999

Impact speeds above which chances of survival or avoiding serious injury decrease rapidly		
Crash Type	**Impact Speed**	**Example**
Car/Pedestrian or Cyclist Car/motorcyclist	30 km/h	Where there is a mix of vulnerable road users and motor vehicle traffic
Car/Car (Side impact)	50 km/h	Where there is a likelihood of side impact crashes (e.g. intersections or access points).
Car/Car (Head-on)	70 km/h	Where there is no separation between opposing traffic streams

6.3 Safer vehicles

Especially in developed economies, the introduction of modern vehicle safety technologies has made a significant contribution to improved road safety. Modern bicycle,motor cycle and pedal rickshaw can be built with the 'safe system' concept central to their design, provided that they are driven within the limits of the environment (road, weather, traffic conditions etc) they are designed to withstand a crash.

The most significant improvements in crashworthiness have been active safety systems such as stability control. Now autonomous emergency braking and other advanced driver assistance systems are further reducing the vulnerability of vehicle occupants and other road users

6.4 Safe road user

Safety edge policy can be useful to prevent fatalities of road users, even protecting the pedestrians. It deals some precautionary rules and customs that are essential to avoid vulnerable road users' crashes. Here 10 tips are suggested for cyclists and motorcyclists.

Figure 9: 10 tips for pedal cyclist and motor cyclist safety in city road

POST CRASH CAR

Increased responsiveness to post-crash emergencies and improvements in the ability of health and other systems to provide appropriate emergency treatment and longer term rehabilitation for crash victims is also an important contribution to the Safe System.With improved bicycle, rickshaw and motorcycle safety and road design the number of deaths is likely to reduce but the long-term care of injured victims is an important social and public health consideration.

7. DISCUSSIONS AND CONCLUSIONS

Clearly the fatalities involving VRUs in road crashes are a serious problem.Crash studies and field investigations showed that indiscriminate driving on road, deficiencies associated with road infrastructure and lack of safe system are major contributors to VRUs fatalities and injuries. It is possible to provide safety for them by ensuring proper measures .Proper safe system andsafety infrastructure can resolve the crash problems of pedestrians, bicyclists, pedal rickshaws and motor cyclists in Dhaka city .Pedestrians and cyclists need to be fully

separated at all times with good line marking and delineation along with wide sealed shoulders. Wide clear median should be introduced whilethere is no median barriers present. Moreover, well managed crossing points need to be implemented for all VRUs ,particularly for motor cyclists. In order to reduce crash severity ,speed limit should not be exceeded 30 km/hr in heterogeneous road users system.The general drink-drive blood alcohol should be limited to 50mg /100ml. Security and aesthetics also are important factors to motivate road users to let VRUs engage with successful safe system.

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A STUDY ON PEDESTRIAN FLOW CHARACTERISTICS FOR SELECTED WALKWAYS IN KHULNA METROPOLITAN AREA, BANGLADESH

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ABSTRACT

Walking infrastructures need to be properly assessed as walking is the most common mode of transportation and related to pedestrian flow, speed and density. This study dealt with the examination and investigation of the characteristics and services requirements of pedestrian facilities in Khulna Metropolitan city, Bangladesh. The pedestrian walking data were collected at five locations in Khulna are analyzed for pedestrians flow characteristics under mixed traffic conditions. The data are presented in the form of mathematical and graphical relationships between speed and volume, speed and density, flow and area module and flow and density. The results of the analysis are compared with those given in the literature. The analysis indicates that the pedestrian free flow speed is high on sidewalks (58.81m/min) and low on precincts (46.89m/min). The free-flow speed of pedestrians is observed to be 58.41m/min which is lower than that reported for western countries. The speed was found to be influenced by the age and gender. Male pedestrians move faster than female pedestrians. Pedestrians in the age group of 15-50 years had the highest speed, 59.72 m/min. The increase in width of the facility resulted in increased space available to a pedestrian, but reduced maximum flow rate and optimum density. Models on speed-density-flow relationships were calibrated and evaluated the maximum flow and the corresponding critical area occupancy was determined on walkways. Level of services (LOS) standards were proposed based on these analysis, which could be used as criteria in the planning of pedestrian walkways.

Keywords: *Speed; Density; Sidewalk; Pedestrian; Flow characteristic.*

1. INTRODUCTION

Walking is the most common mode of transportation. A study conducted in India observed that 64.7% trips were made on foot (Arasan et al. 1994).Walking speed along with other pedestrian characteristics need to be studied, where pedestrian must be able to walk safely and conveniently on walkway. It is known that insufficient crossing time at crosswalk affect traffic movement as well as creating safety problems among pedestrians (TRB, 2000). As such a study on pedestrian characteristics in Khulna Metropolitan City was carried out. The results of this study may be useful to the planners and design a more efficient, adequate and safer pedestrian facilities. This paper examines the pedestrians' movements and flow characteristics on different types of facilities and under varying prevailing conditions. Findings are compared with those reported in literature to ascertain the cultural effects. In view of the above, important research works are discussed in the next section. It is followed by the section on methodology adopted for this research, flow relationships and characteristics, flow characteristics under varying conditions and finally the conclusions.
The objectives of this study is to examine the characteristics and service requirements of pedestrian and pedestrian facilities in Khulna Metropolitan City, Bangladesh. The specific objectives are to conduct the speed studies of pedestrians in Khulna Metropolitan City in different traffic conditions, to establish the relationship among speed, flow, density and area module of pedestrian on walkways, to compare the space occupied by a pedestrian and the

minimum space required for comfortable walking & to develop the level of service (LOS) design standards for walkways.

This study is an attempt to investigate the characteristics of pedestrian and its facilities in Khulna Metropolitan City under mixed traffic conditions. Due to inadequate exclusive facilities available for their movement, there exist a constant conflict between the pedestrian and the vehicle. In the city, inadequate sidewalk space spills pedestrians into the road. These sidewalks must be wide enough to accommodate prevalent pedestrian volumes (Polus et al. 1983). The results of this study may be useful to the planners and designers to design a more efficient, adequate and safer pedestrian facilities in Khulna Metropolitan City. This study was done only for pedestrians in walkways.

2. METHODOLOGY

A photographic technique was employed to collect all the data on pedestrian characteristics in Khulna Metropolitan City, Bangladesh. Khulna has a population of 1.5 million (2011 census) and density of 67,994 persons/km^2. Video-graphic technique was employed for collecting the pedestrian data. A trap of known length was marked on the pedestrian facility using a self- adhesive white tape for measuring the pedestrian speed and flow. The video camera was kept at an elevated point so as to cover the pedestrian movement on the entire trap. The movements of pedestrians were recorded during the morning and evening peak periods (8.30 – 9.30 A.M, and 5.00 – 6.00 P.M) on a working day at each of the study locations. The required pedestrian data were later extracted from the recorded videos. Looking at the continuous flow of pedestrians entering the trap the flow data was extracted on one minute basis though under fluctuating flows lower value of time interval would be more appropriate. The time taken by each pedestrian to cross the trap length was noted to an accuracy of 0.01s to determine pedestrian speed. Based on the pedestrian flow pedestrian density per square meter is calculated. The inverse of pedestrian density yielded the area module. These were found for the entire study duration. The sample size for the classified 5 study locations is given in Table 1.

2.1 Data Collection

Data were collected in the concentrated areas such as sidewalks along the main street at Majid Sharani, Shib Bari Mor and K. D. Ghos road, Hadis Park Mor in Khulna Metropolitan City, Bangladesh. Data of precinct were collected in front of New Market and Safe N Save. Data of Dakbangla Mor was collected as highly restricted side walk. Site descriptions and dimensions of the study areas on walkways are presented in Table-1. The surveys were conducted during both peak and off-peak periods.

Table 1: Description and Dimensions of Observation Sites & Dimensions on Walkways

Site No.	**Observations Sites (Khulna, Bangladesh)**	**Length)m(**	**Effective Width)m(**	**Sample size, pedestrians**
1.	Majid Sharani, Shib Bari Mor)Sidewalk, in front of City Inn Hotel)	10	1.1	281
2.	K. D. Ghos Road, Hadis Park Mor)Sidewalk, in front of Nagar Bhaban(	10	2.1	250
3.	New Market (Precinct, in front of gate no. 1)	10	6.6	317
4.	Safe N Save, Daulatpur (Precinct, in front of gate)	10	7.1	253
5.	Clay Road, Dakbangla Mor (Highly restricted Sidewalk)	10	2.45	521

2.2 Data Processing

The processing of data was carried out by video S player and a monitor. All timing were counted in seconds using the timer installed on the screen of the monitor.

2.3 Method of Analysis

2.3.1 Speed Measurement

Speed is defined as the rate of movement of pedestrians, thus the basic data needed are distance and time. Pedestrian walking speed was calculated by dividing the length or the areas traversed by the time the pedestrian crossed the mark-off area. In this study, the time taken by a pedestrian to traverse the length was measured directly from the timer shown in the recording. Observation were conducted on walkways both in bi-directional direction

2.3.1.1 Pedestrian Classification

In this analysis of the data, pedestrians were classified on the basis of age and gender as these variables seemed to have an effect on pedestrian walking speed. Age was categorized as Adult, Young and Elderly. Young pedestrians observed were from secondary school students .Elderly pedestrians were those pedestrians who appeared to be over 50 years old and were chosen subjectively on the screen of the monitor.

Children (CH)	= Below 15 Years
Adult (AD)	= 15- 50 Years
Elderly/Older (Old)	= over 50 years

Other than age, gender was also classified as to male and female. Significant difference between male and female pedestrians among age group was analysed. The data gathered on walkways were entered in the computer by using Microsoft EXCEL software then statistical analysis was conducted by using a statistical software “SPSS”.

2.3.2 Pedestrian Speed –Density –Flow Measurement

The pedestrian data for the analysis were collected using video graphic technique. A longitudinal trap of 10 m was made on the road by self-adhesive white tape for measurement of density and speed. The camera was mounted at an elevated place so as to cover the entire test section as detailed above. The data for movements in both the directions were collected during morning and evening periods for about 2 hours on a typical weekday. The recorded film was replayed in laboratory to extract the desired information. The number of pedestrians passing through the first line of the test trap in 1 min provided the information on pedestrian flow. For the purpose of speed measurement, 4–5 pedestrians were randomly chosen out of the total count in one minute and the time taken by them to cross the trap length was noted to the accuracy of 0.1 s. The film was paused to determine the density. The pedestrians in the trap length were also counted. All these measurements were made in 1-m width of the test trap. Variation in speed with respect to pedestrian’s personal characteristics like age and gender, and flow conditions like individual movement or platoon movement was also analysed. Speed of pedestrians carrying baggage was studied separately.

The data obtained from all study sites were combined to find the relationships between speed, flow and area module. This is done based on the assumption that the pedestrian characteristics at all sites are the same.

2.3.2.1 Regression Analysis

According to Fruin’s (1971) model, general forms of speed-flow-density relationships are

Speed-Density Relationship, $u = a-bk$ (1)

Flow-Speed Relationship, $q = u\,(a-u)/b$ (2)

Flow-Density Relationship, $q = ak - bk^2$ (3)
Flow-Area Module Relationship, $q = a/M - b/M^2$ (4)

Regression analysis was used to determine the model that best fitted the data on speed and density relationship and parameters 'a' and 'b' were evaluated. A simple regression was analysed by using a statistical software "SPSS''

3. SPEED STUDY

3.1 Pedestrian Walking Speed

Speeds reported in this section are the mean walking speeds of pedestrians crossing the area, measured. The traffic density is high and conflicts between pedestrians are huge in amount. This is under a free flow condition in which pedestrians select their desired walking speeds. It was found that the overall average walking speed of the Bangladeshi pedestrians in Khulna at three selected study sites was 58.41 m/min.
Further analysis on the classification by gender, showed that Bangladeshi male generally walked slightly faster than the female pedestrians with their walking speed of 69.57 m/min and 53.57 m/min, respectively. Table 2 shows the summary of results of pedestrian walking speeds. On the other hand, pedestrian speed varies very little than that of old and child pedestrian walking speed. Evaluation for pedestrian speed in Khulna Metropolitan City, shown in Table 2. The values of highest speed for male pedestrian is 85.7 m/min whereas 75 m/min for female pedestrian. On the other hand, lowest speed of male and female pedestrian is 33.33 m/min and 31.58 m/min.

Table 2: Walking Speeds of Pedestrians on Walkways, Khulna, Bangladesh

M=Male; F=Female; C=Combined

Characteristics		Child (0-15 Years)			Adult (15-50 Years)			Elderly >50 Years		
		M	F	C	M	F	C	M	F	C
Mean speed (m/min)		53.73	44.44	50	62.01	51.4	59.72	48.91	43.9	46.15
Range	High	82.76	70.59	82.76	85.71	77.42	85.71	72.73	68.57	72.73
	Low	36.36	32.43	32.43	41.38	33.33	33.33	34.29	30.77	30.77
Sample Size (pedestrians)			150			1375			90	

Referring to Table 2, the mean walking speeds of young and adult pedestrians were 50 m/min and 59.72 m/min, respectively. The value of combined speed for Child, adult and elderly pedestrian were not vary more than 5 % compared to male and female, respectively.

3.2 Levels of Service Standards on Walkways

Fruin (1971) defined six levels of service for walkways in a somewhat similar manner to the levels of service for vehicular flow in the Highway Capacity Manual (TRB, 2000). As in the Capacity Manual, levels of service range from A, representing free movement, to F, representing breakdown flow. Level of Service E refers to the capacity or maximum flow

condition. Criterion are given in terms of pedestrian modules (M), or the number of m^2/ped necessary to give the desired level of service. Unlike the HCM, where vehicle levels are defined by speed and volume, pedestrian levels are defined in terms of the inverse of density (number of pedestrians per square m). To a great extent, the Highway Capacity Manual (TRB, 2000) adopted Fruin's concepts in the identification of pedestrians levels of service on walkways as shown in the Table 3 at which range of values are expressed both in imperial and metric units.

Table 3: Pedestrian Level of Service Standards for Walkways

Level of Service	Space (M) Area per Person		Flow Rate Person/Minute		Normal Walking Speed	Reverse Flow	Cross Flow	Volume Capacity Ratio (v/c)
	SQ FT	SQ M	PER FT	PER M				
A	≥40	≥3.72	<7	<23	F	F	F	<0.08
B	25-40	2.3-3.7	7-10	23-33	F	F	R	<0.28
C	15-25	1.4-2.3	10-15	33-50	F	R	R	<0.40
D	10-15	0.9-1.4	15-20	50-66	F	R	S	<0.60
E	5-10	0.46-0.9	20-25	66-82	R	S	S	<1.00
F	<5	<0.46	25	82	S	S	S	

Note: F = relatively free, minimum of restrictions or inconvenience
R = restricted, higher probabilities of conflict and inconvenience
S = severely restricted
Source: Highway Capacity Manual (HCM), (TRB, 2000)

Level of service standards for walkways are described below and summarized in Table 4. Pedestrian flow and area module relationship is to aid in visualizing the pedestrian concentrations at the various levels of service of walkways.

Table 4: Proposed Pedestrian Levels of Service Standards Walkways in Khulna Metropolitan City, Bangladesh

Levels of Service	Space (M) Area per Pedestrian(Square Meter)	Flow Rate, Ped/m/min
A	3.7 or greater	23 or less
B	2.3-3.7	23-33
C	1.4-2.3	33-50
D	0.9-1.4	50-66
E	0.46-0.9	66-82
F	0.46 or less	85 or variable

Level of service A
At level of service a pedestrians can freely select their walking speed and basically move in desired paths without altering their movements in response to other pedestrians. Conflicts between pedestrians are unlikely.

Level of service B
At this level, pedestrian begin to be more aware of other pedestrians and respond to their presence in the selection of walking path.

Level of service C
At this level sufficient space is available to select normal walking speeds and to bypass other pedestrians in primarily unidirectional streams. Where pedestrian cross movements and reverse flows exist, minor conflicts will occur, slightly lowering mean pedestrian speeds and potential volumes.

Level of service D
Freedom to select individual walking speed and to freely pass other pedestrians is restricted. Where pedestrian crossing or reverse-flow movement exist, there is a high probability of conflict and to avoid contact with other pedestrians require frequent adjustment of speed and direction. However considerable friction and interaction between pedestrians is likely to occur.

Level of service E
Virtually all pedestrians have their normal walking speed restricted, requiring frequent adjustment at gait. At the lower range of this LOS, forward progress is only possible by "shuffling". Area is insufficient for passing slow moving pedestrian. Design volumes approach the limit of walkway capacity, resulting stoppages interruptions to flow.

Level of service F
All pedestrian walking speeds are severely restricted and forward progress is made only by "shuffling". Unavoidable contacts with other pedestrian are frequent. Cross and reverse flow movement are virtually impossible. Flow is sporadic and unstable where movement is based on those in front. Space is more characteristic of queued pedestrians than of moving pedestrian streams.

3.3 Speed-Density-Flow Relationships on Walkways

It was found in the analysis, that the relationship between speed and density can be assumed linear. The relationship is given by the following equation:

$$u = 73.629 – 67.319k \quad (5)$$

Where u is speed expressed in m/min and k as density expressed in ped/m^2.
Consequently, from the linier relationship, speed and flow as well as flow density relationships are formulated, respectively as follows:

$$q = u\,(73.629 - u)/\,67.319 \quad (6)$$

$$q = 73.629k - 67.319k^2 \quad (7)$$

In follow and density relationship, density is expressed in terms of area module M; then

$$q = 73.629/M - 67.319/M^2 \quad (8)$$

Where, M is expressed in m^2/ped.

These relationships among speed, density, flow and area module also presented in Figure 1 to 4.
The linear model represented the best fit between speed and density relationship and was calibrated in terms of correlation co efficient and other statistical parameters. Parameter "a" From model equation (Equation 5) which is the free flow speed was found to be 73.629 m/min. From Figure 1 it can be seen that as pedestrian speed declined, density increased to a maximum of 1 ped/m^2 where no movement occurred at a level often called as jam density.

Figure 2 and Figure 3 shows the curves derived from model equation (Equation 7 and 8) indicating the rise to a maximum and subsequent fall in the flow levels. The maximum flow was approximately 74 ped/m/min and occurred when the space was about 0.45 m^2/ped. Similarly the reciprocal of pedestrian density, M (m^2/ped) was used for convenience in visualizing relative levels of pedestrian freedom as shown in Figure 4. The curve confirms the normal human walking speed requires significant amount of pedestrian area, and that crowding causes restricted human locomotion.

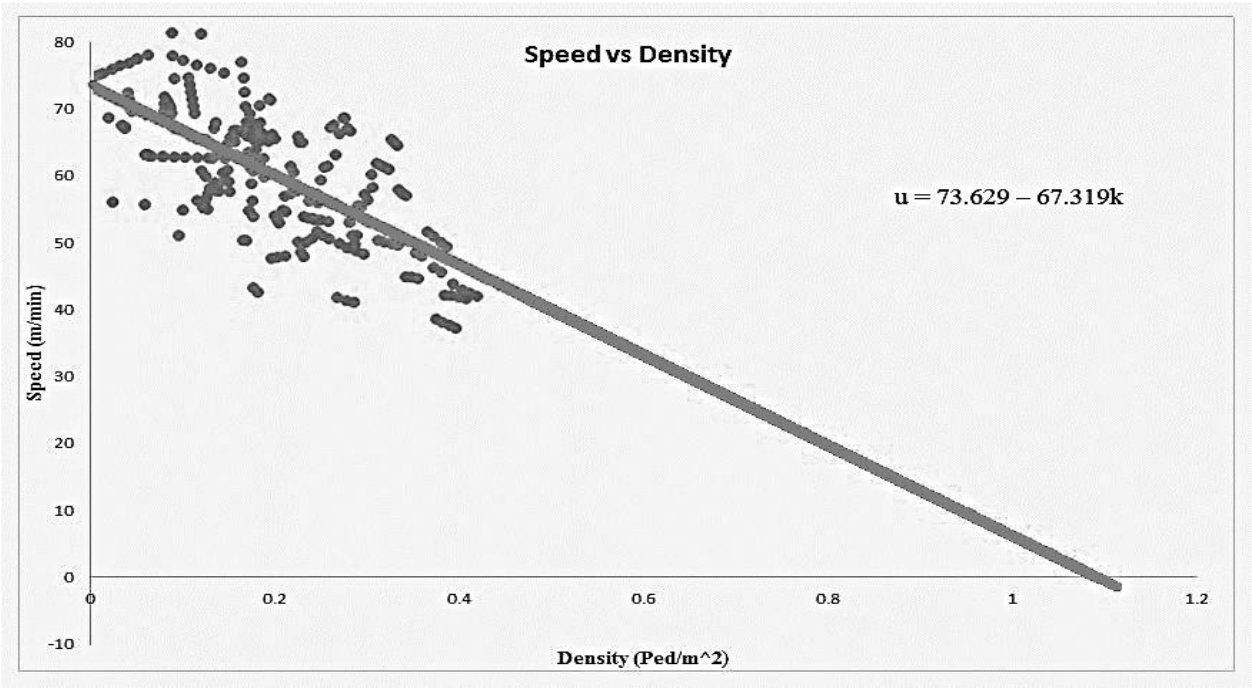

Figure 1 : Speed and Density Relationship for Walkways in Khulna, Bangladesh

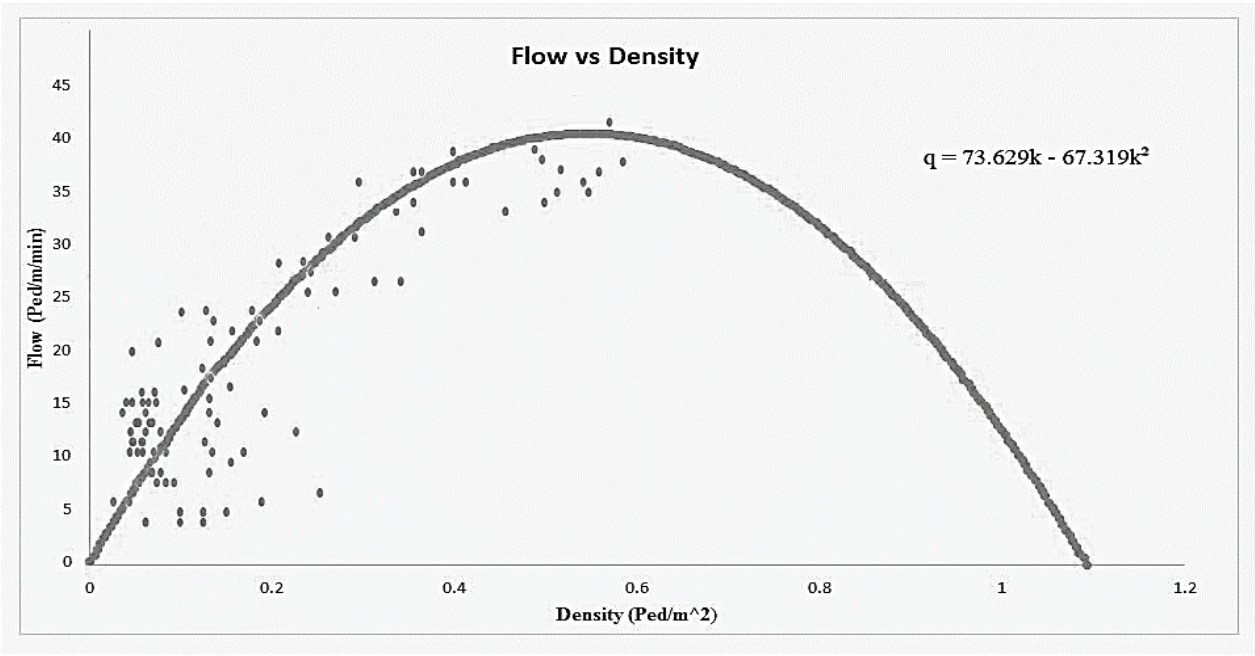

Figure 2 : Flow and Density Relationship for Walkways in Khulna, Bangladesh

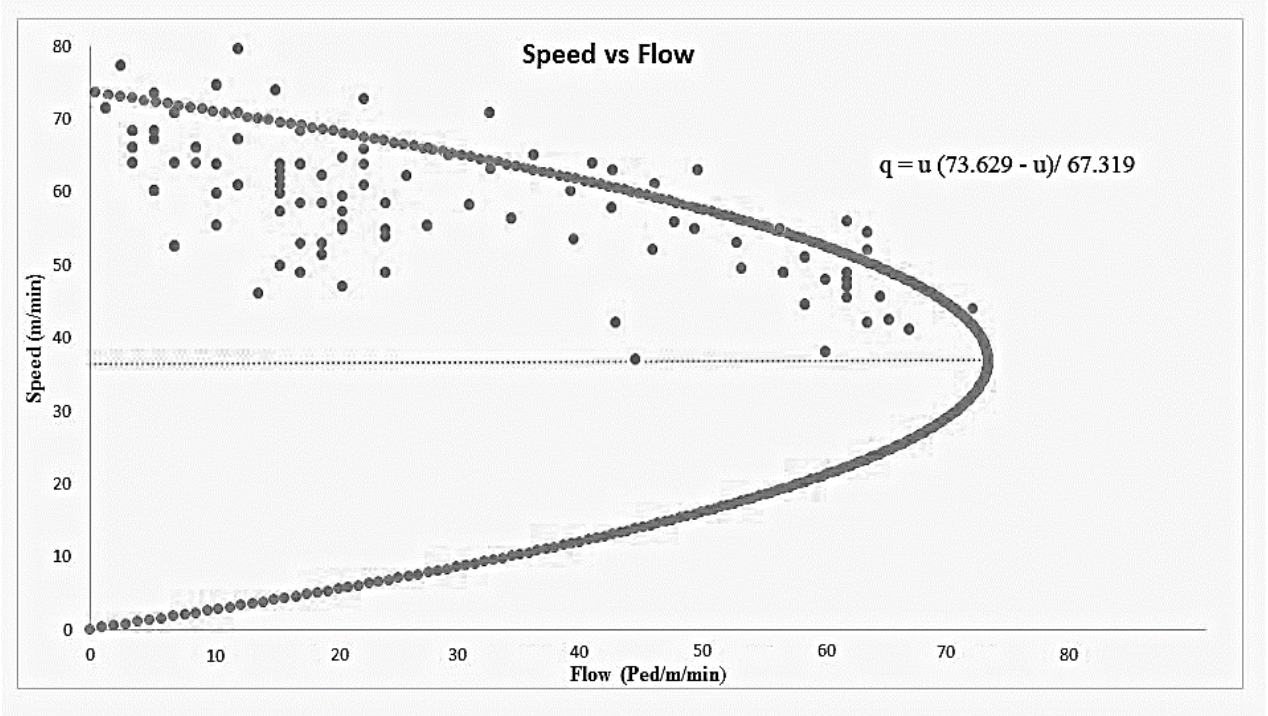

Figure 3: Flow and Speed Relationship for Walkways in Khulna, Bangladesh

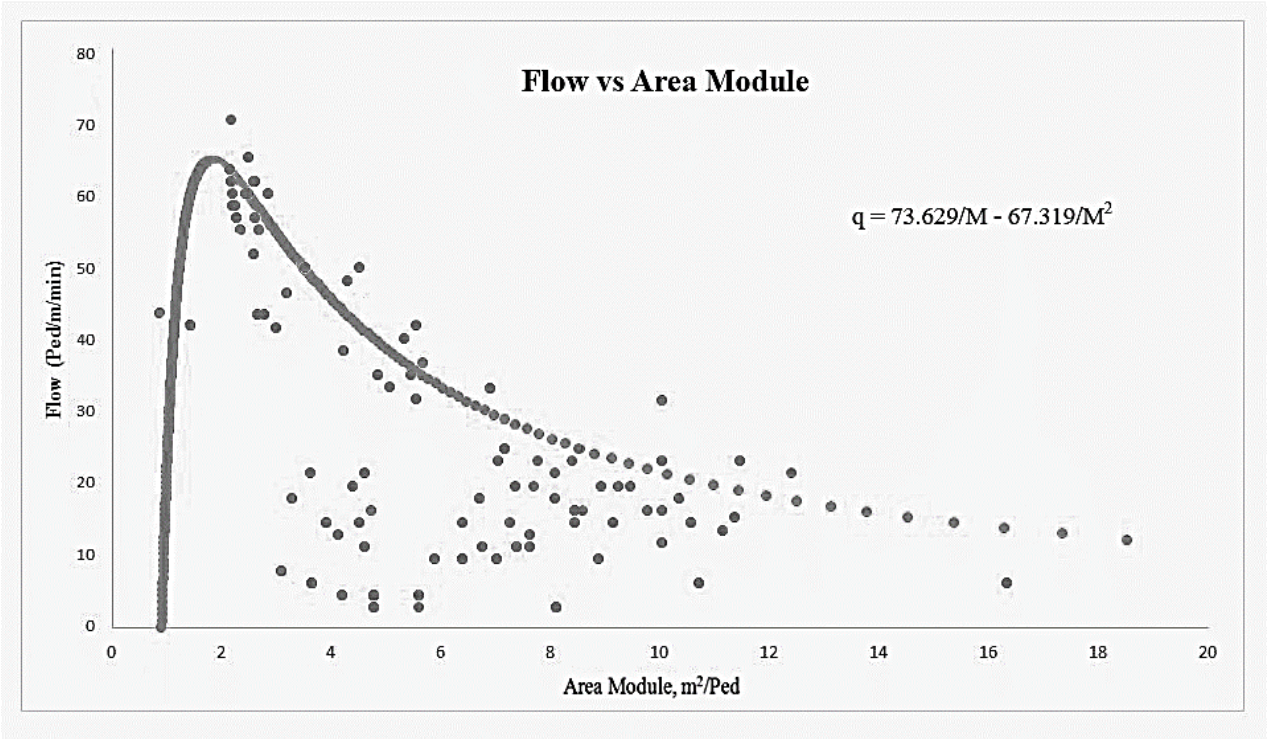

Figure 4: Flow and Area Module Relationship for Walkways in Khulna, Bangladesh

4. RESULT AND DISCUSSION

4.1 Pedestrian Flow Relation for Classified Conditions

Before estimating various flow characteristics for pedestrians at different selected locations, the locations which are found similar (based on pedestrian flow conditions and width of the facility) have been clubbed together. Data the locations are combined under the heads sidewalk, restricted sidewalk and precinct and the flow characteristics like pedestrian flow, speed, density and area module are estimated.

Table 5: Sample size for classified conditions

Classification	locations	Effective Width)m(	Pedestrian number	Total number of Pedestrians
Sidewalk	Majid Sharani, Shib Bari Mor	1.1	281	531
	K. D. Ghos Road, Hadis Park Mor	2.1	250	
Precinct	New Market (In front of gate no. 1)	6.6	317	570
	Safe N Save, Daulatpur (In front of gate)	7.1	253	
Highly restricted sidewalk	Clay Road, Dakbangla Mor	2.45	521	521
				1615

A single-regime approach is used to ascertain the relationship between speed and density due to constraints of the data points. Various distributions like linear, logarithmic, power, polynomial, exponential, etc. are considered to arrive at the best fit distribution. Once this is ascertained, the mutual relationships between flow, density and speed are derived theoretically and their goodness of fit is examined based on data plot and statistical parameters like R^2**.**The goodness-of-fit statistics are calculated for the observed range of the data.

Table 6: Relationships between pedestrian flow characteristics

	Relation	Value of parameters		Model equation	R2 value
		a	b		
Sidewalks	Speed-Density (u-k)	74.281	86.937	u = 74.281 - 86.937k	0.7424
	Flow-speed (q-u)			q = u (74.281 - u)/ 86.937	
	Flow-density (q-k)			q = 74.281k - 86.937k^2	
	Flow-area (q-M)			q = 74.281/M - 86.937/M^2	
Precincts	Speed-Density (u-k)	64.464	129.99	u = 64.464 – 129.99k	0.0304
	Flow-speed (q-u)			q = u (64.464- u)/ 129.99	
	Flow-density (q-k)			q = 64.464k - 129.99k^2	
	Flow-area (q-M)			q = 64.464/M - 129.99/M^2	
Highly Restricted Sidewalks	Speed-Density (u-k)	75.607	92.877	u = 75.607 – 92.877k	0.6017

	Flow-speed (q-u)			q = u (75.607 - u)/ 92.877	
	Flow-density (q-k)			q = 75.607k - 92.877k^2	
	Flow-area (q-M)			q = 75.607/M - 92.877/M^2	
Combination of all kind of facilities	Speed-Density (u-q)	73.629	67.319	u = 73.629 – 67.319k	0.4279
	Flow-speed (q-u)			q = u (73.629 - u)/ 67.319	0.5195
	Flow-density (q-k)			q = 73.629k - 67.319k^2	0.7058
	Flow-area (q-M)			q = 73.629/M - 67.319/M^2	0.8570

The flow relationships developed for different types of pedestrian facilities are shown in Figure 5.

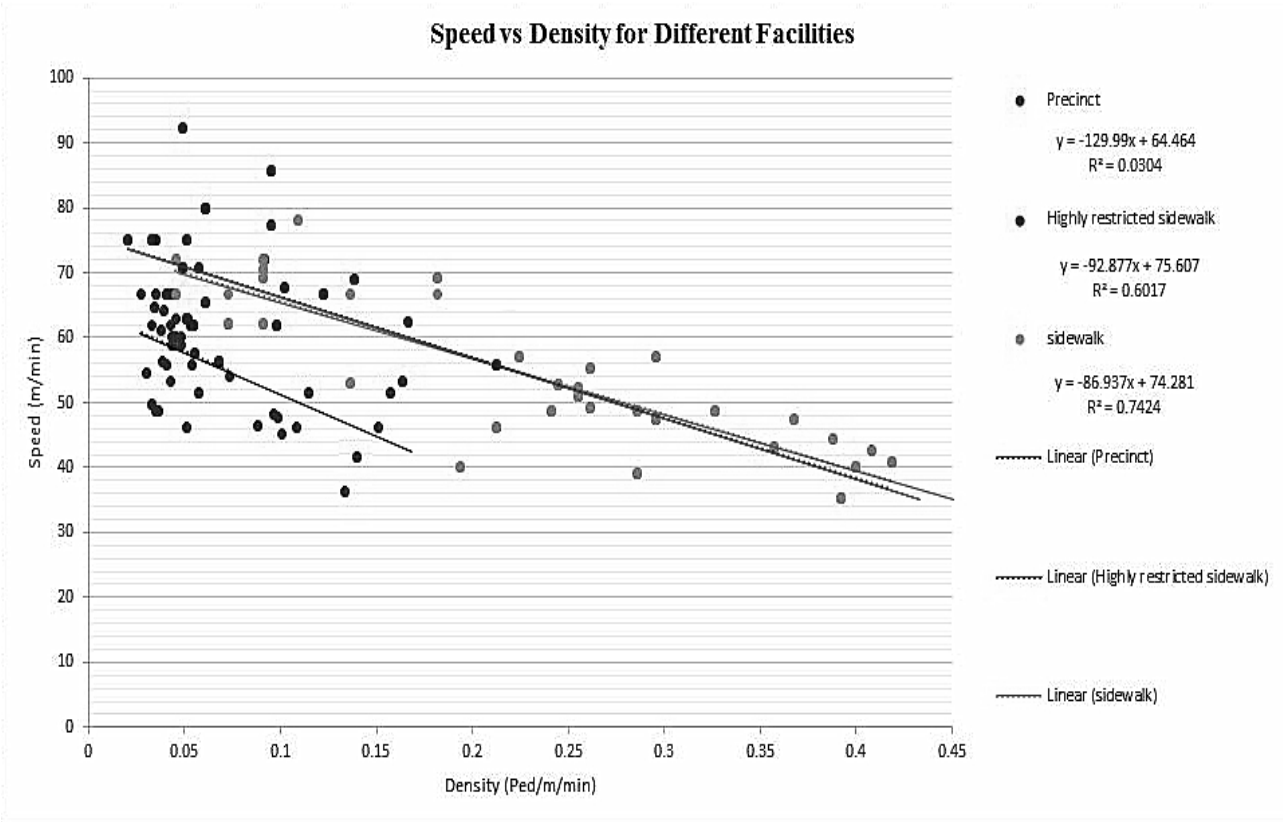

Figure 5: Pedestrian flow characteristics on different facilities

It shows the trend line of restricted sidewalk is steeper than regular sidewalk and less steep than precinct. These relationships clearly indicate the difference in the three types of sidewalk facilities as classified in the present work.

The mean speeds in literature vary from 1.23 m/s to 1.50 m/s on sidewalks/walkways; the variation being from 1.23 m/s to 1.39 m/s in Asian countries (Tanaboriboon et al. 1986, Lam and Cheung 2000, Honggei et al. 2009, Kotkar et al. 2010); from 1.31 to 1.50 in European countries (Oeding 1963, Older 1968); and from 1.31 to 1.37 m/s in the US (Navin and Wheeler 1969, Fruin 1971). Pedestrian walking speeds under mixed traffic are studied by Yu (1993, China), Gerilla (1995, Phillipines) and Kotkar et al. (2010, India). The speed is found lower in China (1.26 m/s) and comparable in Philippines and India (1.38-1.39 m/s). From Equation 1, speed of 73.629 m/min (1.228m/s) obtained locally smaller as compared to

various research in USA, Britain and Israel which speed ranges from 78 to 82 m/min. Speed obtain in Singapore and India is comparatively lower than obtained in Bangladesh.

The maximum theoretically flow obtained locally as a derived from equation 8 is 74 ped/m/min which is higher and can be explained by higher concentration occupied by Bangladeshi pedestrians. Bangladeshi pedestrians typically of small physical sizes tend to require less personal space thus, the density is higher compared to that obtained in USA, Britain and Israel is closer to that obtained in Singapore.

Table 7: Pedestrian flow characteristics under different conditions.

Facility /Condition	Maximum free flow speed (m/min)	Jamming flow (Ped/m/min)
Sidewalks	74.28	0.8544
Precincts	64.46	0.4959
Highly Restricted Sidewalks	75.61	0.8141

Based on the relationship between flow characteristics and characteristics parameter values, the behaviour of the pedestrians on sidewalks and highly restricted sidewalks is found to be more similar than that on precinct.

5. CONCLUSIONS

The following conclusions can be drawn from this study:

- The mean walking speed is 58.41 m/min or 0.97 m/s on walkways was significantly lower as compared to the Asian counterpart as well as European countries and US.
- Male pedestrian walking speed of 69.57 m/min is relatively faster than female pedestrian walking of 53.57 m/min.
- It was found that walking speeds among child (50 m/min), adult (59.72 m/min) and elderly pedestrian (46.15 m/min) vary significantly with each other.
- The relationship between pedestrian walking speed (u), density (k), flow (q) and area module (M) for walkway in bi-directional flows can be represented by following equations:
  $u = 73.629 – 67.319k;$
  $q = u (73.629 - u)/ 67.319;$
  $q = 73.629k - 67.319k^2;$
  $q = 73.629/M - 67.319/ M^2.$

  Where,
  u is in m/min, q in ped/m/min, k in ped/m^2, M in m^2/ped.

The maximum flow of pedestrian at walkways was found to be 74 ped/m/min when space area is 0.45m^2. Which refers Level of Service ‘E’.

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USE OF RECLAIMED ASPHALT PAVEMENT IN BITUMINOUS ROAD

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ABSTRACT

The huge amount of Reclaimed Asphalt Pavement (RAP) obtained from damaged or abandoned pavement. Bituminous pavement is a mix of coarse aggregate, fine aggregate, mineral filler and bitumen. Due to repetition of wheel load and edging effect bituminous concrete tense to wear and tear. Using RAP in pavement construction has now become most common practice in many countries. These materials have been used not only proved to be economical but also environmentally sound. Mixing RAP in fresh materials has been favored over fresh materials in the light of the increasing cost of asphalt, scarcity of quality aggregate, scarcity of asphalt and pressuring need to preserve the environment. An experimental investigation is carried out to evaluate the possible application of RAP in bituminous pavement design and to find out its design characteristics. The strength properties of CA and Marshall design properties of bituminous mixes were performed according to the test procedure specified by AASHTO. From experimental results, it is concluded that the coarse aggregate from RAP materials in the bituminous mixes with fresh aggregates give satisfactory results.

Keywords: *Bituminous road, Marshall Mix design, Reclaimed Asphalt Pavement, Optimum Bitumen Content*

1. INTRODUCTION

Hot mix recycling is the process in which reclaimed asphalt pavement materials are combined with new materials, sometimes along with a recycling agent, to produce hot mix asphalt (HMA) mixtures. Just as in the case of conventional HMA, recycled mixtures must be designed properly to ensure proper performance. The two steps in the mix design procedure are material evaluation and mix design. The objective of the material evaluation process is to determine the important properties of the component materials to come up with an optimum blend of materials to meet the mix requirements. The objective of the mix design step is to determine the type and percentage of bituminous binder with the help of results from compacted test mixes.

Recycling waste materials has become a common practice in the last 20 years in various fields of both manufacturing and construction sectors. However in Bangladesh, the use of RAP is very limited. There is no data regarding the production of RAP in Bangladesh. It is expected that the amount is increasing with time. Now a days, it is necessary to study the use of RAP for surface course constructions.

A lot of research work has been done in the past to make use of reclaimed asphalt pavement materials into the bituminous mix to make it cost effective. Some researchers are performing their researches by using different percentages of RAP as replacement of fine sand and different types of filler is also used to improve the physical property of bituminous mix.

The study reveals that the bituminous mixes with RAP especially at 50% to 100% replacement ratio provide better performance compared to those of new conventional HMA mixtures to improve the mechanical properties, durability performance and also stripping resistance. The addition of RAP has a great influence on improving the indirect tensile strength where the highest values are achieved at 50% RAP content (Ebrahim et al., 2015), Srikant et al.,(2014) showed that the warm mix prepared at 1200°c mixing with 30% RAP content shows higher stability when compared with warm mix prepared at 110°C. Mohamady et al.,(2014) represented that 30% RAP ensured superior field performance after construction. (Tambake et al., 2014) represented that the optimum binder content is reduced by increasing the percentage of RAP content and the recommended percentage of RAP mix is 20%. (Pradyumna et al., 2013) represented that the addition of RAP improves all the properties of the bituminous mixes. This indicates that mixes with 20% RAP would perform better than the virgin mixes under similar condition. Arshad and yanjun, 2012 represented that mixtures containing RAP shows significant variability and the variability increases with the increase in RAP content.

1.1 Benefits of Recycling

Recycling of bituminous pavement materials can

- save money for local government and other purchasers
- create additional business opportunities
- save energy when recycling is done on site
- conserve diminishing resources of aggregate and petroleum products
- finally help local governments meet the goal of reducing disposal of 50 percent

1.2 Objectives

- To determine the percentage of materials in RAP.
- To determine the properties of aggregates in RAP.
- To study the use of RAP materials in bituminous mixes with fresh aggregates

2. METHODOLOGY

In this study the RAP sample was collected from Bornaly to Medical Road in Rajshahi. Quantitative extraction of bitumen from bituminous paving mixtures was done by the test procedure ASTM D2171. After extraction of bitumen from RAP, the appearance of the aggregate is shown in Figure 1. After separating RAP materials 62% coarse aggregates, 28% fine aggregates, 7% mineral filler and 3% bitumen were found. Then the RAP materials were put into the various tests and their suitability were checked for further investigations. The test results of the fresh coarse aggregate and coarse aggregate from RAP presented in Table 1. RAP aggregates were found to satisfy the requirements as per AASHTO (1987), BS (812) and LGED (2008).

Table 1: Strength properties of coarse aggregate

Properties	Coarse Aggregate		Limiting Value
	Fresh	RAP	
Los Angeles Abrasion Value(Grade-A),Percent	17	20	≤ 40
Aggregate Impact Value, Percent	8	10	≤ 40
Aggregate Crushing Value, Percent	16	19	≤ 35
Ten Percent Fines Value, (KN)	300	265	≥ 100

Figure 1: Appearance of coarse aggregate from RAP

2.1 Mix Design

To investigate the behavior of asphalt mixes with different aggregates, continuously graded asphalt macadam is essential. In the continuously graded bituminous macadam, the aggregate blend is designed to be evenly graded from coarse to fine so as to arrive at a dense mix with a controlled void content, hence producing a stable and durable paving.
The objective of the study was to make a comparative study of asphalt mixes with RAP materials in varying percentages with fresh aggregate. Five types of mixes were studied and these were designated as mix types A, B, C, D and E

Mix A: in which Fresh CA is 100%
Mix B: in which Fresh CA is 90% and 10% CA from RAP
Mix C: in which Fresh CA is 85% and 15% CA from RAP
Mix D: in which Fresh CA is 80% and 20% CA from RAP
Mix E: in which Fresh CA is 75% and 25% CA from RAP

2.2 Marshall properties

Marshall Stability test of a mix is defined as the maximum load carried by a compacted specimen at a standard test temperature of 60°C. The flow value is the deformation of the Marshall Test specimen that undergoes during the loading upto the maximum load in 0.25 mm units (Tambake, Kumar, and Manjunath, 2014). Marshall Stability test is applicable for hot mix design using bitumen and aggregates. Marshall properties like stability, flow value, unit weight, total voids in a mix, voids in mineral aggregates and voids filled with bitumen were found for different percentages bitumen and RAP content. The graphs were plotted for bitumen content with 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 maximum permissible air voids is 3%-5% according to MORTH. The average value of bitumen content obtained from the 3 plotted graphs is treated as the optimum bitumen content (OBC). Marshall test results and OBC values for different percentages RAP content is tabulated in Table 2.

Table 2: Marshall test results

Aggregate Types	O.B.C. (%)	Unit Weight (kg/m^3)	Marshall Stability (kN)	Flow Value (0.25mm)	Air voids (%)	VMA (%)	VFB (%)	Marshall stiffness (kN/mm)
A	5.55	2346	16.30	14.6	3.9	13.75	70	1.12
B	5.50	2336	15.45	14.7	3.8	15.20	74	1.05
C	5.45	2320	14.40	15.1	3.6	16.00	78	0.95
D	5.37	2305	13.50	15.3	3.4	16.50	79	0.88
E	5.20	2297	11.70	15.5	3.0	17.20	81	0.75

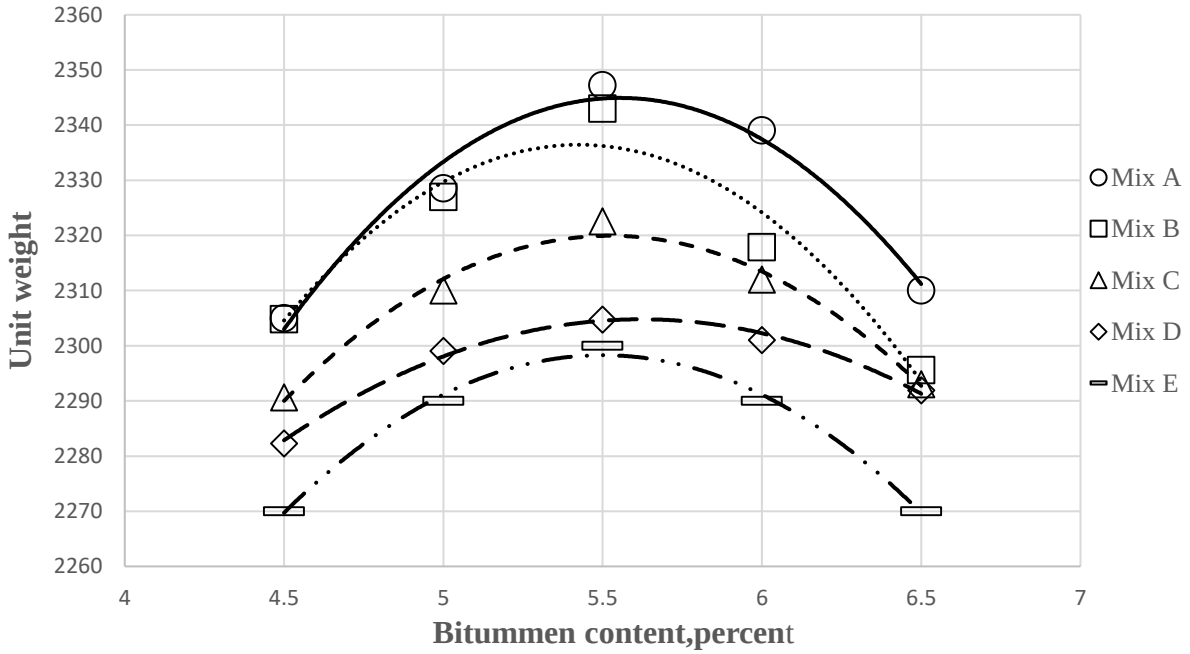

Figure 2.1: Relationship between Unit weight and percent bitumen content for different mixes

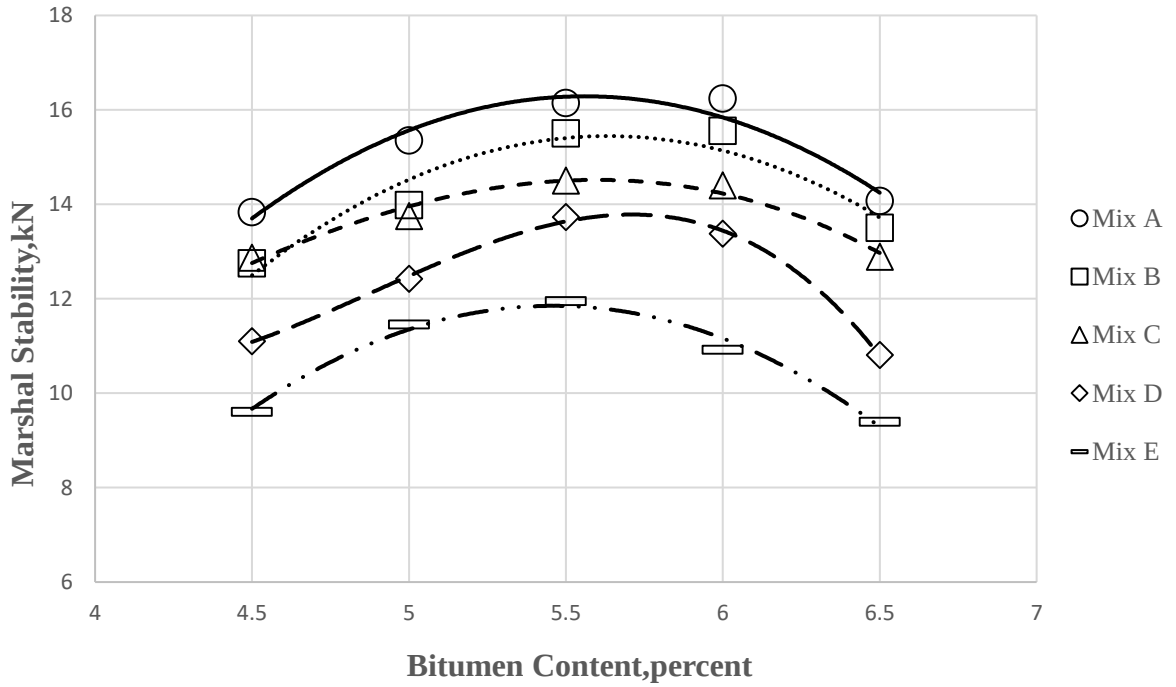

Figure 2.2: Relationship between Marshall Stability and percent bitumen content for different mixes

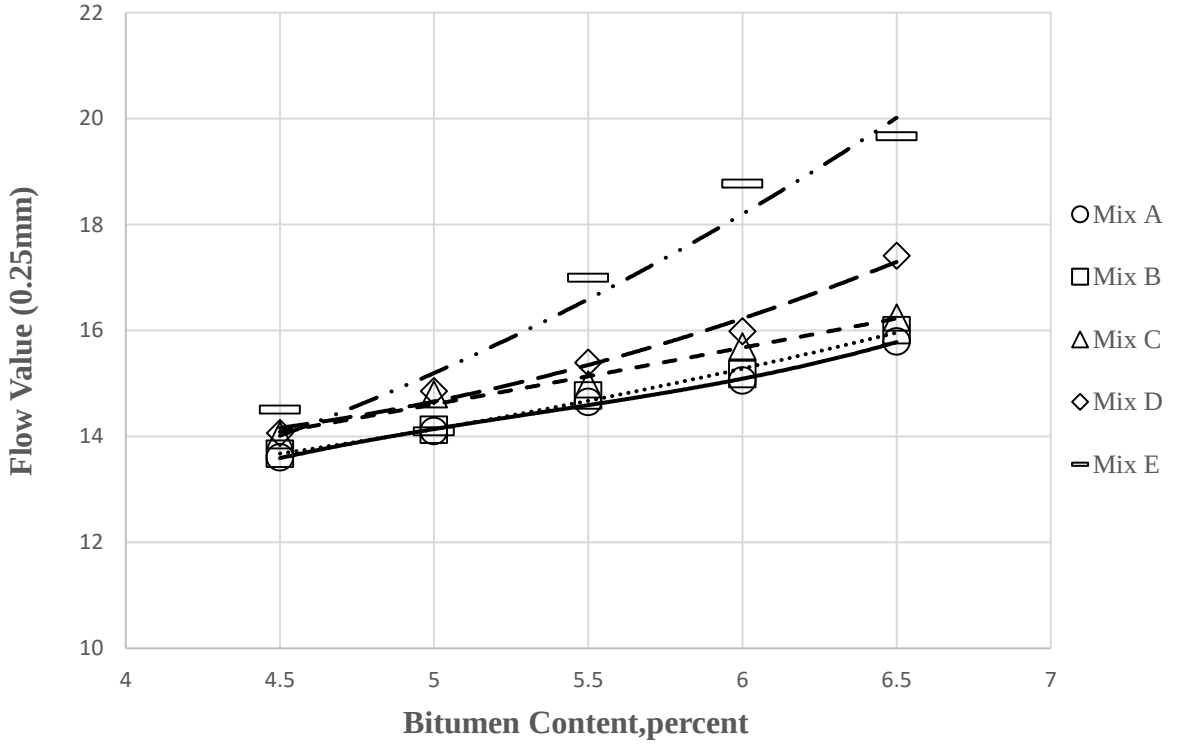

Figure 2.3: Relationship between Flow Value and percent bitumen content for different mixes

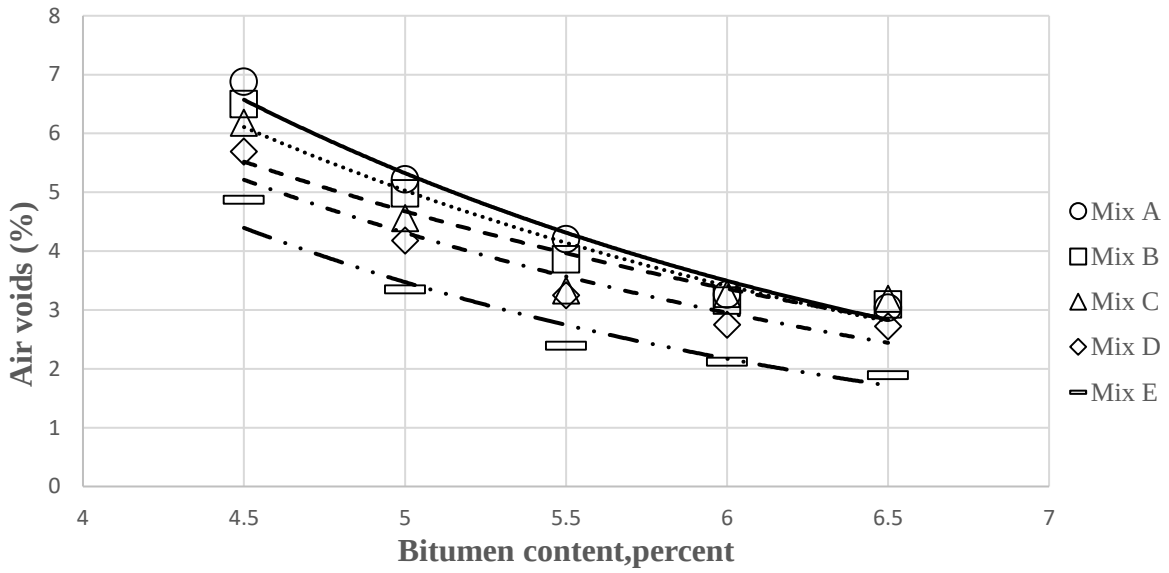

Figure 2.4: Relationship between percent air voids and percent bitumen content for different mixes

3. ANALYSIS OF RESULTS

From the Marshall test results it is seen that the optimum bitumen content percent is decreased as the RAP percent increase. This happens due to the old bitumen filled the pores of the RAP. It also occurs due to the presence of some amount of rounded shape coarse aggregate. Rounded shape particles quickly slips to gain stability and for that reason amount of OBC reduced. Moreover, increasing RAP percent from zero to 25% decreases the optimum bitumen content from 5.55% to 5.2%. This means that saving in optimum bitumen content by about 7% is achieved.

Unit weight is decreasing with the increasing percentages of RAP content. It is remarked that, increasing RAP percent from zero to 25% reduce the unit weight by only 2%. From the Table 2 it is noticed that, the mix stability is decreasing as RAP percent increase. Due to the presence of some smooth and round shape aggregates in the mix shear resistance decreases, ultimately results in decrease in stability. It is also noted that, increasing RAP from zero to 25% decrease the stability value from 16.3 to 11.7 kN i.e. decreased by about 28%. The mix flow increases as the RAP percent increases. When RAP percent increases from zero to 25%, the flow value increases from 14.6 (0.01 inch) to 15.5 (0.01 inch).

The total air voids in a mix is an important factor that must be considered when designing bituminous Concrete mixture. 3% to 5 % of the total mix volume is the limiting of the total air voids in a mix. When air voids are lower than 3% bleeding of bitumen will occur. Otherwise, for air voids percent greater than 5% of the mix, the pavement will be weak and unstable. From these considerations the bituminous binder is a very sensitive element in pavement design. From the table 2 it is seen that increasing the RAP percent will decrease the corresponding air voids ratio. This causes due to the old bitumen filled the aggregate pores which minimize the voids percent. Increasing the RAP percent from zero to 25% decreases the air voids percent from 3.9% to 3%.

From Table 2 it is found that the voids in mineral aggregate and voids filled with bitumen are increased as the RAP percent increases. This causes due to the ineffective old bitumen in the aggregate pores which prevent the new bitumen from occupying deeply the aggregate

pores. With the increasing percentages of RAP Marshall stiffness gradually decreases because Marshall stability value gradually decreases and flow value increases gradually.

4. CONCLUSIONS

On the basis of experimental results of this study, the following conclusions are drawn.

- Aggregates collected from RAP known as waste aggregates are suitable for the bituminous mixes from the consideration of aggregate properties.
- Although stability gradually decreases with the increase of RAP aggregates in the bituminous mixes with fresh stone aggregates, the characteristics of mixes satisfy the Marshall Design criteria.

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ESTIMATION OF PASSENGER CAR EQUIVALENT FOR DIFFERENT VEHICLES ON SELECTED ROAD SECTIONS IN KHULNA METROPOLITAN AREA USING ARTIFICIAL NEURAL NETWORK MODEL

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ABSTRACT

In a developing country like Bangladesh, the traffics on local urban highway are highly heterogeneous comprising of different static and dynamic characteristics. In order to reduce the heterogeneous behavior and convert the mixed traffic stream into a homogeneous equivalent, the term passenger car equivalent (PCE) is used. The PCE for a vehicle is dynamic in nature and changes with traffic volume, pavement width, shoulder conditions, directional split and percentage of slow moving vehicles. Data were collected from four road sections as Fulbarigate, Daulatpur, New Market and Rupsa in Khulna Metropolitan City. The goal of this study is to develop an Artificial Neural Network (ANN) based model using MATLAB for the estimation of PCE values for different types of vehicles such as Bus, Mini-bus, Large Truck, Medium Truck, Motorcycle, CNG, Mahindra in Khulna Metropolitan City. Finally, the PCE values obtained in this study are compared to the values established earlier. The PCE values obtained from ANN for Bus and Large Truck is within the range of 3.00 to 3.50, for Mini-bus and Medium Truck 2.00 to 2.50, for Motorcycle 0.50 to 0.60 and those for CNG 0.80 to 1.00. These results are finally compared with the values established by Geometric Design Standards for Roads & Highways Department in Bangladesh (MoC, 2000).

Keywords: *Passenger Car Equivalent (PCE) , Mixed Traffic, Artificial Neural Network, MATLAB*

1. INTRODUCTION

Traffic on local urban highways in Bangladesh and many other developing countries in the world are highly heterogeneous. Road transport is a very popular mode of transport used by the public. Road networks are heterogeneous used by the passengers to move from one part from another part of country, by the companies to provide scheduled delivery of their services and to transfer other needs throughout the country. Operating conditions on this roadway becomes complex when all these vehicles of different sizes move on the same road space without any physical segregation and occupy any lateral position on the roadway depending upon availability of the road space. Small size vehicles like motorized two-wheelers penetrate into the gaps between two large size vehicles and make the operating conditions poorer. Expressing traffic volume in terms of vehicles passing a given section of a roadway per unit time will be meaningless in such situations unless volume information is accompanied by the traffic composition.

As a result it is necessary to convert the heterogeneous traffic into a stream of homogeneous traffic by using appropriate passenger car equivalent (PCE) for analyzing the mixed traffic. In addition, appropriate PCE are also used for capacity analysis as well as traffic engineering research.

The concept of 'Passenger Car Equivalent' (PCE) was first introduced in the Highway Capacity Manual (HCM) (Transportation Research Board, 1965) for the analysis of mixed traffic by converting the different types of vehicles into equivalent number of passenger cars.

Thus, these PCE values are essential in carrying out most of traffic analysis. PCE provided by the HCM for trucks and buses on freeways and multilane highways represent their effect when traffic is operating in an ideal conditions. An accurate and easy estimation of PCE factors for different vehicles are useful in determination of traffic volume/capacity and level of service (LOS), which can make the decision of future expansion of highways and roads (widening and improvement) more constructive. Therefore these factors affecting PCE values should be incorporated suitably for accurate estimation of traffic volume. Most of the traffic engineers may use the only set of PCE factors included in the US HCM (Transportation Research Board, 2000) for analysis in different situations, ignoring acknowledged affecting factors resulting in significant amount of error in traffic/capacity studies. It is therefore necessary to determine the PCE on the basis of current roadway and traffic conditions of Khulna metropolitan city, Bangladesh. Passenger car equivalent is not only important for capacity reasons, but also as an input in highway cost allocation studies. The Federal Highway Administration (FHWA) has recently completed a highway cost allocation study to determine the cost responsibilities of the various classes of vehicle using the nation's highway system.

The current study aims at developing an Artificial Neural Network (ANN) based model using MATLAB software for estimating passenger car equivalent (PCE) of different types of vehicles in Khulna metropolitan city. ANN based model is of importance because of a number of independent affecting factors, Results of developed ANN based model are compared with the quoted results and are found with high degree of correlation.

2. METHODOLOGY

Four different road sections were selected where all the vehicles move freely without any restriction. The four different sites are Fulbarigate, Daulatpur, New Market, Rupsa. The selected site was properly visible from the roof of building from which video were taken easily. Figure 1 shows the GIS location map of the selected sites.

2.1 Data Collection

A certain length was fixed for each site. Length was measured by using tape. From the selected site, video was taken by digital camera for a duration of one hour. This video covered the entire length of the carriageway which is being selected. Then, time taken for each vehicle to pass the selected length was counted from the video is being taken. The speed needed for each type of vehicle was calculated by dividing the selected length with counted time. Average speed was measured by dividing the summation of the calculated speed with the number of speed measurements. The selected vehicles are Buses, Mini buses, Trucks, Medium Trucks, Car/Pick up/Jeep, CNG/Mahindra/Atul, Motorcycle. Directional split and percentage of slow moving vehicles were calculated by counting the number of vehicles in both directions. Rickshaws, Bicycles, Van, Easy-Bike etc. were taken as slow moving vehicles. Shoulder of the selected road sections were categorized as very poor, poor, fair, good and excellent. Numerical value for shoulder were taken as 1 for very poor, 2 for poor, 3 for fair, 4 for good and 5 for excellent, respectively. The pavement width of the road sections were measured by using tape.
The dimensions of the selected vehicles were then measured to calculate the PCE values according to the formula (Chandra, 1995). The dimension of the selected vehicles and factors affecting PCE values are shown in the following Table 1 & Table 2.

2.1.1 Data Selection and Data Division

In order to develop ANN architecture, data were collected from four different road sections of Khulna metropolitan city. Some previous data were also collected from previous study in order to train the neural network. In the present work, 10 data sets are randomly selected. Training data set comprises 6 data entries, and the remaining data entries 4 are divided

between the validation and testing sets. To test the reliability of the neural network model, 2 samples were randomly selected as the test set and another 2 samples as the validation set. To construct the neural network model, and an independent validation set to estimate model performance, 70% of the data set was used for training, 15% of the data set was used for validation of the model, and the remaining 15% of the data set was used for testing the neural network model. Figure 2 shows the division of data set.

2.1.2 Inputs and Targets

The accuracy of a neural network depends on the scattering of input information for training of the network. For this reason, classification of input information is very important in training. Therefore the input information is classified in five cases and in each case classification is based on one of the factors affecting PCE values. Factors affecting PCE value includes pavement width, shoulder condition, directional split, surface characteristics, percentage of slow moving vehicles, and so on. In order to develop artificial neural network model, four most affecting factors as pavement width (Yagar, 1983), shoulder condition (Turner, 1982), directional split (Sachdeva, 2004), and percentage of slow moving vehicles (Botma, 1988) are considered as the input and the corresponding PCE values as output or target. The qualitative categorization of shoulder was taken as very poor, poor, good, and excellent which were assigned with numerical values as 1, 2, 3, 4 and 5 respectively. Figure 3 shows the developed neural network model.

3. ILLUSTRATIONS

3.1 Figures and Graphs

Figure 1: GIS Location Map

Figure 2: Division of Data Set

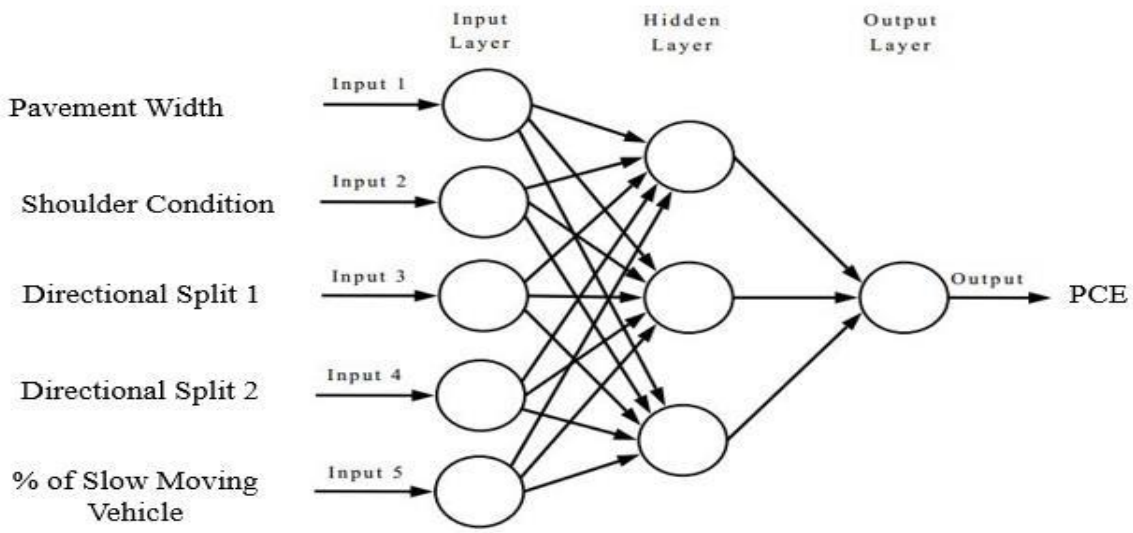

Figure 3: Developed Neural Network Model

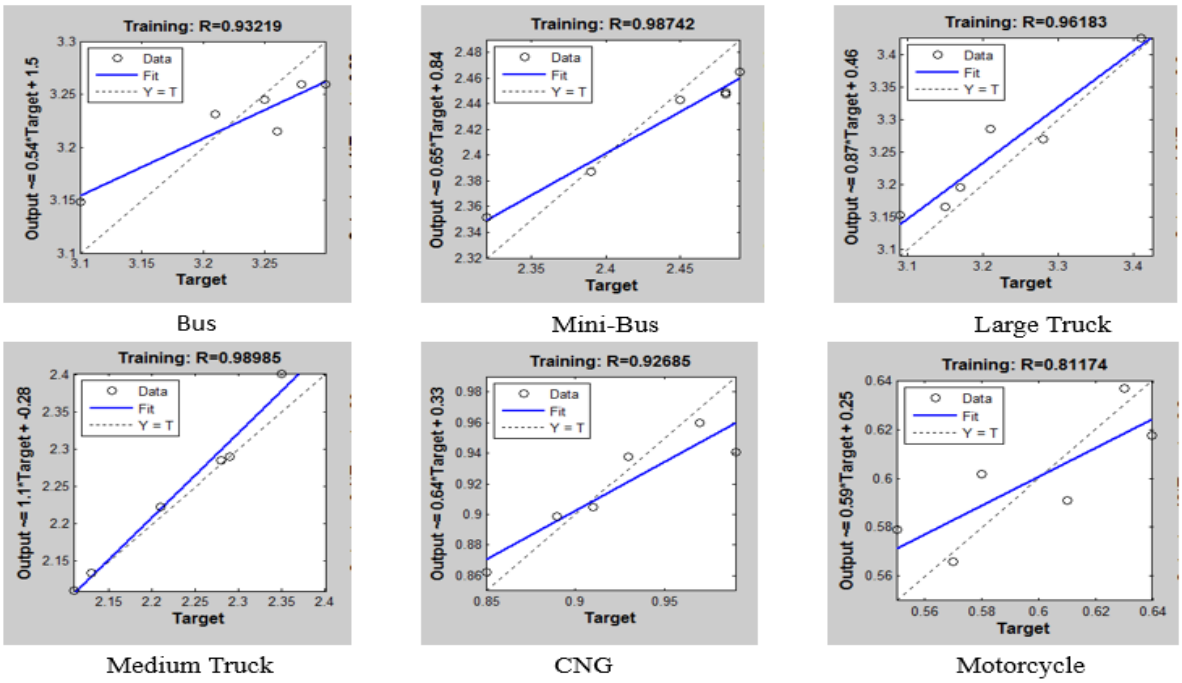

Figure 4: Regression Diagram of Training Set

Figure 4 shows the regression value of training set data were found 0.93219 for Bus, 0.98742 for Mini-bus, 0.961833 for Large Truck, 0.98985 for Medium Truck, 0.92685 for CNG and 0.81174 for Motorcycle. The regression value for Bus, Mini-bus, Large Truck, Medium Truck and CNG are close to 1 which represents that the obtained results are very close to the results established earlier. But for Motorcycle, the regression value of training set data was found 0.81174 of the present study which is not close to 1 because of large variation between the data and small network size.

3.2 Equations

PCE value for different vehicles under mixed traffic situation is directly proportional to the speed ratio and inversely proportional to the space occupancy ratio with respect to the standard design vehicle that is car (Chandra, 1995).

PCEi = (Vc/Vi) / (Ac/Ai)

Where
PCEi = passenger car equivalent value of the ith vehicle.
Vc/Vi = speed ratio of the car to the ith vehicle
Ac/Ai = space ratio of the car to the ith vehicle

3.3 Tables

Table 1: Dimension of Selected Vehicles

Vehicle Name	Length (m)	Width (m)	Area (m^2)
Bus	8.15	2.50	20.38
Mini-Bus	6.06	2.24	13.57
Truck	8.10	2.50	20.25
Medium Truck	5.23	2.33	12.19
Passenger Car / Pick Up / Jeep	4.37	1.52	6.64
CNG / Mahidra / Atul	3.05	1.52	4.64
Motor Cycle	2.20	1.00	2.20

Table 2: Factors Affecting PCE Values

Road Section	Road Name	Pavement Width (ft)	Directional Split (%)	% of Slow Moving Vehicle	Shoulder Condition
01	Fulbarigate	30	55:45	28	Fair
02	Daulatpur	41	57:43	25	Poor
03	New-Market	34	60:40	21	Good
04	Rupsa	38	52:48	32	Fair

Table 3: PCE value obtained from ANN for different road sections

Road Section	Road Name	PCE values Predicted from ANN						
		Car/ Pick up	Bus	Mini-Bus	Truck	Medium Truck	CNG / Mahindra	Motor Cycle
01	Fulbarigate	1.00	3.29	2.39	3.27	2.27	0.91	0.59
02	Daulatpur	1.00	3.26	2.28	3.21	2.11	0.98	0.55
03	New-Market	1.00	3.17	2.47	3.33	2.31	0.90	0.61
04	Rupsa	1.00	3.06	2.32	3.41	2.19	0.88	0.54

Table 4: Standard Value of PCE According to RHD (MoC, 2000)

Vehicle Type	Car	Bus	Mini-Bus	Truck	Medium Truck	CNG	Motorcycle
PCE Value	1.00	3.00	3.00	3.00	3.00	0.75	0.75

Table 3 shows the PCE value obtained from ANN for different road sections and Table 4 shows the standard values of PCE according to Roads & Highway Department. It can be seen that PCE values for buses and trucks is almost near to the standard results given by

Roads & Highways Department. But, in case of other vehicles (mini-bus, medium truck, CNG and motorcycle) the obtained value of PCE is deviated from the standard values. This deviation occurs due to faulty road geometry, insufficient roadway width, poor shoulder conditions, frequent side roads enter, increasing amount of slow moving vehicles on the road, etc. The speed of the vehicles is restricted when slow moving vehicles move through the same lane and speed breakers placed after certain distance. Also, pedestrians move from one side to another by avoiding rules which breaks driver's attention and hence speed is decreased. PCE value of any vehicle is greatly hampered due to these speed restrictions. Furthermore, hawkers and parking vehicles on the road consume a portion of roadway width. For this reason, the vehicles moving on the road can't get sufficient space for free movement and hence reduce speed & roadway capacity.

4. CONCLUSIONS

In the present study, an Artificial Neural Network based model is developed by using four well identified affecting factors such as pavement width, shoulder condition, directional split and percentage of slow moving vehicle for the estimation of PCE values for different types of vehicles on Khulna metropolitan city. In this Artificial Neural Network based analysis 1000 iterations was used. The number of neuron was kept as ten in the hidden layer. The PCE values obtained from ANN for Bus and Large Truck is within the range of 3.00 to 3.50, for Mini-bus and Medium Truck 2.00 to 2.50, for Motorcycle 0.50 to 0.60 and those for CNG 0.80 to 1.00. The results so obtained are compared with the quoted results in the literature and high degree of correlation is observed. This will open a new direction for the traffic engineers for accurate easy estimation of PCE value and hence traffic volume, capacity and level of service in any situation giving due weightiness to different affecting parameters.

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TRAFFIC CHARACTERISTICS ON MOGHBAZAR-MOUCHAK FLYOVER

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ABSTRACT

There is little realistic regularity that is as worldwide as the following: no matter what the track of economic growth a country has followed, urbanization has been an inevitable consequence across the world. So, transportation system plays an important role in urbanization. Moreover, the major requirement for sustainable economic development of a city depends on its adequate and efficient transportation systems. Dhaka, the capital of Bangladesh, is one of the world's fastest developing cities, with a population currently around 15 million. The fast-growing migration rate to Dhaka has already put tremendous stress on transportation systems. As a result, traffic jam has become a consistent feature of Dhaka city. It not only puts negative effects on our trade and commerce but also acts as the source of air and sound pollution. So, reducing traffic congestion is the crying need of the citizen of Dhaka city. To reduce the traffic congestion a flyover has been constructed to over the Moghbazar-Mouchak road intersections in the center of Dhaka city. Although, this project, which connects the northern and southern portion of Dhaka city aims to reduce traffic congestion, the condition of the traffic below the flyover has not been improved. Throughout the study, total volume of traffic using the flyover in different days and time has been analyzed and the velocity of each vehicle along with the perceptions of the commuter towards the flyover has been revealed.

Keywords: *urbanization, migration, congestion, traffic volume, perceptions.*

1. INTRODUCTION

Dhaka is a diverse city situated in central Bangladesh along the Buriganga River. Not only is it the capital city, but it is also the largest and central official zone in the country. In 2016, the population is 18.237 million and the city has shown the population growth of about 4.2% annually in the Greater Dhaka Area according to World Population Review (2017). Most of the government offices are also situated at Dhaka. Thereby it has been found that the yearly growth of total traffic is about 21.03%, which is much complex than the factor presently used by transport authorities in Bangladesh according to ULLAH, HAQUE & NIKRAZ (Traffic Growth rate and Composition of Dhaka-Chittagong Highway (N-1) of Bangladesh: The Actual situation). Only 9% of roadways and 6% of pavement area are available, in which 62 km functional primary, 108 km secondary and 221 km connector road serve the city road network (Mahmud et. al., 2008). Citizens continuously face the unbearable difficulties of the traffic jam, which not only causes damage to our time, health and livelihood but also affects our earnings. People from subaltern economic area bear their heavy loss due to the excessive jam, due to congestion in Dhaka city, the excess fuel cost was estimated 178.55 million USD in 2013. The average traffic speed in Dhaka is 6.4 kph. But if vehicle growth continues at its current pace, without substantial public transport investment the average speed may fall to 4.7 kph by 2035 according to "The Daily Star" report on "The smartest ways to deal with traffic congestion in Dhaka". That is why reducing traffic jam of Dhaka city is the main concern of policymaker. To reduce the traffic congestion a flyover was constructed to over the MaghBazar road intersections in the centred of Dhaka city. This project, which will connect the northern (Malibagh, Maghbazar) and southern (Satrastha, kawranbazar), portion of Dhaka city. On the other hand, a huge congestion had been noticed in the ramp of the Flyover in front of a VIP zone of Hotel Pan Pacific Sonargaon Dhaka and

in the ramp of Banglamotor portion. As a result, the road user loses their valuable time at the starting and end portion of the ramp. Through the flyover was constructed to ensure continuous flow and moderate speed of the motorized vehicle, the speed of the vehicle was observed less than the standard. That's why, it is necessary to evaluate the traffic volume, velocity and perceptions of the flyover users.

2. DATA COLLECTION

In order to reach at the preferred aims, data has been collected from primary and secondary sources. Primary data has been collected through concentrated survey by manually and Video Camera method. Data was collected on Sunday, Tuesday, Thursday and Friday at the time 08.00AM, 10.00AM, 12.30PM, 05.00PM respectively for each an hour. Volumes were measured manually and with the help of video Recording. To find the instantaneous velocity speed gun was used. To find out the driver's perception a questionnaire survey has been designed. The secondary data has been collected from numerous published and authorized sources. All the data has been processed by SPSS PC software to build a discrete choice model.

3. LITERATURE REVIEW

Peiris & Fernando (2011) have studied the suitability of a flyover as a traffic management measure. They found that 67% of accidents were happening on the flyover. Buses and heavy vehicles add to 74% of accidents at the ends of the flyover and also mentioned about an abrupt speed drop at the flyover. They have acknowledged that the disruptive design of the flyover at the method level blocks the graphical path of the users and the lack of overtaking chances occur under weighty traffic condition. Finally they have suggested that the land use compatibility be estimated with the transport system before hosting expensive traffic management implements such as flyovers. Meadows (2010) have mentioned that the insufficient width of both sides of the road and trading events on the footpaths are reasons for the matters. He has also mentioned that the "Marine Drive" project from Moratuwa to Dehiwala would be a good solution for the existing issue; here he suggests using water road instead of roadway. From Li, et al., (2013), they revealed that the probability of rear-end impacts is highest when traffic impending from upstream is at capacity state while traffic down-stream is highly congested. Md. Majumder and Islam found that two flyovers at Mohakhali and Khilgaon intersections of the city could not bring blameless outcome as it were expected before, as real field experience is not good-looking. In their study they took opinion from 80 businessmen from Mohakhali and 110 businessmen and 30 landowners from khilgaon and found that monthly revenue of businessmen has reduced after construction of the flyover. Job prospect has also been reduced on the neighbouring shops. But no study has been conducted on Moghbazar-Mouchak flyover.

4. DATA ANALYSIS

The field data and the questionnaire data has been analyzed through pie chart, bar chart which have been shown below:

4.1 Percentage of Different Vehicles Using the Flyover

A traffic survey was arranged to assess the percentage of different vehicles using the flyover. It was done using video camera. The data was collected on Sunday, Tuesday, Thursday, Friday and the time was 08.00AM to 09.00AM, 10.00AM to 11.00AM, 12.30PM to 01.30PM, 05.00PM to 06.00PM. So, the total four hours in each day was selected to count the vehicle. The average volume for different vehicles has been shown in the following table 4.1:

Table 4.1: Average Volume for Different Vehicles

Types of Traffic	Volume
BUS	303
PICKUP	541
CNG	2831
CAR	6404
MOTORCYCLE	3457

From the table it is seen that total five types of vehicles uses the flyover and the maximum number of vehicle using the flyover was private car and it is 6404 per four hour. The lowest number is 303 and it is for bus. The details of the survey have been demonstrated in the following pie chart in figure 4.1:

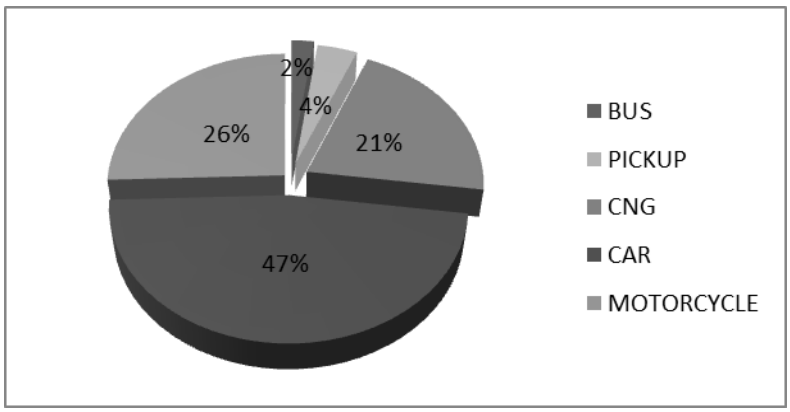

Figure 4.1: Average Volume for Different Vehicles

From the pie chart it is found that the maximum portion of the pie has been covered by private car and it is 47% of the total vehicle and the lowest portion is for the bus and it is only 2% of the total. It is concluded that maximum beneficiary of the flyover is private car user.

4.2 Vehicles in Different Days

The survey data was processed to find out the daily variation of the total traffic using the flyover. The details finding has been shown in the following table 4.2:

Table 4.2: Vehicular Volume in Different Days

Day	Volume
Sunday	13308
Tuesday	13202
Thursday	18482
Friday	9138

From the table it is found that on Thursday, maximum number of the traffic used the flyover and on Friday the number is lowest. One of the reasons for highest number of vehicle on Thursday may be that it is the day before weakened that day the total commuter is high on that day. The data from the table has been shown in the following bar chart in figure 4.2:

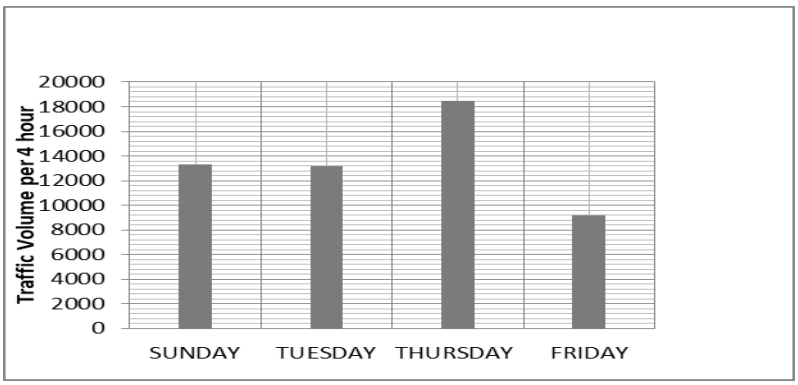

Figure 4.2: Variation of volume shown by the bar chart

From the bar chart it is shown that top of the bar is for Thursday and it is just upper than 18000 vehicles per four hours and the lowest bar is for Friday and the total vehicle per four hour is about just upper than 9000. As Friday is weekend in Bangladesh, the total road users are very low on that day.

4.3 Vehicle in Different Times

Traffic volume study is time dependent that's why, traffic survey was conducted to find out the total vehicles in different time. As we conducted the survey for four days. The average data of four days in different times in given below in the table 4.3:

Table 4.3: Total Vehicles in Different Times

Time	Volume
8.00AM -09.00AM	2848
10.00AM-11.00AM	3447
12.30PM-01.30PM	3068.5
05.00PM-06.00PM	4167

From the table, it is found that from 05:00PM to 6.00PM the road was occupied the highest number of vehicles and it is 4167. The second highest number of vehicle was found between 10.00AM to 11.00AM. The data was illustrated in the following figure 4.3:

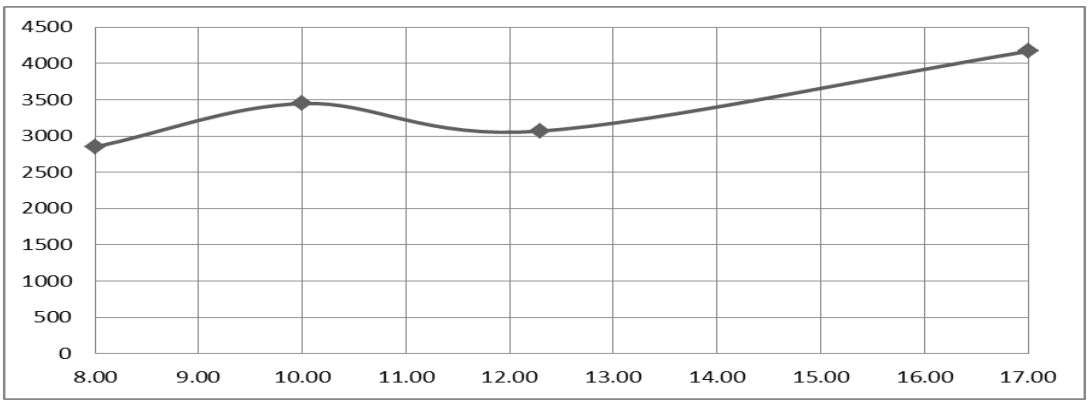

Figure 4.3: Total Vehicles in Different Times

Volume of traffic is increasing from 08:00AM to 10:00AM and then it's started to decrease up to 12:00PM and the highest pick is noticed at 05:00PM and the lowest pick is on 08.00AM.

The reason is for the highest pick for 05:00PM is that a large number of offices are closed at 05:00PM and the ramp of the flyover is just near the industrial zone.

4.4 Vehicular Variation in Per Hour

As volume of different vehicles have been collected for days average of four days data have been used to show the variation of volume of different vehicles on different times is given below in Table 4.4 :

Table 4.4: Vehicular Variation in Per Hour

Type of Vehicle	08.00am-09.00am	10.00am-11.00am	12.30pm-01.30pm	5.00pm-06.00pm
Bus	74	59.5	58.5	110.5
Pickup	160	171.5	120	89
Cng	522	808.5	699	801
Car	1296.5	1638.5	1446	2022
Motocycle	795.5	769	745	1144.5

From the table, the highest numbers of buses were noticed on 05:00PM to 06:00PM and the lowest number was seen on 08:00AM to 09:00AM. The highest volume has been seen by car on 10:00AM to 11:00AM. The data of the table has been illustrated in following figure 4.4:

4.5 Velocity of Different Vehicles

Instantaneous velocity of different vehicles in the mid portion of the flyover has been collected by using speed gun. The details finding regarding speed has been shown in the following table 4.5:

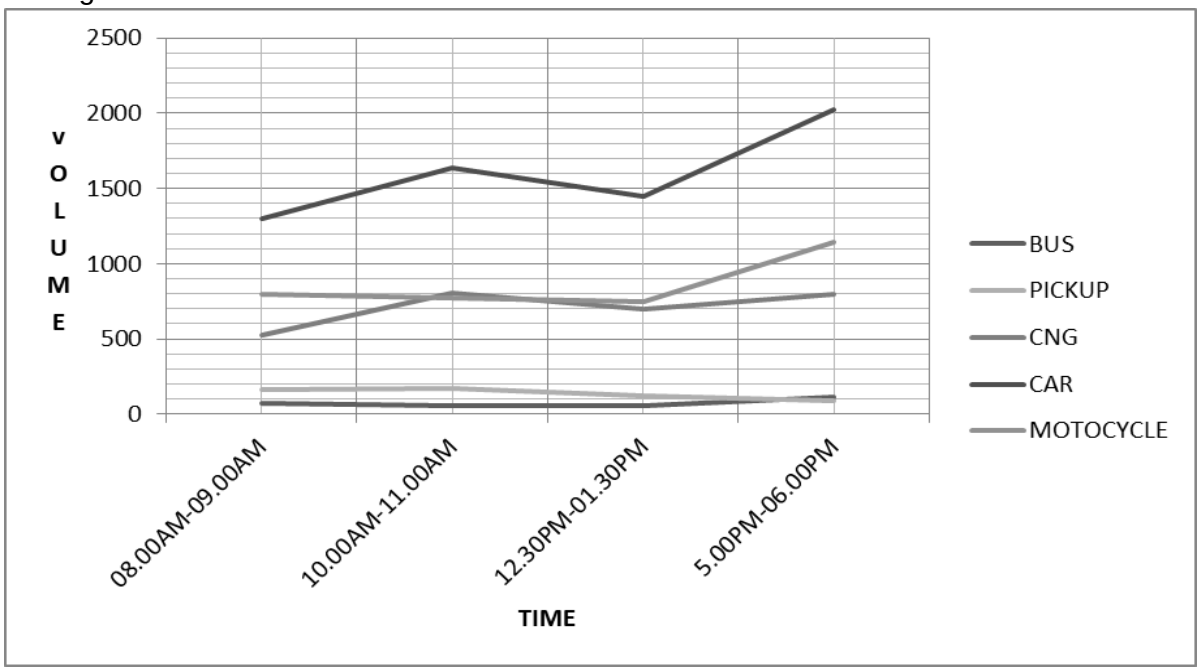

Figure 4.4: Total Vehicles in Different Times

Table 4.5: Velocity Variation in Mile per Hour

Type Of Traffic	Velocity(Mile/Hr)
Bus	17
Pickup	18
Cng	18
Car	20
Motorcycle	24

The data has been demonstrated in the following bar chart:

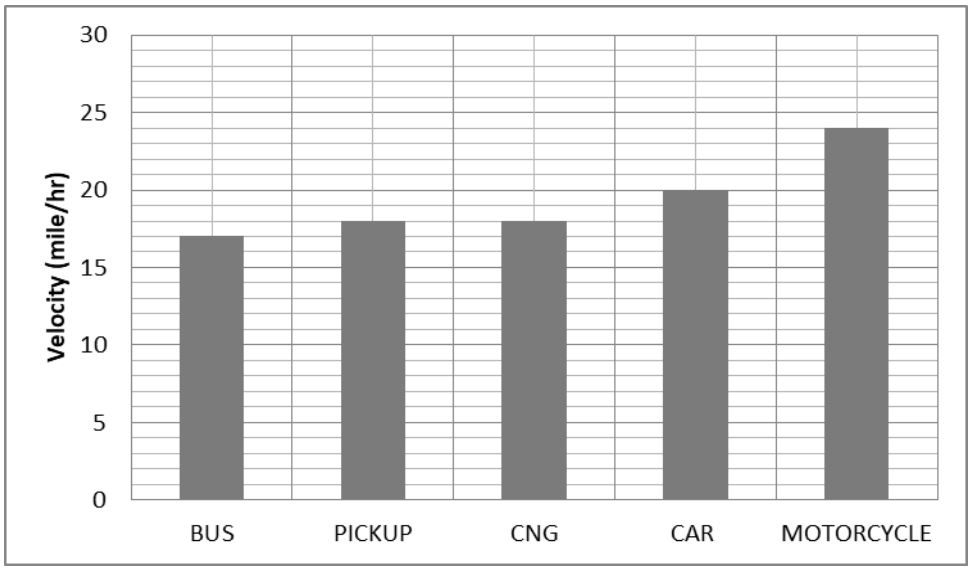

Figure 4.5: Velocity Variation with Type of Traffic (Mile/hr)

Among the vehicles, maximum speed was attained by motorcycle and it was 24 mile per hour and the operating speed of bus was only 17 miles per hour. Though the safe operating speed on flyover is 31 miles per hour, none of the vehicles could move with the maximum safe operating speed.

5. PERCEPTION ANALYSIS OF THE FLYOVER USERS

Three questions were designed and the respondents were the drivers of CNG, Bus and Car. Total sixty samples were collected.

5.1 Preferred Time

First question was designed for finding the preferred time for using the flyover. Three time ranges were selected for the questionnaire. The outcomes of the survey have been given in the following table and pie chart.

Table 5.1: Preferred Time and Respondents

	Time	Respondents
A	8AM-12PM	21
B	12PM-4PM	23
C	4PM-8PM	16

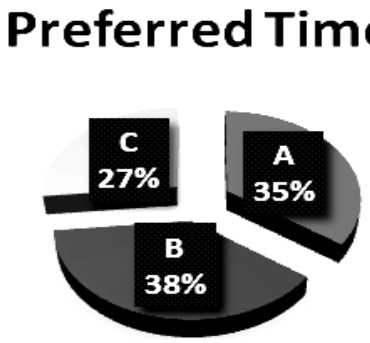

Figure 5.1: Preferred Time and Respondents with Pie Chart

A major number of respondents prefer the time 12.00PM to 04.00PM for using the flyover which is 38 % of the total. Drivers are interested to use the flyover at off peak hour as in this time flyover can help to reduce the travel time but at the peak hour it is not so much effective as congestion in the flyover kills their valuable time.

5.2 Fare Variations

Sometimes drivers demand extra charge for using the flyover especially the CNG driver. Total 56 answers regarding the extra fare were collected. These data have been processed to find out the fare variation in the following table and pie chart.

Table 5.2: Fare Variations and Respondents

Fare variation	Respondents
YES	18
NO	28

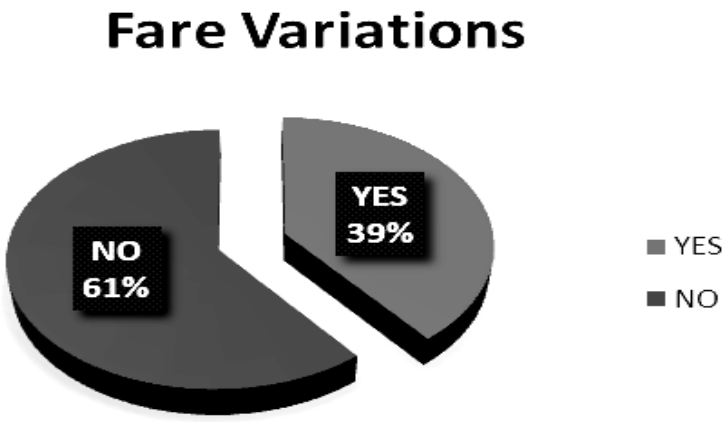

Figure 5.2: Fare Variations with Pie Chart

From the pie chart it is found that more than half (61%) of the drivers do not demand extra charge for using the flyover as it helps to reduce their travel time and fuel cost.

5.3 Savings of Travel Time

Travel time along with the fuel cost saving is the major issue for constructing the flyover. A question was set to find the effectiveness of flyover in terms of travel time. The data has been illustrated in the following table and pie chart.

Table 5.3: Travel Time and Respondents

Reduction of Travel time	Respondents
YES	44
NO	16

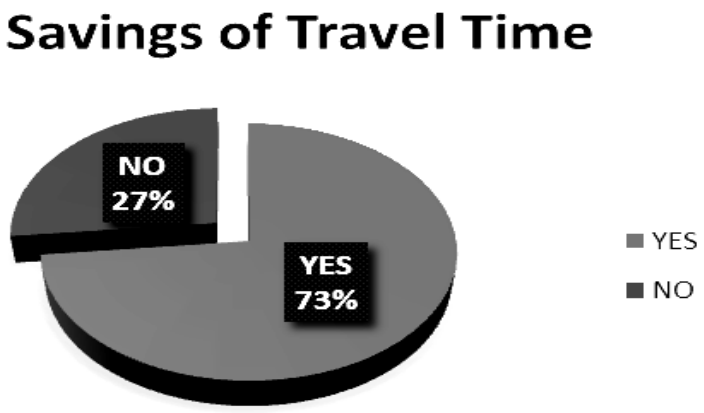

Figure 5.3: Savings of Travel Time

About three fourth (73 %) of the respondents believe that this flyover can reduce their travel but a few drivers (27%) gave the negative answer by mentioning that they have to face the congestion in the ramp of the flyover due to signals.

6. CONCLUSION AND FURTHER RECOMMENDATION

Though flyover has been constructed for mass number of public transport, highest beneficiary of this flyover is private car. About 47 % of the total vehicles are private car. The highest number of vehicles was seen on Thursday comparing to other day and after the office hours from 5.00 PM to 6.00 PM was the peak hour on the flyover. There was no pedestrian and bicycle facility on the flyover which indicates that it is not a sustainable solution for the environment. Through our study, data was collected on regular interval but data on night was not collected. As a result, traffic behaviour on night was not examined. Traffic flow on below the flyover was not considered. Hence, impact of flyover on the road below it was not evaluated. So, there is a large potentiality of future research considering the impact of traffic flow on the linkage road of flyover.

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CHILD PEDESTRIANS SAFETY FACILITIES CLOSE TO THE SCHOOL PREMISES LOCATED IN MAJOR ARTERIAL STREETS IN DHAKA CITY

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ABSTRACT

Children are at maximum danger of pedestrian collision, mainly because of the commencement of free movement while their skills and perception to use roads are not yet quite developed. The objective of this paper is to investigate the availability and adequacy of existing child pedestrian safety facilities at few selected school premises in Dhaka metropolitan area. A questionnaire survey was conducted at four vulnerable junctions identified out of fifty two (52) junctions previously surveyed by ARI, BUET. From these three junctions four (4) schools were selected, namely Dhanmondi Govt. Boys High School, Oxford International School, Monipir High School and College and Rajdhani Govt. High School. Parents took part in the survey on behalf of the students aging 3-5 years and 6-10 years. However students aged 11-15 years responded spontaneously at their own. Result shows that majority of the students' walk or use school van or private car on the way to and from school. Most of the students cross the road at their own responsibilities without using any pedestrian facilities. Only a few students use zebra crossing. It depicts that students are very much casual on crossing roads using existing facilities. More than half of the students claimed speedy vehicle is a major difficulty while crossing the road. There are number of methods that might enhance the safety of child pedestrians.

Keywords: *child pedestrian; pedestrian facilities; speedy vehicle.*

1. INTRODUCTION

Pedestrian injury is a significant cause of casualty and disability among children in developing as well as developed cities. Everyday thousands of people are killed and injured on roads worldwide. According to WHO report 1.24 million deaths and more than 30 million injuries worldwide caused by traffic accidents in 2010. Fatalities due to road accidents are frequent in developing countries encompassing 90% of the world's road fatalities. The burden of injury is heaviest among the poor with the burden greatest on children in the poorer countries with lower incomes (WHO, 2008). Approximately 95% of child injuries occur in low and middle income countries (Harvey et al., 2009). A study made by Sayer et al. (1997) revealed that on an average, 20 percent of all people killed in traffic accidents in developing countries are aged under 16. Another study (WHO, 2006) shows that on an average children in the age group 5-14 years, injury accounts for more than a quarter (27%) of all deaths worldwide. Children are at maximum danger of pedestrian collision, mainly because of the commencement of free movement while their skills and perception to use roads are not yet quite developed. Since children, especially those aged between 5 and 9 years, have to get to and from school, they may be exposed as "commuters," particularly if they walk to school, but also as they walk to and from the buses, cars or rikshaws that take them to school. Large portion of pedestrian injuries occur near schools, as children travel to and from school (Warsh et al., 2009; Abdel-Aty et al., 2007) and hence there is a greater chance of children being hurt near schools (Abdel-Aty et al., 2007).

Children between the ages of 5 and 9 years are at greatest risk for pedestrian death and injury, and comprise 49% of all child pedestrian fatalities (RTMC, 2008). Child pedestrian safety is likely influenced by individual differences in temperament and personality (Barton and Schwebel, 2007; Briem and Bengtsson 2000). Even children may have ample awareness to be safe pedestrians, their safety might be jeopardized if they are inattentive while crossing streets. Literature suggests that young children are less competent in traffic than adults because of poorly developed perceptual, attention, and cognitive abilities (Connelly et. al.1998; Dunbar et. al, 2001). Pedestrian safety is also influenced by the type of environment a child pedestrian walks within in several ways. The most significant hazardous issue may be the population and traffic density of that area. Since higher exposure to traffic consequences to greater pedestrian injury risk, children in urban with high population and high traffic density areas are more likely to experience pedestrian injury than those in less populated areas (Schieber and Vegega, 2002; Cho et al. 2009).

Dhaka is the capital city of Bangladesh and the tenth largest city in the world. Dhaka is situated in the economic and commercial heartland of Bangladesh. It has an estimated population of more than 15.5 million people in the greater Dhaka city which is expected to reach 36 million by 2024 (Hoque and Alam, 2002). Rapid urbanization and traffic growth has led to the high population densities and lack of delineation of people and vehicles (Sukhai, et al., 2004) in developing cities. The development of informal neighborhoods, especially those located beside arterial roads consequences a challenge where children and youngsters are compelled to traverse busy streets to and from school. A study by Bass et al. (1995) shows that child pedestrian injuries commonly occur on residential roads nearby or close to the child's home or school, whether in urban or rural settings. Unfortunately, lots of schools are located at Arterial streets in Dhaka city where children get a close contact to motor vehicles while commuting to school. Besides children are most at risk while crossing the road because of their age, psychology, immaturity and inabilities. Therefore, it is extremely essential to ensure safe environment for children while commuting to school. There is evidence that sometimes pedestrians do not use the facilities provided for them to cross the road (for example zebra crossing, overpass or underpass). It is also true that some of the pedestrian facilities are not well designed so that pedestrians are not interested to use it. Moreover policies and institutions related to pedestrians and walking environments in Asia shows that generally, there is lack of relevant policies dedicated to institutions and political support that cater the needs of the pedestrians (Leather et al. 2011).

Pedestrian's especially children are among the most vulnerable road users group as they travel to and from school. Engineers are challenged to design safe and convenient pedestrian facilities that will function well even for those persons who purposely or unconsciously disobey rules of safe walking behavior. An inclusive strategy to prevent child pedestrian injuries as well as to improve pedestrian safety is to increase childrens road safely knowledge and skills (Duperrex et al., 2002; Wyke et al., 2007). Pedestrian safety education can enhance children's knowledge and observed road crossing behavior, but the range to which this lessens actual child pedestrian injury occurrence is unknown (Duperrex et al., 2002). The value of child pedestrian safety education versus the implementation of engineering countermeasures has long been debated by researchers (Schieber and Vegega, 2002).The specific objective of this research is to investigate the availability and adequacy of existing child pedestrian safety facilities at few selected school premises in Dhaka metropolitan area.

Following this introduction, description of the study area is provided in Section 2. Survey methodology followed by data analysis is portrayed in Section 3. The final section of this article provides a conclusion regarding the results of the analysis.

2. DESCRIPTION OF STUDY SITES

The study has been conducted in the greater Manik Mia Avenue area and in Mirpur area in Dhaka city. The survey was conducted near four vulnerable junctions identified out of fifty two (52) junctions previously surveyed by ARI, BUET. Four (4) schools located near the junctions were selected for the survey namely Dhanmondi Govt. Boys High School, Oxford International School, Monipir High School and College and Rajdhani Govt. High School were. Moreover all of them are located on major arterial streets. Study locations of this research are given in Figure 1 and Figure 2. From 1998-2012, 43 accidents occurred in the Manik Mia Avenue and Indira road junction which is the 2nd highest number of accidents among the 4 junctions in the study site. From 1998-2012 total 38 accidents occurred in the junction just in front of the Dhanmondi Govt. Boys' High School of which 12 accidents involved pedestrians. The junction (Lalmatia - Aarong) connecting Mirpur Road and Manik Mia Avenue has the highest number of accidents among the junctions of the study area. In 14 years from 1998-2012, 48 accidents occurred in this junction. This junction also has the highest number of pedestrian accidents. There were 18 accidents involving pedestrians in

Figure 1: Google Map of Study Locations

Oxford International School Main Campus besides Dhanmondi 27 (major arterial road)

Dhanmondi Govt. Boys High School besides Mirpur road (major arterial road)

Monipur High School & College, Shewrapara, Mirpur (major arterial road)

Rajdhani High School, Besides Manik Miah Avenue (major arterial road)

Figure 2: Study locations

this junction during this period among which 11 accidents were fatal. Majority of the victims (12 victims) were near the center line of the road when they met the accident.

3. METHODOLOGY

The research involves two step survey procedures which includes questionnaire survey and model development. The questionnaire survey was conducted during the morning peak period (just before school starts) and during noon when school ends. In-person interview survey method was adopted. A set of 17 questions were asked to 400 respondents. The survey was conducted near four schools located close to the vulnerable junctions identified out of fifty two (52) junctions previously surveyed by ARI, BUET. Near these four junctions four (4) schools were selected, namely Dhanmondi Govt. Boys High School, Oxford Intl. School, Monipir High School and College and Rajdhani Govt. High School for te survey. Parents took part in the survey on behalf of the students aging 3-5 years and 6-10 years. However students aged 11-15 years responded spontaneously at their own. For the research, binary logistic regression model was developed with 390 complete questionnaires.

3.1 Questionnaire Survey

The questionnaire was divided into three parts. First part was about respondents demographics information such as their age, occupation, gender and main mode of travel. Second part consists questions regarding the existing condition of crossing facilities near schools and the role of guardians or accompanying person during crossing roads. Crossing facilities refer to foot over bridge, zebra crossing, traffic/community police, and traffic signal in this research. Third part was respondents opinion about the reason of accidents, and users level of interest to follow traffic rules & regulations.

3.2 Results

3.2.1 Travel mode to and from school

Majority of the students come to school on foot, or by rikshaws or school van or by private car. Few students come by public bus or school bus as shown in Figure 3.

3.2.2 Problems faced by the respondents during crossing the road

Most of the respondents (75%) focused on speedy vehicle as major problem while crossing the roads on the way to and from school as shown in Figure 4. Some expressed that scattered rikshaws (11%) and sidewalk with street shops (6%) as problems while crossing. Non-availability of foot-over bridge or zebra crossing is also a problem as expressed by the respondents.

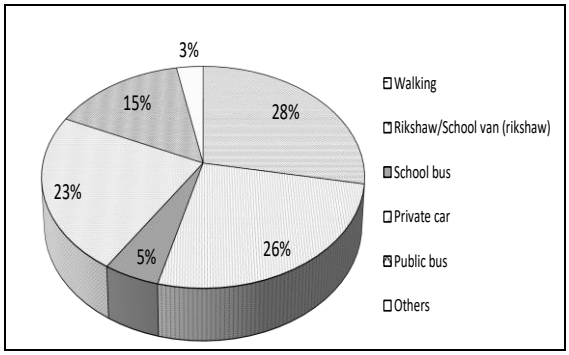

Figure 3: Travel mode during coming to school

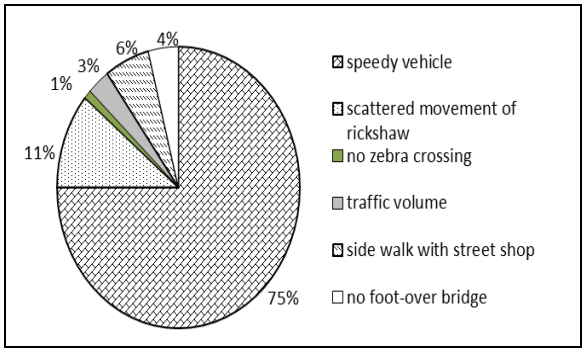

Figure 4: Problems faced by the respondents during crossing the road

3.2.3 Students accompanied by adults' on the way to school

Majority of the students are accompanied by an adult on their way to school as revealed in Figure 5. Students within the age group of 3-5 years are always accompanied by parents. Students in the age group of 11-15 are not accompanied by adults always.

3.2.4 Utilization of road crossing facilities

Most of the students (77%) cross road on their own responsibility without using any pedestrian facilities. Some of the students (12%) use zebra crossing. Very few (8%) students use foot over bridge even if it is available on the site as revealed in Figure 6. Only 3% of the students take help from traffic/community police while crossing the road. Whatever facilities might be available on the site, very few students are particular in using those facilities. 50% of the respondents replied they use the existing facilities sometimes, 30% use the existing facilities always, and 20% never use them.

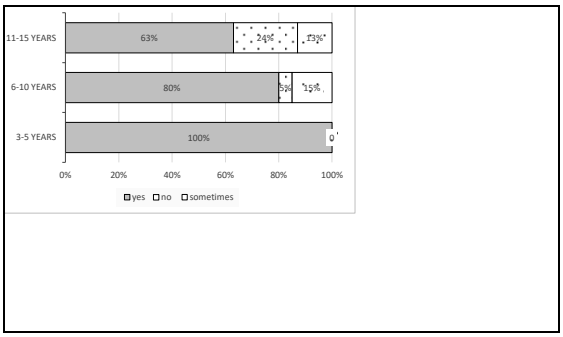

Figure 5: Percentage of students accompanied by an adult

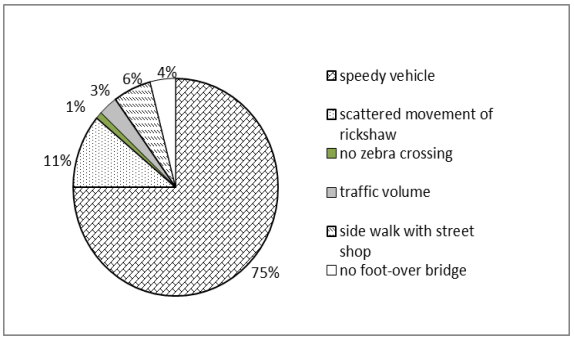

Figure 6: Utilization Road Crossing Facilities

3.2.5 Problem on the sidewalk

The respondents were asked abut the problem they face while using sidewalk. Figure 7 shows that 42% of respondents do not use sidewalk because of roadside hawker, 21% due to other reasons (for example may be due to tiredness), 20% due to presence of dustbins/garbage and rest (17%) of respondents do not use due to presence of cycles or motor cycle.

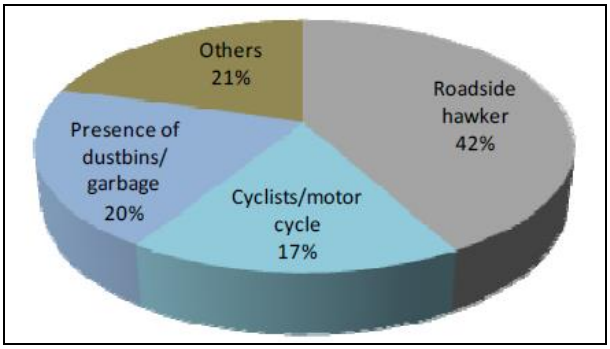

Figure 7: Respondents opinion about the problem they face while using sidewalk

3.3 Binary Logistic Regression Model

The Binary Logistic Regression (BLR) model is one of the most commonly used statistical techniques for the analysis of binary categorical response variable (Nelder and Wedderburn, 1972; Agresti, 2007). The model assumes a binomial distribution for the binary dependent variable and a logit link function. Binary logistic regression analysis was employed in this research to explore the adequacy of crossing facilities near selected schools using software LIMDEP. The model parameter estimates are provided in Table 1. The model coefficients has very small *p-value*, i.e. far lower than .05, which means the independent variables make a significant difference in predicting the adequacy of crossing facilities. The value of the chi-square distribution with 8 degrees of freedom is 51.997. For the Binary logit regression "Hosmer and Lemeshow test" was conducted fo check the goodness-of-fit. The value is less than 0.05 inferring a good model fit. In this research, the demographic variable gender has substantially contributed to explain the adequacy of crossing facilities. The coefficients for gender were negative, which implied that male thinks that the crossing facility is not adequate for their children which is opposite for females. In the model, choice of vehicle type to and from school was found significant. Those traveling by rickshaw think the facility is adequate for child pedestrians. The reason may be that rikshaws drop the passengers near the school gate and can pick them from close to the school as well. There is a probability that

Table 1: Binary Logistic Regression model for adequacy of crossing facilities in Dhaka city

Variables	B	S.E.	Sig.	Exp(B)	95% C.I.for EXP(B)	
					Lower	Upper
Gender (male)	-.614	.252	.015	.541	.330	.886
Cross			.572			
1) Alone	-.801	.768	.297	.449	.100	2.021
2) With guardian	-.790	.767	.303	.454	.101	2.039
Vehicles			.153			
1) Rickshaw Cycle	.763	.374	.041	2.145	1.030	4.468
2) Bus	.695	.411	.090	2.004	.896	4.480
3) Walking	.815	.460	.077	2.258	.917	5.562
Facility			.041			
1) Own responsibility	.834	.550	.129	2.302	.784	6.764
2) Manual police	1.432	.587	.015	4.188	1.327	13.225
Speed	.831	.527	.115	2.296	.817	6.453
Foot over bridge	.034	.425	.937	1.034	.450	2.378
Sidewalk			.853			
1) Road side hawker	-.253	.510	.619	.776	.286	2.109
2) Cyclists Motorcycle	.037	.572	.949	1.037	.338	3.180
3) Presence of dustbins/ garbage	-.018	.634	.977	.982	.283	3.402
4) Rickshaw	-.176	.434	.685	.839	.359	1.962
Accident			.609			
1) Fault of drivers	-.274	.305	.368	.760	.418	1.381
2)Lack of knowledge of pedestrian	-.040	.339	.906	.961	.494	1.867
Drivers			.501			
1) Careless	-.035	.411	.933	.966	.432	2.162
2) Over speeding	-.419	.470	.373	.658	.262	1.654
Defective Vehicles			.001			
1) Brake	2.112	.561	.000	8.262	2.754	24.790
2) Tire burst	1.401	.977	.152	4.057	.597	27.560
3) Mechanical fault/lack of fitness	.207	.341	.543	1.231	.631	2.400
Pedestrian			.022			
1) Careless	-.474	.414	.252	.622	.277	1.400
4) Negligence of traffic Law	.378	.513	.462	1.459	.534	3.986
Dangerous			.227			
1) Rickshaw/ cycle/car/minivan	3.047	1.538	.048	21.051	1.033	428.86
2) Laguna tempo	2.166	1.453	.136	8.725	.506	150.36
5) Bus	.615	.527	.243	1.849	.659	5.191
Forbidden			.207			
1) Laguna	.623	.940	.507	1.864	.296	11.759
2) Bus	2.708	1.545	.080	14.993	.726	309.77
Ability			.046			
1) Significantly	2.824	1.254	.024	16.838	1.442	196.670
2) Better than average	3.106	1.229	.012	22.337	2.008	248.53
3) Average	2.351	1.258	.062	10.498	.893	123.47
4) Worse than average	2.725	1.288	.034	15.254	1.221	190.57
Teach	.797	.307	.009	2.218	1.216	4.044
Chi squared test: χ^2 = 51.997; df = 8; p-value = .00						
Hosmer and Lemeshow test χ^2 =12.942; df = 7 ; p-value = .013						

respondents who cross the road with the assistance of mannual/community police think that the crossing facility is adequate. Defective vehicle specially brakes are the main reason of accidents as perceived by the respondents. The respondents perceive that Rickshaw/Cycle/car/minivan are maily responsible for pedestrian accidents. Respondents who rate their child's ability to safety cross the road compared to other children of same age perceive the crossing facilities are adequate. Result shows that respondents who teach their child to follow traffic laws or rules perceive the crossing facilities are enough.

4. CONCLUSION

This study reveals the respondents' perception about the availability and adequacy of existing child pedestrian safety facilities near the school premises of Dhaka metropolitan area. The problems faced while using sidewalk are roadside hawkers, presence of dustbins/garbage, cyclists/motor cycle etc. Most of the children, cross the road at own responsibility without using any crossing facilities. Children may not always posses adequate knowledge to comprehend the danger and cannot accurately judge oncoming vehicles speed and distance. Moreover it is somewhat difficult for a child to decide safe crossing points in the road etc. This paper aims to identify some of the factors associated with child pedestrians crossing facilities for young child under the age of 16 years in few particular school locations in Dhaka city, to raise awareness of the issues amongst the users. Although guardians are much aware of their children safety yet they do not follow safety rules during crossing the road.

Based on the study it can be inferred that rickshaw/cycle/car/minivan are maily responsible for pedestrian accidents as observed by the respondents. Respondents who rate their child's ability to safety cross the road compared to other children of same age stated that the crossing facilities are adequate.

Parents tend to believe their children are safe pedestrians and allow their children to walk alone on streets, despite the fact that they recognize the limitations of child pedestrian skills (Morrongiello *et al*., 2009). Because of the carelessness and inattentiveness accidents occurs while crossing the road. A major contributory factor in many of these accidents is a lack of road safety knowledge leading to unsafe behavior by children and guardians who accompany the children. In order to attain safe pedestrian capabilities parents, teachers or elders should train children to cross independently together with following safety rules. In addition to education, parents and authorities should encourage for safer pedestrian atmospheres. Education can train children to become safe and independent road users (Quimby, 2001). The objective of road safety educational programs is to reduce pedestrian injuries usually emphasise on furnishing individuals with information and skills to safely accomplish the traffic environment. Few recommendations can be considered as footpath should be free from hawkers and traders and motor cycle or car parking. Footpath should be user-friendly and free from garbage. Foot over bridge on major arterial roads is essential for the safety of child pedestrian. To improve the facility more, ability to cross the road safely and also to acknowledge child pedestrians about rules and regulations is very important.

It is expected that the results of this study could lead to better understanding of pedestrian crossing behavior in Dhaka and support policy makers in their decision making regarding the improvement of road crossing facilities in Dhaka city and thereby contribute to decrease fatality.

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ASSESSING BUS SERVICE QUALITY BASED ON PUBLIC PERCEPTION: A CASE STUDY IN CHITTAGONG CITY

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ABSTRACT

This paper proposes a methodology for evaluating the quality of service perceived by users of a bus transit service. Even though bus service plays crucial role for transportation of significant number of people in emerging cities, their services are frequently insufficient to meet demand. A quality service is necessary to retain the users and to attract new user for using public transport more, rather than the individual transport to reduce traffic congestion. The main aim of this paper is to assess the service quality (SQ) of bus in Chittagong city based on public perception. Achieving the research objective, a questionnaire survey was conducted on 12 major locations of Chittagong City. 715 regular city bus users of different profession participated in the survey in June, 2017. The result shows that about half of the users in Chittagong city rated overall bus service quality as poor. The respondents evaluated the bus service quality attributes for example convenience, frequency, punctuality, fitness, reliability, waiting time, seat conditions, noise level, personal safety, cleanliness and travel time during office days as poor while movement flexibility inside the bus, courtesy of helpers/conductors, behavior of driver, level of personal safety inside the bus were ranked very poor. However the respondents perceive that speed of bus, availability of information of bus, transport cost, lighting facility and travel time during holidays are satisfactory. The findings of this study offer significant comprehensions for enhancing the bus service presently being offered and the aspects on which the greater attention may be provided.

Keywords: *Chittagong city, Bus Service Quality, Users' Perception*

1. INTRODUCTION

Bus service performs a significant function for movement of considerable number of people in developing cities where the mobility needs are increasing due to rapid urbanization. Even though bus service plays crucial role for transportation of significant number of people in emerging cities, their services are frequently insufficient to meet demand. Usually the services provided by the buses are insufficient (Ali, 2010). Users' are accommodated to meet up their mobility needs by public buses with associated challenges in delay and discomposure (Davidson and Knowles, 2006) leading to dissatisfaction (Aidoo et al, 2013).

Chittagong is the second largest metropolis and Chief port of Bangladesh, with density of 47,500 people per square mile (Demographia, 2017). Although other modes of transportation like railway and waterway exist in this metro city, they are not suitable for the internal transportations. Hence, the roadway is the most operational transportation system in Chittagong city like other overcrowded cities in the world. The majority of trips in Chittagong are served by public transport since a significant numbers of people can't afford personal vehicle. As the fare of non-motorized transport (NMT) or other para-transits are more expensive than the bus fares (Rahman, 2009), most of the people are heavily dependent on public transport for their travel (Hossain 2006). However, non-motorized transport (NMT) or

other para-transits users may use the bus or other mass transportation services if it provides safe and adequate facility to the passengers.

Public transport system of Chittagong city necessitates significant improvement of service quality, which can be accomplished by a comprehensive understanding of travel behavior and its user needs and expectations for explaining the factors affecting bus service quality which can help policymakers to implement targeted improvement strategies. The research explores the overall situation of bus service; particularly the major problems the passengers are facing, based on their experience on existing service quality. The main aim of this work is to assess the service quality (SQ) of bus in Chittagong city based on public perception.

2. LITERATURE REVIEW

Passenger satisfaction in transport perspective may result by the judgment of expectations previous to travel and experience followed by the travel. Satisfaction is accomplished if a feeling of contentment results comparing users experience to their expectation. The expected service quality can be achieved by giving priority to the most important variables those affect the users to make a decision about to use or not to use the public transport service. Service quality (SQ) is perceived as an important determinant of users' demand (Prioni & Hensher, 2000) to identify importance of service quality for users' satisfaction. According to Parasuraman et al, (1988) the feeling of satisfaction may depend on several factors like service quality, product quality, price, status and individual attributes.

Service quality is a measure of how well the service level that is delivered matches customer expectations, while a firm delivering quality service means conforming to customer expectations on a consistent basis (Joewono and Kubota, 2007; Transportation Research Board, 1999, 2004; Lai and Chen, 2010). Service quality is an abstract concept that is hard to be defined, and in practice, often used interchangeably with satisfaction (Lai and Chen, 2010; Sumaedi et al. 2011).

Oliver (1997) explains that service quality is more specific and related to cognitive judgments while satisfaction is more holistic and associated with effective judgments. Furthermore, other researchers (Parasuraman et al. 1994; Zeithaml and Bitner, 1996;) stated that satisfaction judgments include many factors, i.e. product quality, price, situation and personal attributes, not to mention service quality.

Several researches have shown that reliability (arrival of bus on time) is an influential factor (Hensher et al. 2003; Disney 1999) whereas convenience and comfort such as cleanliness of bus service, availability of seat, physical condition, light, fan, seat condition are well known arguments (Anable, 2005). Other important and major aspect is safety (Eboli & Mazzulla 2007; Fellesson & Friman 2008; Eboli & Mazzulla 2012). Tyrinopoulos & Antoniou (2008) indicated that the key satisfaction indicators were the service frequency, transfer distance, ticketing system, and vehicle cleanliness. (Rohani et al. 2013) suggested that bus service reliability, safety, comfort and cleanliness are the major factors for bus service in Dhaka. Rahman and Nahrin (2012) found that most of the respondents are satisfied with the cost of ticket but very unsatisfied with the waiting time as they have to wait for the bus sometimes about an hour. Mannan & Karim (2001) stated that long waiting time, delay on regular schedule, overloading, discomfort, long walking distance from the residence and work place to bus stop and struggle for acquiring seats are some of the obvious problems faced by the users in their daily life. According to Alam et al., (2012), cheapest mode available as mass transit, are constrained by poor service conditions: long waiting, delay on plying, overloading and long walking distance from the residence/work place to bus stoppage. Hossain et al. (2012) pointed out that the excessive travel time, waiting time and dreadful services in terms

of comfort, regularity and on-time performance hindered the prospect of the public bus service of Dhaka city.

Regarding the safety and security condition, main three reasons of dissatisfaction of passengers' are unsafe driving practices, poor boarding and alighting facilities and lack of law enforcing agencies surveillance, that reason the service make unsatisfactory including irregular service provided by buses, regular overcrowding, lack of good standard buses and lack of cleanliness. In spite of these negative views, users' possessed a positive attitude for buses which is the low travel cost (Rahman et. al. 2017).

3. METHODOLOGY

A comprehensive questionnaire survey was carried out face to face at 12 locations of major bus stands in Chittagong city. The survey was conducted in June 2017 at Agrabad, Nasirbad, Khulshi, G.E.C. Circle, New Market, Andarkilla, 2 No. Gate, Halishohor, Gosaildanga, Jamal khan, Cheragi hill and Bohaddar hat in Chittagong city. The survey was accomplished between 09:00 am to 05:00 pm during morning and evening peak periods. The questionnaire had a total 40 questions including seven main parts regarding "Trip characteristics", "Quality of service", "Quality of bus", "Safety and security of bus", "Quality of bus stop", "Courtesy of Helpers/Conductors" and "Reliability and accessibility of bus". The passengers were asked to rate their perception on these service components on a five point likert scale ranging from 1 to 5 (1 is for 'excellent' and 5 is for 'very poor'). Total 715 samples were interviewed by seven enumerators. Table 1 shows general information of respondents.

Table 1 General information of Respondents

Features	Statistics
Gender	Male (71%), Female (29%)
Age	10~19 Years old (13%), 20~29 Years old (48%), 30~39 Years old (25%), 40~49 Years old (10%), 50~60 Years old (3%), >60 Years old (1%)
Occupation	Student (45%), Private Service (24%), Public Service (12%), House Wife (6%), Labor (4%), Businessman (9%)
Monthly income	<10000 Tk. (31%), 10000~30000 Tk. (45%), 30000~50000 Tk. (16%), 50000~70000 Tk. (7%), >100000 Tk. (1%)
Cars ownership	Did not any car (87%), A unit (11%), Two units (2%), Three units or more (0%)
Motorcycles ownership	Did not own any m-cycle (71%), A unit (23%), Two units (6%), Three units or more (0%)
Main mode of travel	Bus (86%), Rickshaw (2%), Para transit (2%), Motorcycle (7%), Car (3%)
Monthly travel expenditure	1%-10%Travel cost (38%), 11%-20% Travel cost (47%), 21%-30% Travel cost (13%), >30 Travel cost (2%)
Trip purpose	School/College/Polytechnic/University (45%), Office/Business (39%), Emergency/Hospital (3%), Park/Zoo/Museum (1%), Other (12%)
Reason of using bus	Low cost (63%), No own transport (20%), No other option (9%), Safety (6%), Fast travel (2%)
Users take mode to get bus stop	By waking (62%), Rickshaw (27%), Para transit (8%), Motorcycle/Cycle (2%), CNG (2%)
User time for reach bus stop	5 min (25%), 10 min (43%), 15 min (20%), 20 min (9%), 25 min (4%)

Data Analysis and Results

According to the survey report maximum (75%) respondents' answered they travel by local bus every day while 14% replied they travel more than twice a week but not every day.

Figure 1 shows users' frequency of travel by local bus. Figure 2 shows that about half of the respondents (51%) answered that the convenience of service of bus is poor while 28% answered satisfactory and 15% answered very poor. 6% of the users consider the convenience of service is good.

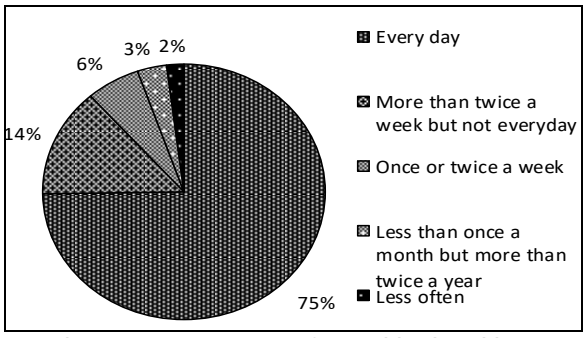

Figure 1: Frequency of travel by local bus

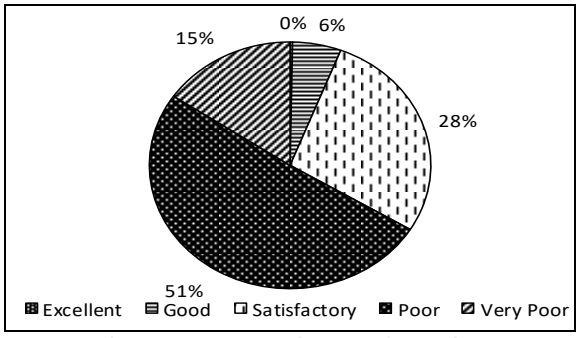

Figure 2: Convenience of Service

About half (51%) of the respondents' answered the frequency of the bus service is poor while 36% answered satisfactory. 10%, 2% and 1% answered good, very poor and excellent respectively as shows in Figure 3. Result shows that more than half (55%) of the responded replied the punctuality of service is poor while 22% responded satisfactory and 19% replied very poor as shown in Figure 4.

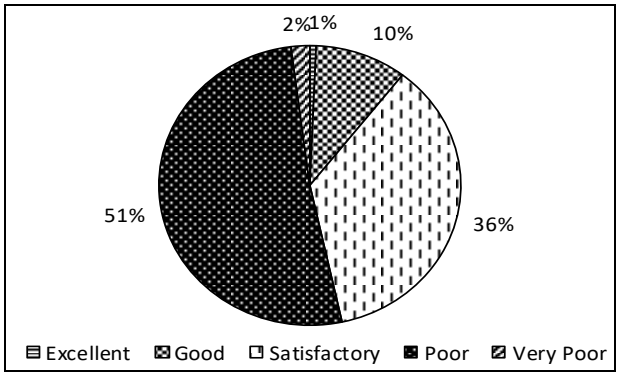

Figure 3: Frequency of bus service

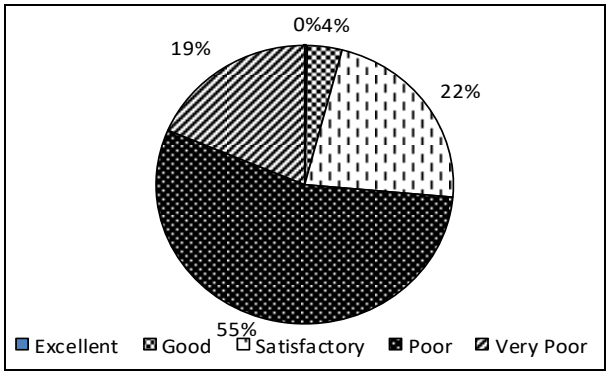

Figure 4: Punctuality of transport

Result shows that 49% of the respondents answered the movement flexibility on road is poor while 22% and 28% answered satisfactory and very poor respectively as shows in Figure 5. Figure 6 shows the sitting arrangements inside the bus for men and women. 42% of the respondents rated it as poor and 41% replied very poor. 15% of the responded consider the sitting arrangement as satisfactory.

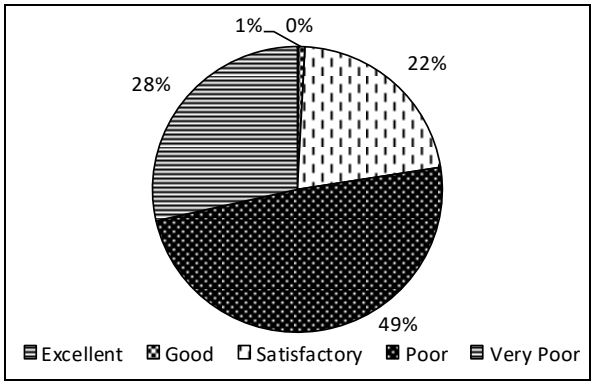

Figure 5: Movement flexibility (On Road)

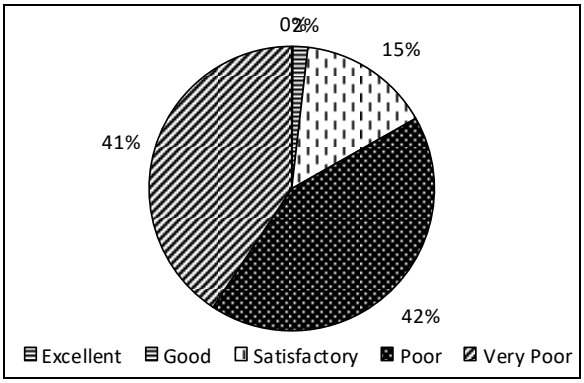

Figure 6: Sitting Arrangements

About 38% respondents assessed the speed of the bus as satisfactory while 30% and 23% evaluated as poor and very poor as described in Figure 7. Nobody rated the speed of bus as excellent. About 36% respondents rated the availability of information of bus service as satisfactory while 31% ranked poor as shows in Figure 8.

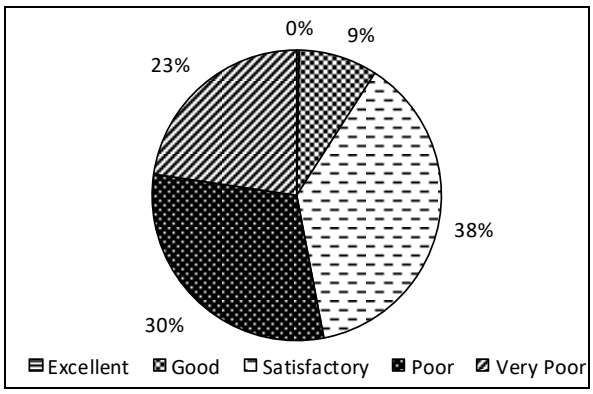

Figure 7: Speed of bus

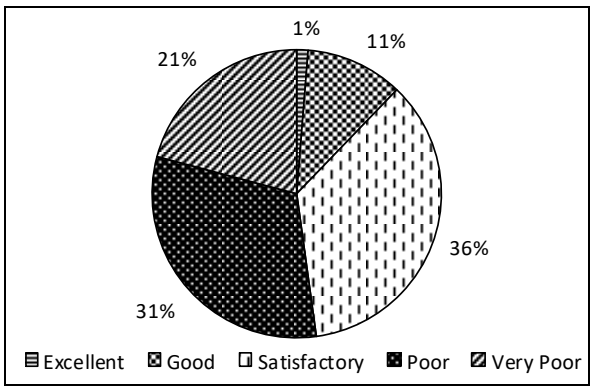

Figure 8: Availability of information of bus

40%, 30% and 19% of the respondents rated the ticketing system poor, satisfactory and very poor respectively as shows in Figure 9. Figure 10 shows that in Chittagong city majority (55%) of the respondents perceive the transport cost as satisfactory while 18% respondents think it as poor.

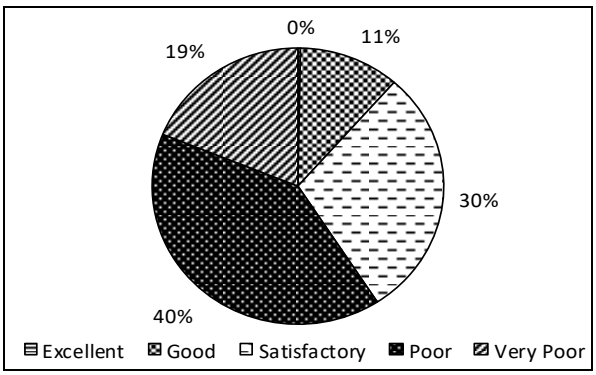

Figure 9: Paying fare/Ticketing system

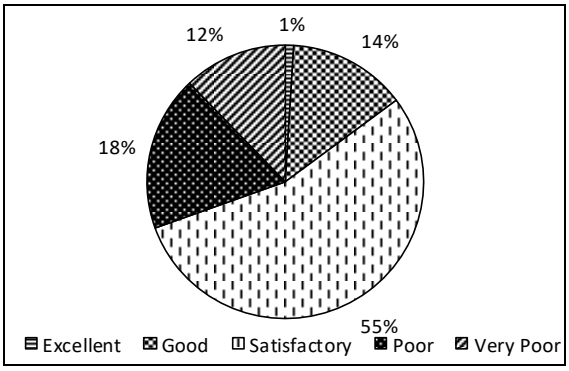

Figure 10: Transport cost

About half (49%) of the respondents expressed that the overall fitness of bus is poor while 29% said very poor and 20% said satisfactory as shown in Figure 11. As illustrated in Figure 12, majority of the respondents (55%) said that the seat condition of bus is poor 37% revealed it as very poor. said by (55%) and 37% respondents respectively.

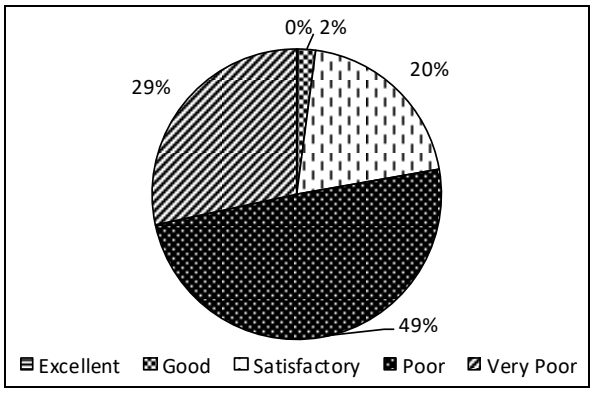

Figure 11: Fitness of bus

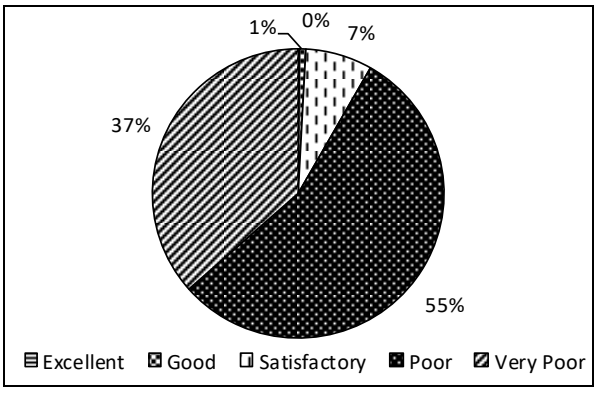

Figure 12: Seat condition

Figure 13 shows that about half of the users' (51%) answered that the cleanliness of bus is poor while 30% and 17% replied very poor and satisfactory respectively. About 55% users strongly agree that the bus is always over crowded as shown in Figure 14.

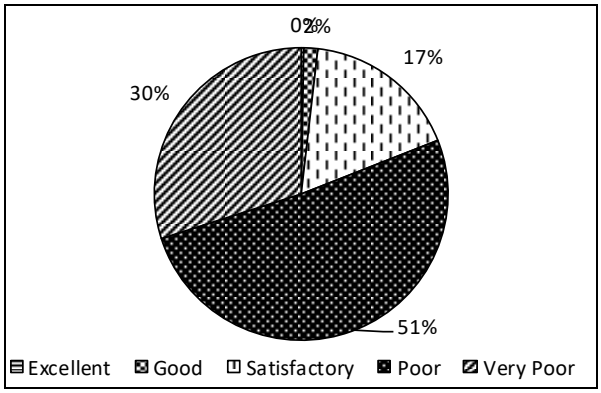

Figure 13: Cleanliness of bus

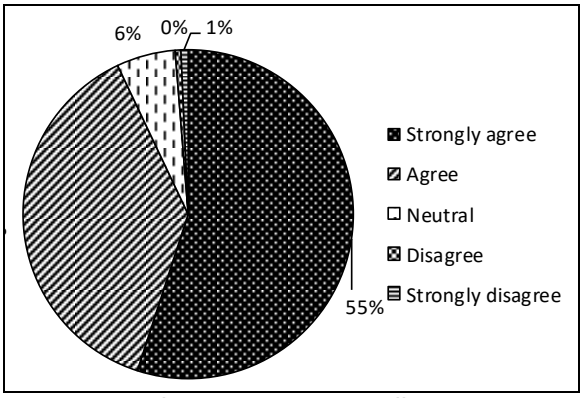

Figure 14: Overcrowding

Figure 15 shows the lighting facility of bus services. According to the survey report maximum (43%) respondents perceive that the lighting facility is satisfactory while 39% answered poor. Figure 16 shows maximum (54%) respondents rated the noise level of the bus as poor.

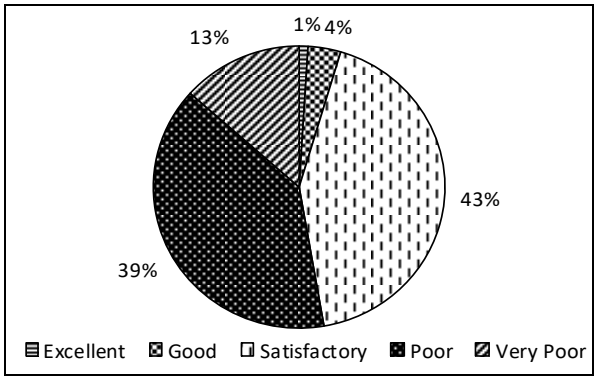

Figure 15: Lighting facility

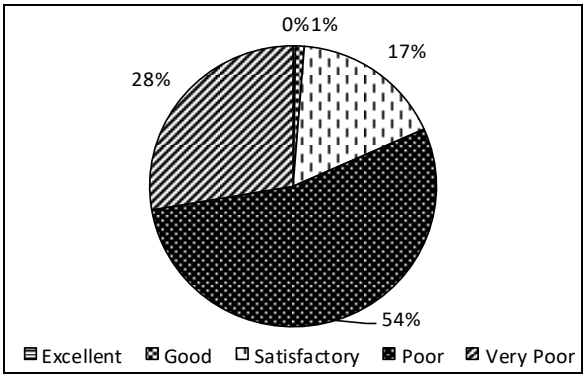

Figure 16: Noise level of the Bus

Figure 17 illustrates that about half of the respondents (51%) perceive that the movement flexibility inside the bus is very poor and 41% think poor. Figure 18 shows that respondents' opinion about the comfort level of bus service ranges from poor (49%) to very poor (42%).

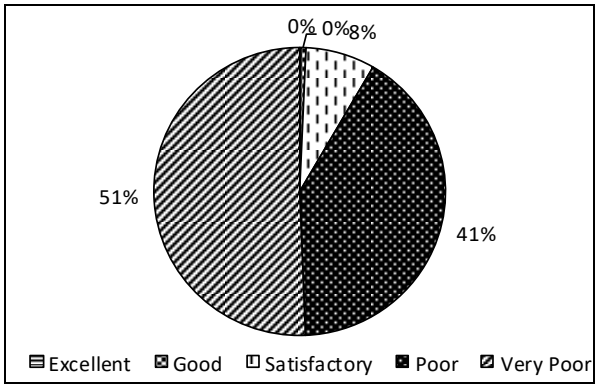

Figure 17: Movement flexibility (Inside)

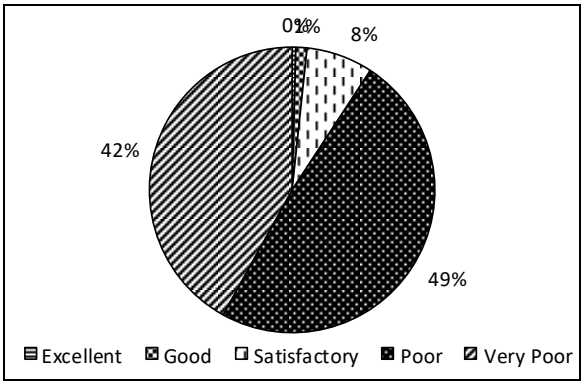

Figure 18: Comfort level

Most of the respondents (62%) assessed the physical condition of bus as poor while 14% and 24% answered satisfactory and very poor respectively as described in Figure 19. Respondents were asked to rate the quality of bus services. About half (53%) of the

respondents' rated the service quality as poor while 20% ranked as satisfactory. 24% of them thinks that the service quality is very poor as shown in Figure 20.

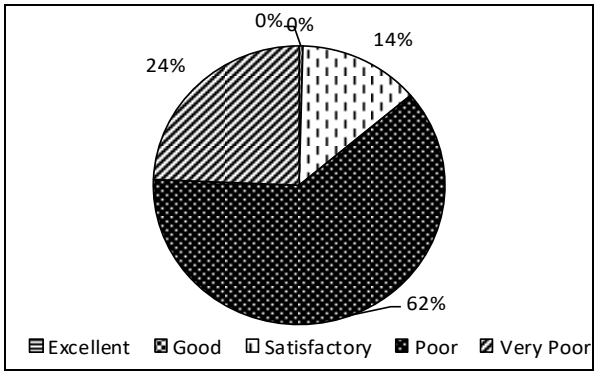

Figure 19: Physical condition

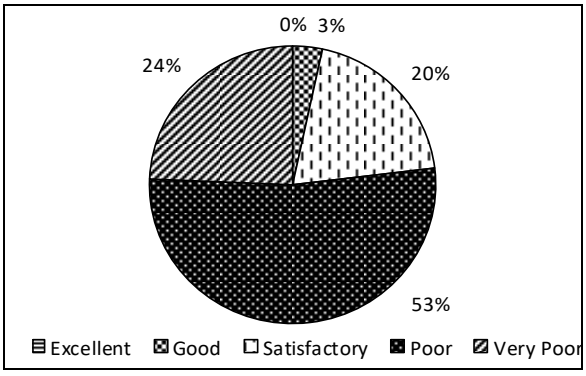

Figure 20: Quality of bus services

Figure 21 shows that 52% of the respondents' ranked the cleanliness of bus stop as poor while 33% and 14% rated very poor and satisfactory respectively. About half (52) of the respondents' replied that the condition of bus stop is poor as shown in Figure 22.

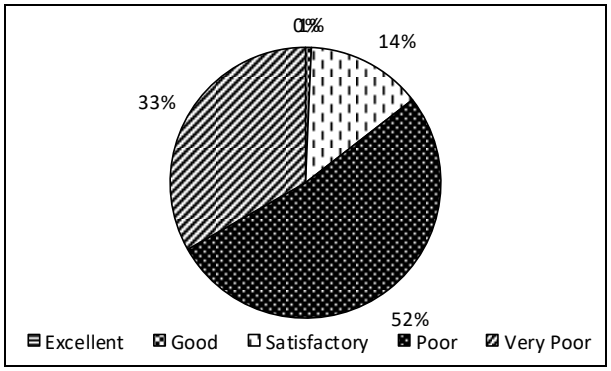

Figure 21: Cleanliness of bus stop

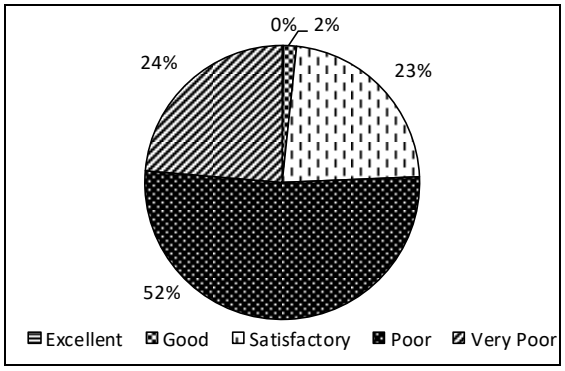

Figure 22: Condition of bus stop

Figure 23 shows users' perception about ease of entry and exit facilities of bus. Majority (55%) of the respondents rated it as poor while 36% replied very poor. Figure 24 shows that about half (50%) of the users in Chittagong city perceive the courtesy of helpers/conductors is very poor.

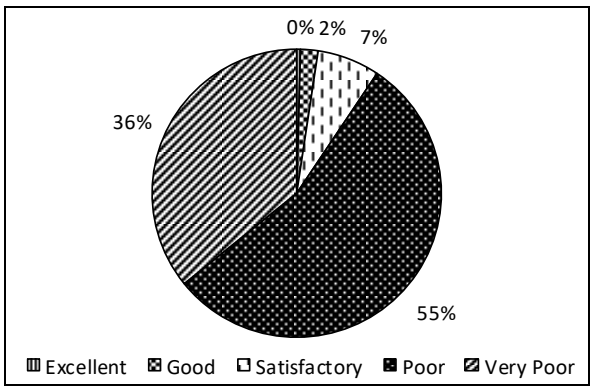

Figure 23: Entry and Exit

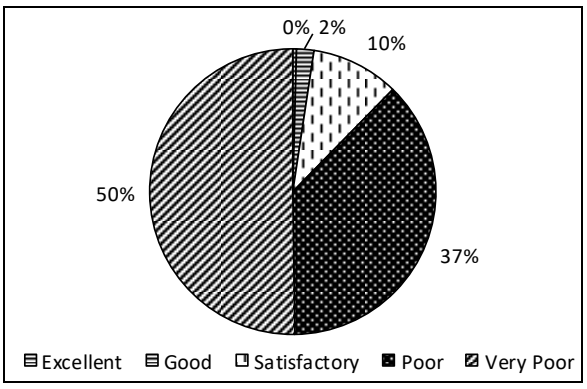

Figure 24: Courtesy of Helpers/Conductors

Figure 25 shows that majority (35%) of the respondents replied that the behavior of drivers is very poor while 31% and 29% replied fairly poor and neither good nor poor respectively. About (38%) of respondents mentioned that the driver skill is poor while 29% mentioned both very poor and satisfactory as shown in Figure 26.

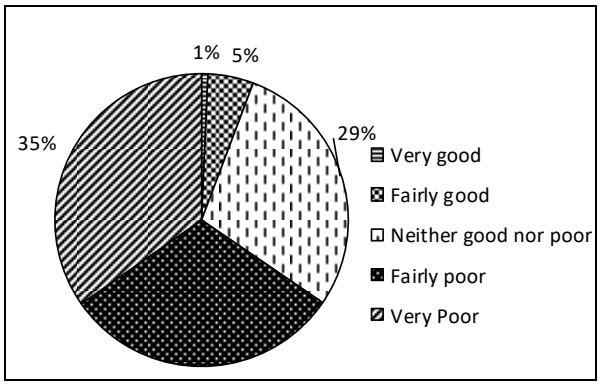

Figure 25: Behavior of driver

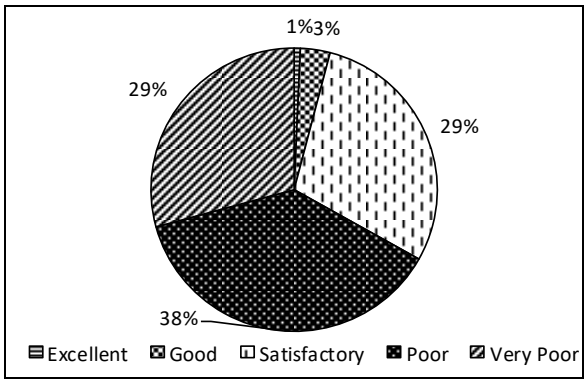

Figure 26: driving safety (Drivers Skill)

Majority of the respondents perceived that the accessibility of bus stop (48%) as well as accessibility of bus (49%) is poor as mentioned in Figure 27 and Figure 28.

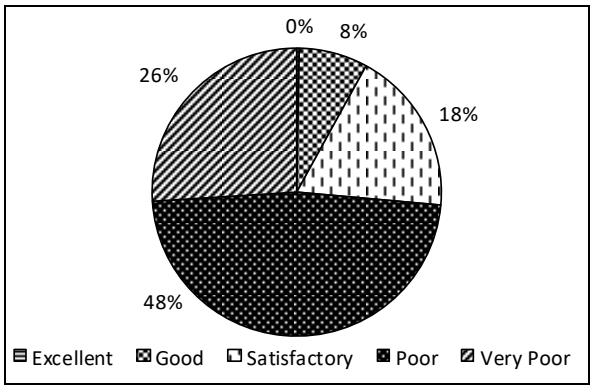

Figure 27: Accessibility of bus stop

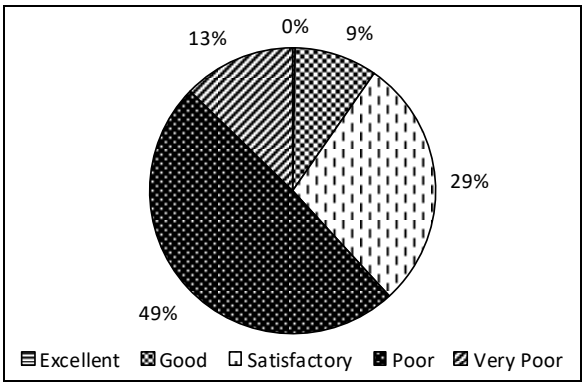

Figure 28: Accessibility of bus

About 42% respondents answered that the waiting time for the bus service is 10 to 15 minutes while 39% answered 5 to 10 minutes and 13% answered 15 to 20 minutes as shown in table 2. Table 2 shows that majority (31%) of the users rated the reliability of bus service neither good nor poor while 26%, 20%, 19% respondents replied fairly poor, very poor and fairly good respectively.

Table 2: Users' perception about waiting time and reliability of local bus services

Waiting time for the service	Percentages	Reliability of local bus services	Percentages
5 min-10 min	39%	Very good	3%
10 min – 15 min	42%	Fairly good	19%
15 min-20 min	13%	Neither good nor poor	31%
20 min-25 min	3%	Fairly poor	26%
25 min-30 min	2%	Very Poor	20%

48% of the respondents replied that the travel time of bus service during office days is poor (shown in Figure 29) while 38% rated it as satisfactory during holidays (shown in Figure 30). On the other hand 37% and 17% of the users think the travel time of bus service during office day and holidays is excellent.

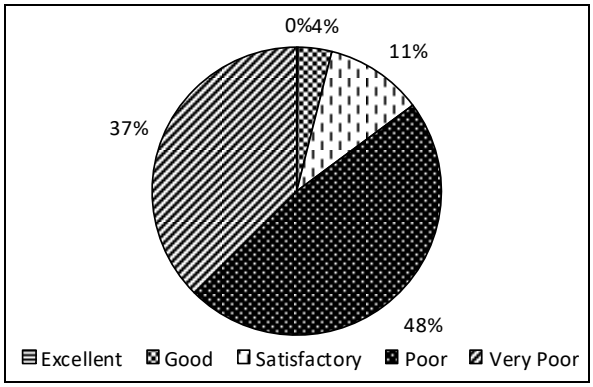

Figure 29: Travel time (office days)

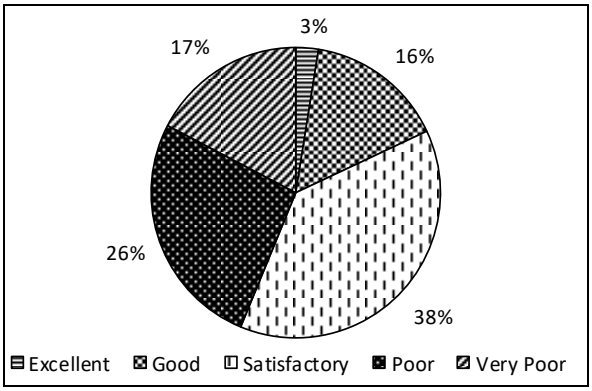

Figure 30: Travel Time (holidays)

Majority of the respondents perceive that the safety at bus stop (43%), security at bus stop (47%), level of personal security inside the bus (35%) and security of passengers in off peak period (58%) is poor as shows in table 3.

Table 3: Safety and security at bus and bus stop

Rating Scale	Safety at bus stop	Security at bus stop	Level of personal safety inside the bus	Security of passengers in off peak period
Excellent	0%	0%	0%	0%
Good	3%	2%	5%	2%
Satisfactory	18%	22%	25%	10%
Poor	43%	47%	35%	58%
Very poor	36%	29%	35%	29%

4. CONCLUSIONS

This study evaluated passengers satisfaction level of various service aspects provided by public transport in Chittagong city. About 86% of the respondents of Chittagong city stated that bus is their main mode of transport. 63% of them indicated the reason of using bus is its low cost. Result indicates that 75% of the respondents travel by local bus every day. About half of the respondents of Chittagong city rated the service quality features for example convenience of service, frequency of bus service, punctuality of transport, seat condition, cleanliness of bus, noise level of bus, physical condition of bus, cleanliness of bus stop, condition of bus stop, entry and exit facilities of bus, security of passengers (off peak period), movement flexibility of bus on the road, sitting arrangements, paying fare/ticketing system, fitness of bus, comfort level, driving skills, accessibility of bus, accessibility of bus stop, travel time during office days, safety at bus stop, security at bus stop, level of personal safety in the bus as poor. Movement flexibility inside the bus, courtesy of helpers/conductors, behavior of driver, and level of personal safety inside the bus were rated very poor. However the respondents rated the following service quality attributes as speed of bus, availability information of bus, transport cost, lighting facility, travel time during holidays as satisfactory. Finally about 53% of the bus users' ranked the overall bus service quality as poor. Majority of the passengers are not satisfied with the service provided by the public bus transport though bus is the main mode of transport in Chittagong city.

The findings of this study offer significant comprehensions for enhancing the bus service presently being offered and the aspects on which the greater attention may be provided. Although findings of this research offers prompting direction in evaluating service quality of bus, some limitations is also acknowledged. The sample had a gender bias. This could be due to the fact that female were less enthusiastic in answering the questionnaire. Further

variation in samples as adding more survey locations may help to obtain more accurate conclusion of bus service quality.

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AN ARTIFICIAL NEURAL NETWORK MODEL FOR ROAD ACCIDENT PREDICTION: A CASE STUDY OF KHULNA METROPOLITAN CITY

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ABSTRACT

Highway related accidents are considered one of the most serious problems in the modern world as traffic accidents cause serious threat to human life worldwide. The increase in the number of vehicles and inefficient drivers on the road, as well as to the poor conditions and maintenance of the roads, are responsible for accident crisis in Khulna Metropolitan city, Bangladesh. Prediction of future traffic accidents is therefore of utmost importance in order to appreciate the magnitude of the problem and speed up the decision making towards its alleviation. In this study, it was developed a design of an Artificial Neural Network (ANN) model with the aim of identifying its suitability for prediction of traffic accidents under Khulna cities conditions.In the ANN model development, the sigmoid activation function was employed with Levenberg-Marquardt algorithm. This model was developed using the data from the year 2000 to 2013. In the design, vehicle type, accidents type, junction type and collision type were selected and used as model parameters. The model results indicate that the junction point is the most important parameter that affects the number of accidents on highways. The results demonstrated that the estimated traffic accidents, based on sufficient data, are close enough to actual traffic accidents and thus are reliable to predict future traffic accidents in Khulna Metropolitan city. The performance evaluation of the model signified that the ANN model is better than other statistical methods in use.

Keywords: *Artificial neural network, road, accident, back propagation, vehicles*

1. INTRODUCTION

Road accidents are one of the major causes of death, injury and disability all over the world both in developed and developing countries. With a broad estimation, in every one minute, two people are killed and 95 people are severely injured or permanently disabled in traffic accidents worldwide. Traffic accident related deaths and injuries result is not only substantial economic losses but also serious physical and mental sufferings. Developing countries are much more affected from traffic accidents than developed countries. According to the world health organization (WHO) statistics, 75% of deaths resulted from traffic accidents occur in developing countries, although they own only 32% of the motor vehicles in the world. While the annual fatality per 10,000 vehicles ranges from 20 to 200 in low or middle income countries, it varies between 1.5 and 5.0 in industrialized countries. Each year more than 500000 people die in road accidents around the world (Mannan & Karim ,1999).

There has been an alarming rise in road accidents, significantly highway accidents, in Bangladesh over the past few years. According to a study conducted by the Accident Research Institute (ARI) of BUET, road accidents claim on average 12,000 lives annually and lead to about 35,000 injuries. According to World Bank statistics, annual fatality rate from road accidents is found to be 85.6 fatalities per 10,000 vehicles. Hence, the roads in Bangladesh have become deadly.

The number of injured and killed people is currently increasing rapidly in Khulna Metropolitan city. If until 2020 the trends in RTAs continue, it will be considered as the second most noted cause of fatalities in Bangladesh. RTAs contribute greatly in huge economic overheads, extreme human distress and disaster. A long term sustainable road traffic system can be achieved if the traffic safety work is developed and intensified.

Artificial Neural Network (ANN) systems have been applied in different information technology problems, such as traffic in communication and transportation engineering (Ozgan & Demirci, 2008). ANN has been widely applied in travel behaviour, flow and management (Himanen, V.1998). The use of artificial neural networks can reveal the relationship that exists between vehicle, roadway and environment characteristics and driver injury severity (Abdelwahab & Abdel-At, 2001). Traffic forecasting problems involving complex interrelationships between variables of traffic system can be efficiently solved using ANN. They provide realistic and fast ways for developing models with enough data (Riviere et al., 2006). Considering this high capability researchers are researching on new generations of ANN with more power and precision. This study explains the use of neural networks in the modeling of the number of persons fatally injured in motor vehicle accidents in data sets of the Khulna Metropolitan city. The ANN models help us to compare the cities road safety performance by the number of motor vehicle fatalities.

The advantage of ANN over conventional programming depends on its ability to solve complex and non-algorithmic problems. ANN uses past experience to learn how to deal with the new and unexpected situations. The statistical distribution of the data does not need to be known when developing an ANN model. There is no need for prior knowledge about the relationships amongst the variables being modeled. ANN has the ability to model complex, nonlinear relationships without previous assumptions of the nature of the relationship, like a black box. The most important key element of ANN paradigm is the novel structure of the information processing system. The synapses associated with irrelevant variables readily show negligible weight values; relevant variables present significant synapse weight values. Neural networks, which are good at broad and flat transformation of data, are nonlinear, able to relate input with output, and are error tolerant. Another advantage of ANN analysis is that it allows the inclusion of a large number of variables. Traffic forecasting problems involving complex interrelationships between variables of traffic system can be efficiently solved using ANN.

The traffic accident situation in Khulna city as well as Bangladesh is really alarming and the loss of lives and property damages are expected to continue if suitable corrective measures are not taken accordingly by applying proper engineering measures through extensive research and investigations. This situation is very dangerous particularly in metropolitan cities. About 20 percent of road accident occurred in metropolitan cities viz. Dhaka, Chittagong, Khulna and Rajshahi (Hoque, M.M., 1991). Because of the alarming increase of the road traffic accident at Khulna metropolitan city, it is important to prediction of road accident considering the basic factors of those causing accident in this area. Therefore, it is important that accident prediction should be carried out for these cities on a priority basis.

2. METHODOLOGY

2.1 STUDY AREA

The study area is under the five police stations of Khulna Metropolitan City, which are: Khulna Sadar, Daulatpur, Khalishpur, Khanjahan Ali and Sonadanga.

2.2 DATA COLLECTION

In the current study, highways of Khulna Metropolitan city has been considered as a case study. The road traffic accidents (RTA) data from 2000 to 2013 were collected from the Accident Research Institute (ARI) of BUET.

2.3 DEVELOPMENT OF ANN PREDICTION MODEL

To estimate the ANN model, there are a number of software packages ready to perform the Levenberg Marquardt algorithm was chosen for this study. In the ANN model, independent variables are named as the input, and dependent variables are named as the output. The input importance chart shows the relative importance of each input column. The data is divided into three sets; training data. (About 70% of the total data), validation data (about 15% of the total data), and testing data (about15% of the total data). Training, validation and testing of the network was performed using MATLAB .Multi-layer perceptron ANN adopts different learning algorithms; and one the most well-known techniques is back propagation and it was used in this study. The years, accident types, collision types, junction types and vehicle types used as model factors. The designed Multi-Layer Perceptron Neural Network (MLPNN) consists of the input layers, hidden layers and an output layer, as shown in Figure 1.

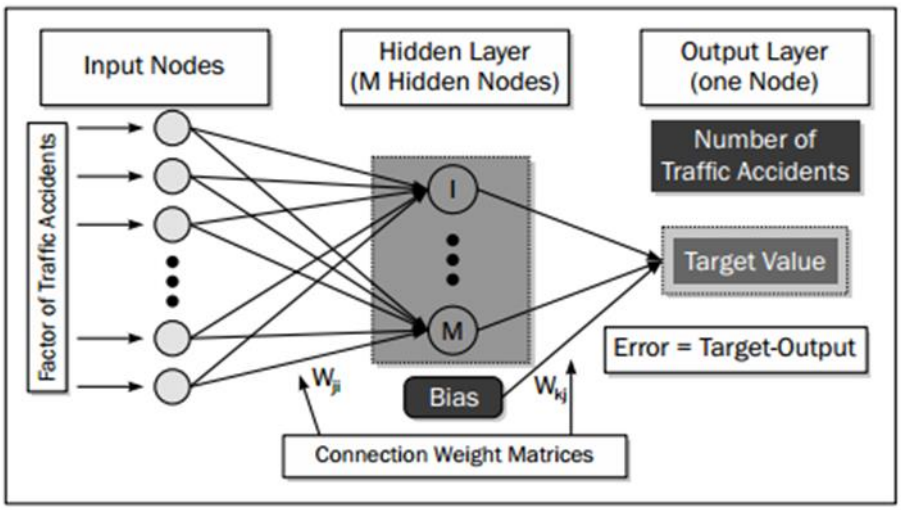

Figure 1: Structure of artificial neural network model for traffic accidents

The Selected transfer functions were

- Input hidden layer: Tan-sigmoid transfer function
- Output hidden layer: Linear transfer function
- The training process includes the following operations:
- Setting initial values for weights
- Evaluating the output based on initial weights.
- Measuring the error (mean square error or any function to calculate the error)
- Adjusting the weights using rate of learn(usually small value such as 0.01)
- The weights continue to be modified as each error is computed. If the network is capable and the learning rate is set correctly, the error is eventually driven to zero.
- In the validation phase, no adjustment occurs to the weights. Validation is necessary to measure the performance of the network model where the predicted values are compared with the actual as given by the validation data. This process can be integrated with training process to improve the performance of the model.
- Through the testing process, the predicted values are compared with the input values using testing data that was not used in training or validation process.

The Multi-Layer Perceptron Neural Network (MLPNN), which is also called the multilayer feed-forward neural network, was chosen and used in this study. Figure 2 is a graphical representation of the overall architecture of the proposed system.

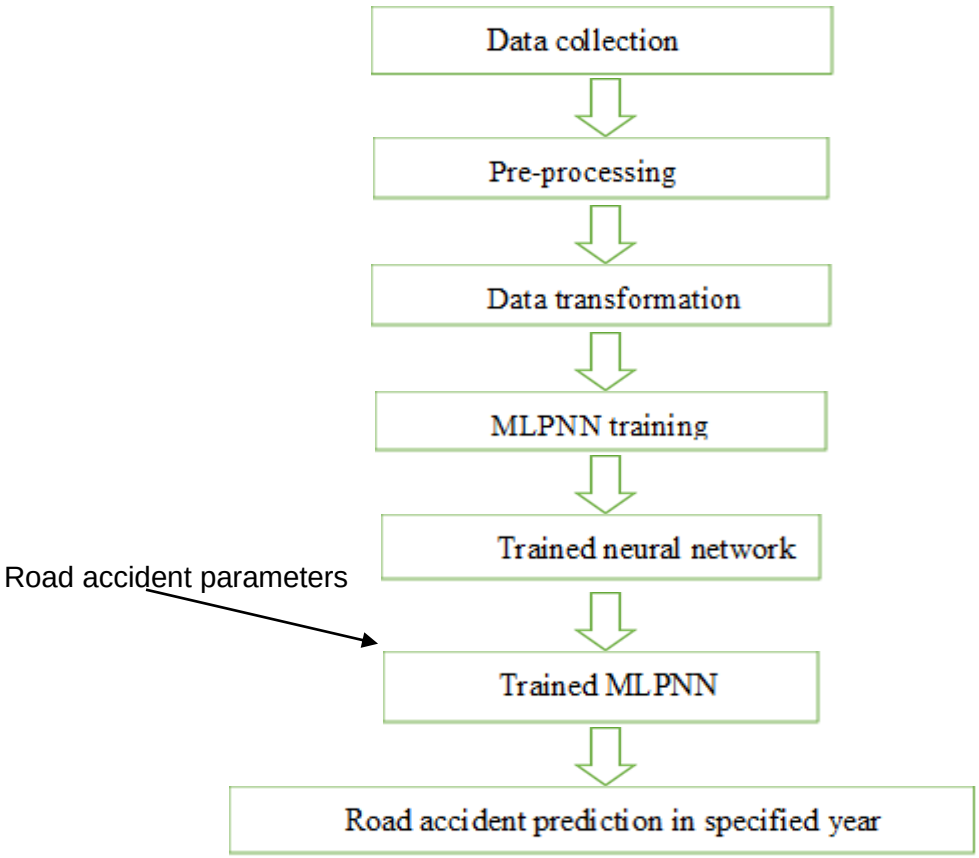

Figure 2: The Training Architecture

The major aim for carrying out training in a multilayer feed-forward network is to obtain ANN output weight values to match the actual target values very closely. To design and train multilayer perceptron network involves several challenges, which include determining the number of hidden layers to be used in the network, determining the number of neurons to be used in each hidden layer, establishing a general acceptable solution that avoids local minima, converging to an optimal solution as and when due or in good time, and validating the neural network to test for over fitting. Though there exist errors and noise in the training set, ANN still possesses the capability to find the dependencies that are hidden and are not linear, and it also learns from past experience as it completes its training.

In this study, the adjustment of the weight value was carried out using conjugated gradient algorithm with help of gradient during backward propagation of errors in the network. The conjugate gradients algorithm uses more paths that are direct to best group of weight values when compared with the gradient descent.

3. RESULTS AND DISCUSSION

The designed Multilayer Perceptron Neural Networks (MLPNN) contains three input layers with two hidden layers and one output layer. The output layer carries out the prediction of the RTA rate when presented with the factors.

Table 1: Summary of 2007 and 2013 RTA

Year	2007	2013	Remarks
Person dead	48	22	54% reduction in the number of persons dead
Person injured	40	11	73% reduction of persons injured

It was observed that 2007 has the higher number of persons dead and also number of persons injured between the year 2007 and 2013 RTA.

The comparative analysis of 2007 against 2013 made the prediction of RTA for 2013 to 2020 using primary source collected data capable of allowing an accurate and good data model. The multilayer feed-forward neural network with its learning technique worked through the output value comparison with the accurate answer and also performed the computation of the already established error function. The error is inputted back to the ANN algorithm and it adjusts the weight values of every connection to bring down the values of the error function to minimal. From the analysis of 2007 against 2013 the RTA target verses actual from 2000-2020 were obtained through prediction from collected data.

Table 2: Actual and predicted number of accidents using ANN

Year	Actual	Predicted	Residual	Year	Actual	Predicted	Residual
2000	69	76	7	2007	78	82	4
2001	55	62	7	2008	38	44	6
2002	56	55	9	2009	52	55	7
2003	38	45	7	2010	54	55	3
2004	20	27	7	2011	34	40	6
2005	35	42	7	2012	21	25	4
2006	59	58	9	2013	31	33	2

The Neural Networks allow the development of different alternatives by changing the number of hidden layers. Three model was developed for three different parameters to determine the coefficient of determination. The results were found to be very satisfactory with relatively small residuals especially in recent years where more reliable data bases are available through using more advanced data compilation techniques.

The following regression plots display the network outputs with respect to targets for training, validation, and test sets. For a perfect fit, the data should fall along a 45 degree line, where the network outputs are equal to the targets.

Figure 3 shows the accident type parameter where the fit is reasonably good for all data sets, with R values in each case of 0.99987.

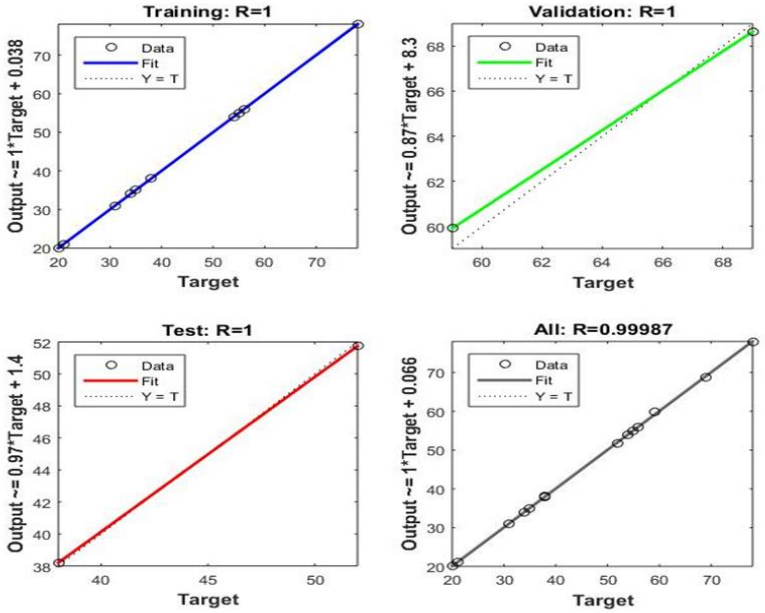

Figure 3: ANN Output for Different Types of Accident

Figure 4 shows the collision type parameter where the fit is reasonably good for all data sets, with R values in each case of 0.993 or above.

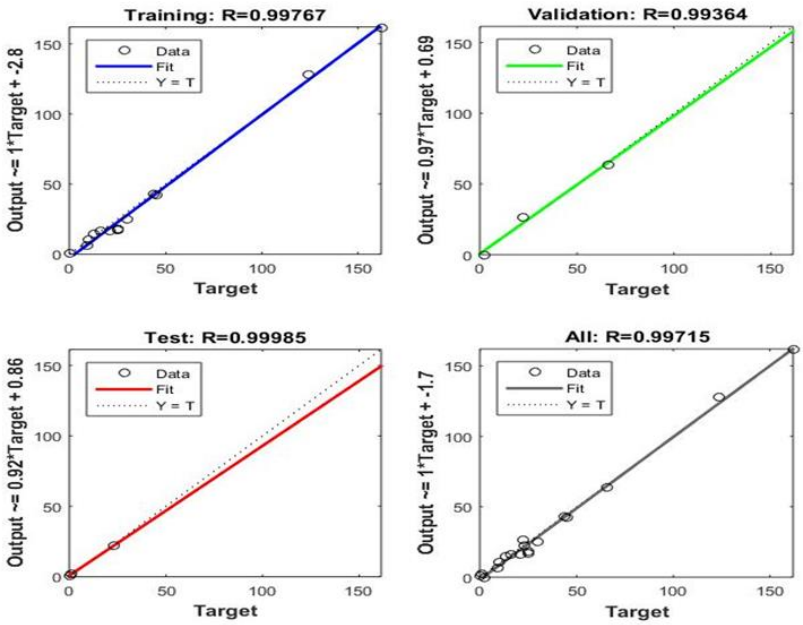

Figure 4: ANN Output for Different Types of Collision

Figure 5 shows the accident type parameter where the fit is reasonably good for all data sets, with R values in each case of 0.999 or above.

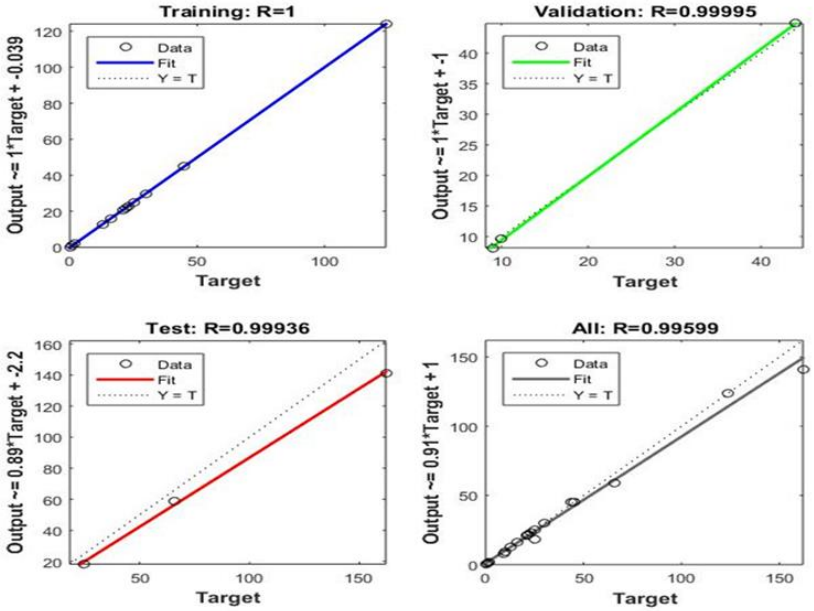

Figure 5: ANN Output for Different Types of Junction

This training stopped when the validation error increased for two iterations, which occurred at iteration 31. For finding the Performance in the training window, a plot of the training errors, validation errors, and test errors appears, as shown in the following Figure 6. In this study, the result is reasonable because of the following considerations:

- The final mean-square error is small.
- The test set error and the validation set error have similar characteristics.
- No significant over fitting has occurred by iteration 27 (where the best validation performance occurs)

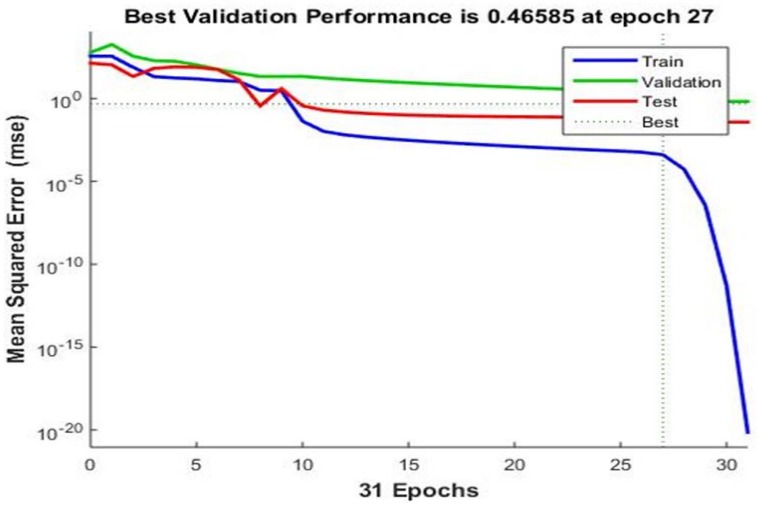

Figure 6. Error graph versus learning epochs for Different Types of Accident

Each time a neural network is trained, can result in a different solution due to different initial weight and bias values and different divisions of data into training, validation, and test sets. As a result, different neural networks trained on the study problem can give different outputs

for the same input. To ensure that a neural network of good accuracy has been found, retrain several times. The difference between actual and estimated values in case of injury cases was not as higher as in case of total accident cases and that indicates a further scope of improvement of the injury prevention measures which have been taken by the respective authorities.

The multilayer feed-forward neural network with its learning technique worked through the output value comparison with the accurate answer and also performed the computation of the already established error function. The error is inputted back to the ANN algorithm and it adjusts the weight values of every connection to bring down the values of the error function to minimal.

4. CONCLUSIONS

In this study, the factors which cause accidents have been investigated, for providing road safety, and accident prediction models which include relations between these factors have been established. In this study the obtained data from the database have been investigated with ANN as a tool of forecasting techniques. Since ANN method is a more flexible and assumption-free methodology and furthermore, capable of evaluating/comparing all of the traffic accident characteristics, it is selected for modelling the traffic accidents data. The low values of mean squared error indicate superiority of the model. The results demonstrated that the predicted traffic accidents, based on sufficient data, are close enough to actual traffic accidents and thus are reliable to predict future traffic accidents in Khulna Metropolitan City.

ANN showed its advantage over conventional programming in this study. This is due to its capability to provide solutions to non-algorithmic problems and can learn how to deal with the new and unexpected situations by the help of past experience. Neural networks are able to relate input with output, allow large number of variables and are error tolerant.

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KEY SAFETY APPROACHES IN BANGLADESH RAILWAY

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ABSTRACT

Bangladesh Railways have been an integral part of the country's transportation system since the British era. At present it covers a length of 2,877 route kilometers. Train accident data collected from Bangladesh Railway revealed that train accidents reduced from around 590 per year for 2001-10, to around 250 per year for 2010-2015 and to 166 for 2015-16. Data also shows that derailments are the major concern in railway safety. Mixed railway gauges, rail weight, battered and damaged rails, low sleeper density and damaged sleepers, lack of maintenance of fittings and fastenings, and inadequate amount of ballasts are the main reasons for such derailments. So as a safety approach against derailments Bangladesh Railway has taken rail track rehabilitation projects as well as speed restriction programs. 2015-16 data showed benefit of such restriction program. A speed map is prepared according to the speed restriction program and speed capacity of different sections of the railway network.

Keywords: *Train accident, safety approach, speed restriction, speed map*

INTRODUCTION

Increasing demand for transport, increasing road congestion, increasing concern over safety and environmental matters, and technology-led cost reductions have given rising interest in railways for inter-urban, urban and even rural transport services. Many countries, both in the developed and developing worlds, are finding that rail transport is cost effective at meeting some of the growth in demand through the construction of new lines or more effective and efficient use of existing lines and services as well as provides a safe, efficient means of transport with minimal environmental impact (Godward, 1992). Though, railway transportation system is recognized as a safest mode of land transport around the world, railway accident has always been the major challenge for rail safety as well as a point of attention to the engineers and researchers (Agarwal, 2005; Agarwal, 2007; Brabie, 2005; Wu and Wilson, 2006). Moreover, rail accident is not the result of a single cause but the combination of several contributory factors, which are associated with the rail users, the vehicle, the track and the rail environment (Ahsan et. al., 2014c). It is therefore, important in our context to understand the overall accident problem so as to be able to reduce accident and thereby improve the safety environment of rails.

Bangladesh Railway (BR) has been experiencing a large number of train accidents since its development in 1972 (Ahsan and Islam, 2015). Disruption to services, substantial financial losses and safety risk to staff and passengers are highly obvious from such occurrence (Barkan et. al., 2003). However, very few researches have been carried out regarding train accidents in Bangladesh to determine the underlying causes for the development of effective countermeasures to enhance railway safety. This paper thus attempts to investigate accident data in the light of accident classification, accident distribution, accident factors and accident casualties as well as investigates the effectiveness of the safety approaches of Bangladesh Railway in this regard.

ACCIDENT DATA ANALYSIS

2.1 Train Accidents

A train accident is termed as any occurrence which does or may affect the safety of the railways, its engine, rolling stock, permanent way, works, passengers or servants which either does or may cause delays to trains or loss to the railways (Arora and Saxena, 2006).

Data collected from Bangladesh Railway revealed that train accidents reduced from around 590 per year for 2001-10, to around 250 per year for 2010-2015 and to 166 for 2015-16 (Bangladesh railway, 2009-2016). These accidents are presented according to accident classification, accident distribution, accident factors and accident casualties in the following sections.

2.2 Accident Classification (Types)

Accidents are classified into three major groups with a total of ten types as shown in Table 1. Derailments are the highest type of accident around 90 per cent of the total incidence (Ahsan et. al., 2014b). However, 2015-16 data showed a reduction of derailments to 74.1 per cent.

Table 1: Accident Classification

Accident Classification (Types)			**Percent**
(A) Accident to trains:	(1) Collision	a. Passenger trains	5.0
		b. Other trains	1.7
	(2) Derailment	a. Passenger trains	20.2
		b. Other trains	22.0
(B) Fires:	(1) Fire in trains.		0.2
(C) Other accidents:	(1) Trains running over cattle on the line		0.0
	(2) Train running into road traffic at level crossing		0.0
	(3) Train running over obstruction not covered in 1 and 2		0.2
	(4) Derailment of vehicles in yard		41.0
	(5) Derailment of light engines		6.6
	(6) Bursting of points		1.3
	(7) Averted collision		1.9
			100.0

2.3 Accident Distribution (Departments held responsible)

Bangladesh Railway had allocated accidents considering responsibilities of various departments involved in railway services according to their internal process as shown in Table 2.

Table 2: Accident Distibution

Departments held responsible	**Percent**
(1) Traffic department	8.8
(2) Engineering department	12.7
(3) Mechanical department	17.7
(4) Signal and Traffic department	1.2
(5) Engineering and Traffic department	0.7
(6) Engineering and Mechanical department	2.5
(7) Traffic and Mechanical department	1.7
(8) Other departments	8.9
(9) Pending	45.8
	100.0

2.4 Accident Factors (Causes)

The total train accidents were attributed by human elements, technical defects and other causes. Table 3 shows that other causes consist of the highest share of 47 per cent. This is perhaps due to weak reporting system. However, there is a sudden change in 2015-16 reporting with human elements as 84.94 per cent, technical defects as 10.84 per cent and other causes as remaining 4.22 per cent.

Table 3: Accident Factors

Accident Factors (Causes)		**Percent**
(A) Human elements	(1) Breach of rules, wrong manipulation of block instruments and setting of points, etc.	6.2
	(2) Passing of signal at danger	4.5
	(3) Breach of rules by Locomotive Masters and Assistant Locomotive Masters	15.2
(B) Technical defects	(1) Engines	1.4
	(2) Vehicles	8.7
	(3) Tracks	14.9
	(4) Signaling and interlocking apparatus	0.7
	(5) Other technical defects	1.4
(C) Other causes	(1) Miscellaneous	47.0
		100.0

Track condition causes the highest accident reflecting technical defects. Mixed railway gauges (BG, MG & DG), rail weight (75 lbs & 90 lbs) and wear (battered, damaged, increase in friction and expansion gap), inadequate amount of ballasts, sleeper materials and density, and lack of appropriate fastenings are found to be the weaknesses of railway track (Ahsan et. al., 2014a).

2.5 Accident Casualties

Table 4 shows percentage of killed and injured for passenger, railway employees and other persons.

Table 4: Accident Casualties

	Casualties (Percent)	
	Killed	Injured
Passenger	12.8	37.5
Railway Employees	1.3	9.2
Other Persons	8.3	30.9
	22.4	77.6

3. SAFETY APPROACH

Around the world, railways have come to be recognized as a safest mode of mass transportation because of its inherent characteristics. Therefore, safety becomes the foremost issue while transporting man and materials in railway system. To ensure railway safety around the world all the activities includes according to the three-tier approach as follows (Rail Safety New Zealand, 2011).

3.1 Education

Education includes (i) Advertising, (ii) Publicity and media relations, (iii) Awareness raising events and campaign, (iv) Development of education resources for schools (v) Publication and display of rail safety pamphlets brochures (vi) Training, etc.

3.2 Engineering

Engineering includes (i) Ensuring structural and functional integrity of the infrastructure and its subsystem (Track improvements, periodic maintenance, level crossing up gradation, Enhanced track inspection technology etc.), (ii) Ensuring structural and functional integrity of the rolling stock, (iii) Ensuring appropriate operational procedures and information management for effective train handling etc. (improved signaling and interlocking system).

3.3 Enforcement

Enforcement includes (i) Application of appropriate warnings or prosecution against those who fail to obey the rules and regulations.

However, Bangladesh Railway has considered speed restriction as the most effective safety measure against derailments. Some rail track rehabilitation projects along with modernization of signal interlocking system are also in the process.

4. MAXIMUM SPEED AND SPEED RESTRICTIONS

Permissible line speed is the maximum speed at which trains may operate on a track. It is also called maximum allowable speed or allowable speed. Each route section has a published speed limit which will vary locally according to track and route features such as junctions where trains pass between different routes (Bangladesh Railway, 2016). There are two types of speed restrictions.

4.1 Temporary speed restriction

Due to engineering works, a temporary speed reduction (TSR) may be enforced at a particular location. Temporary Speed Restrictions apply to all other conditions not covered by the permanent timetable including track defects, line side hazards and maintenance works.

4.2 Permanent speed restriction

Permanent speed restrictions are imposed where the route encounters a hazard such as a tight radius curve, level crossings, certain junctions, tunnels and bridges. It is also called a slow zone. Permanent Speed Restrictions are those that represent maximum safe speed.

5. SPEED MAP

Based on the information collected from Bangladesh Railway on speed restriction on different lines a speed map is prepared and is shown in Figure 1.

From the map, it can be seen that Parvatipur-Shantahar section has a maximum speed of 95 km/hr. This section has newly installed concrete sleeper, correctly aligned rails, uniform ballast formations and elastic fastenings. In contrast, Jamalpur- Tarakandi section has a maximum speed of 30 km/hr due to having worn out steel sleepers and non-maintained rails. Similarly in Santahar-Parvatipur section, maximum allowable speed is 10 km/hr due to severly damaged rails. But Poradaho-Pachuria section, despite of having wooden sleeper, has an allowable speed of 80km/hr.

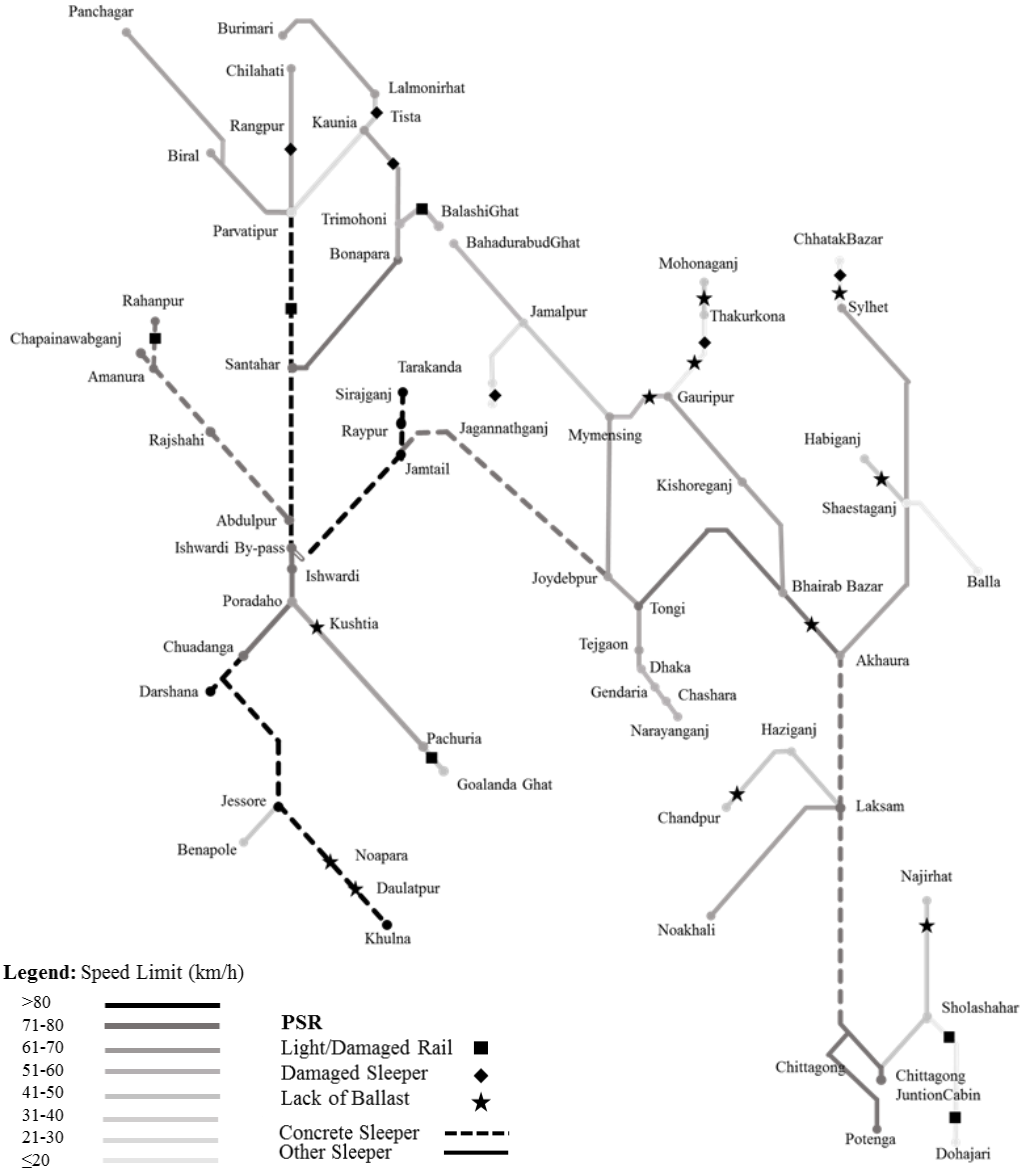

Figure 1: Bangladesh Railway Speed Restriction Program

6. KEY IMPROVEMENT OPTIONS

The accident problem can be corrected to a great extent by simple engineering techniques as well as by the enforcement of laws. In this respect some measures are suggested which may be considered to minimize the frequency and severity of accidents.

6.1 Accident Report Form

There is a need for suitable refinement in present accident reporting criteria and data collection system. The present system of preparing accident report is time consuming and not ideal. Specific details of accident location, track, signal, interlocking, and vehicle condition are not mentioned. The exact time of accident and types of vehicles involved in each accident should also be recorded properly.

6.2 Track Maintenance

Accident data shows that track condition is responsible for maximum number of accidents. Rehabilitation is therefore, needed for tracks and bridges (Ahsan et. al., 2016).

The conventional method of track maintain by human resource are still in practice. More sophisticated track maintain arrangements such as, mechanical track lifting, slewing, tamping and laying machines should be used for track maintain.

Moreover, maintenance work does not complete on schedule time because of administration complicity and lack of budget. So, the administration complicity should be eliminated and as well as budget is needed to be increased.

6.3 Modernization of the Signalling System

Modernization of the signalling system using colour lights and relay interlocking should be done to minimize the incidence of accidents particularly on account of human failure (Ahsan and Biswas, 2015). Such improvements also have the potential of increasing the line capacity.

7. CONCLUSIONS

Train accident data of Bangladesh Railway revealed that accident reporting and analysing system should be improved for fruitful detailed engineering based investigation and derailments are the major concern in railway safety. Rehabilitation and modernisation of the track network, signalling and rolling stock are needed for safe running of the Bangladesh Railway. However, as a safety approach against derailments Bangladesh Railway has taken rail track rehabilitation projects as well as speed restriction programs. 2015-16 data showed benefit of such restriction program.

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