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TRAFFIC FLOW DISTRIBUTION AND PREDICTING SHORT TIME TRAFFIC FLOW COMPOSITION USING MONTE CARLO SIMULATION

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ABSTRACT
For developing countries like Bangladesh due to rapid urbanization and mix-traffic flow condition, traffic management becomes more challenging day by day. Knowledge of traffic flow distribution and traffic flow composition are significant for traffic assignment, traffic prediction, traffic guidance, and traffic management. In this paper chi-square test is used to find the traffic flow distribution. The hypothesis of the fitting tests includes Beta distribution, Normal distribution, Log-normal distribution and other four kinds of distribution. For better traffic management, it also needs to predict short time traffic flow composition. For this prediction, Monte Carlo simulation is used. The analyses are done for different traffic conditions such as working day, weekends and both for peak time and off-peak time traffic flow condition. This time the Mean Average Percentage Error (MAPE) becomes 6.6%

Keywords: prediction; distribution; traffic-flow; Monte Carlo simulation; Chi Squared test.

INTRODUCTION
With the prospective development in transportation system, a new term called Intelligent Transportation System (ITS) has been introduced nowadays and practically used largely to improve the efficiency, safety, and productivity of the surface transportation system. The Intelligent Transportation System (ITS) integrates the advanced information technology with data communication technology, electronic technology, sensor technology, and computer processing technology which can bring great convenience for people's travels showing the distribution characteristics and providing short-term traffic flow forecasting. However, the traffic system is a random system with strong uncertainty and complexity. A large number of uncertain factors cause short-term traffic flow to highly complex nonlinear characteristics. For these reasons, it's difficult to improve the precision of single prediction mode or to expand the scope of application which results in different combined forecasting models with different advantages. At the same time, it is also essential to understand the working process behind all these methods to get an idea about the stability, reliability and the limitations associated with each of them.

Scope of the study
From previous research works it has found that travel time generally follows Normal distribution (Harman and Lam, 1984). Again some found that it varies with time and location (Iida, 1997). On the other hand, Zhang, (2003) found that Beta distribution is well acceptable for the goodness of fit. In this paper, traffic flow distribution has been studied which is totally a new approach. And it is tested on numerous data sets with Chi-squared test. After that, the dataset is simulated 144*100 times and forecasted traffic flow with the Monte Carlo simulation. Because Monte Carlo simulation is a wide ranged used great tool for simulation in different sectors. Many research has done with the help of

Monte Carlo simulation. Sometimes it gives more accurate results than time series analysis (Stathopoulos et al., 2003). Adding with that Kumar et al., (2013) used multivariate ANN modeling approach for short-term traffic prediction on the non-urban highway. Zeng et al. (2013) had applied Monte Carlo method in combination with fuzzy mathematics and MATLAB to design a method for intelligent traffic lights based on the traffic flow pattern in single intersection. Sau et al. (2007) applied particle filter approach to develop a stochastic traffic model that enables travel time estimation and prediction with high reliability using Monte Carlo procedure. Having a large number of uncertainties the Monte Carlo simulation is used here for short term traffic prediction and the result have been found quite amazing.

METHODOLOGY

Study location and data collection

The data used here have been found from the Transport Infrastructure Ireland. The traffic volume used here is from the link road between junction-1 and junction2 of Dublin Airport route, Ireland from January 31, 2018, to February 03, 2018 [Fig 1].

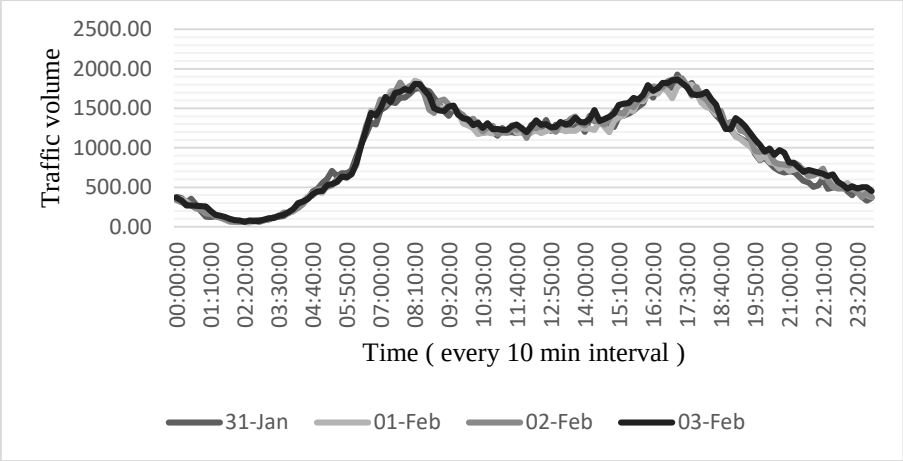

Fig. 1: Observed traffic flow of 4 days for 24 hours each.

The Chi Square test

This statistically test is mainly used to determine whether the association between two qualitative variables is significant or not or how much significant with each other. The Chi Square statistic is a measure of how far the observed counts are from the expected counts. The generalized formula of the statistic is:

$$x^2 = \sum \frac{(expected-actual)^2}{expected}$$

But another important function of Chi-Square test is to determine the distribution characteristics. It is the most powerful method to find out the distribution among the data sets. It has different equations and functions for log-logistic distribution, log-normal distribution, Gompertz distribution, Weibull distribution etc. The brief mathematical calculations and approaches are proved already. The summary of each distribution follows: for log-logistic distribution,

If we consider the hypothesis $H_0 : F(t) = 1 - \frac{1}{1+(\frac{t}{\theta})^v}$, $t \geq 0$

Meaning that the distribution of the failure times is log-logistic. Here $\theta > 0$ & $v > 0$; θ is the scale parameter and also the median of the distribution; $v>0$ is the shape parameter. The distribution is unimodal when $v>1$ and its dispersion decreases as v increases. Then the null hypothesis is rejected with approximate significance level α, if

$$x^2 = \sum_{j=1}^{k} \frac{(u_j-e_j)^2}{u_j} + Q \geq x_\alpha{}^2(k)$$; alternative parameterization

Thus all the equations of other distributions and calculations used here for analysis are sited from the Basic Practice of Statistics (6th ed.) book.

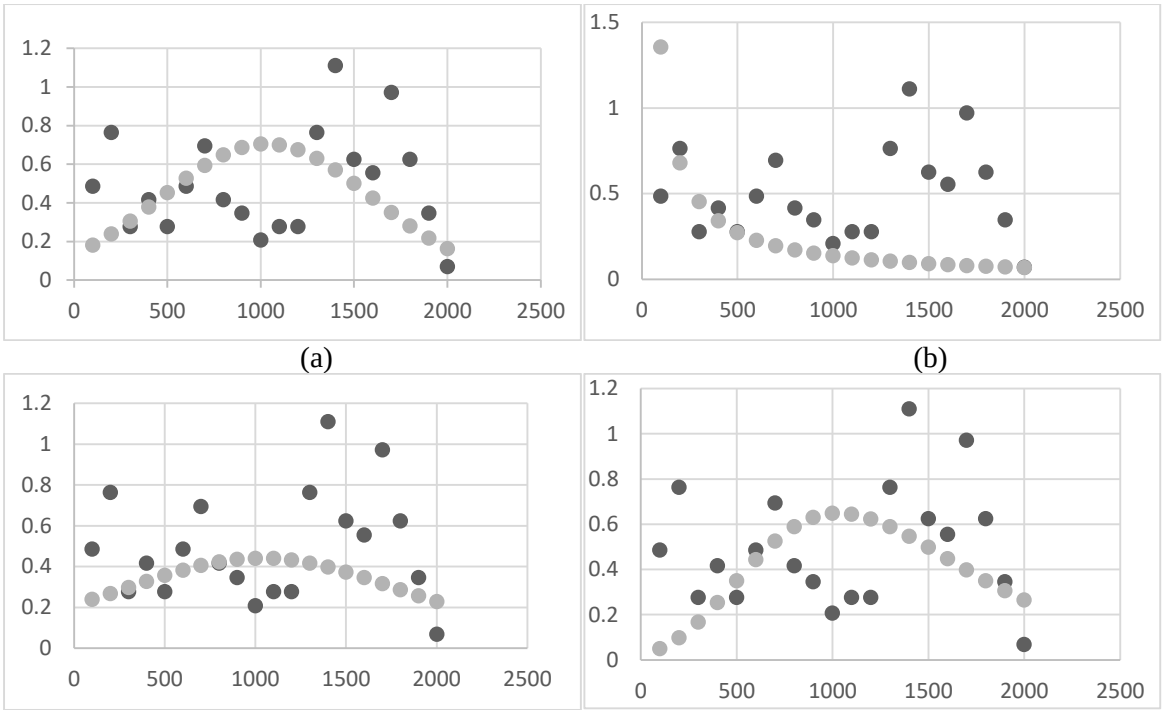

Fig. 2: (a) Normal Distribution, (b) Log-normal Distribution, (c) Logistic Distribution, (d) Gumbel Distribution

Table 1: Data analysis for Chi square test

Mean	Median	Mode	St. Deviation	Sample variance	Kurtosis	Skewness	Range	Min.	Max	Sum	Count
1031.4	1208	74	565.588	319890.7	-1.255	-0.29196	1871	70	1941	148522	144

Monte-Carlo simulation

Monte Carlo simulations are used to model the probability of different outcomes in a process that cannot easily be predicted due to the intervention of random variables. It is a technique used to understand the impact of risk and uncertainty in prediction and forecasting models.

Periodic flow = ln (present actual flow/previous flow value)

Next calculated the AVERAGE, STDEV.P, and VAR.P functions on the entire resulting series to obtain the average periodic flow, standard deviation, and variance inputs, respectively. The drift is equal to:

Drift = average periodic flow – (variance/2)

Alternatively, drift can be set to 0; this choice reflects a certain theoretical orientation, but the difference will not be huge, at least for shorter time frames. After that to obtain a random input:

random value = standard deviation * NORMSINV(RAND())

next 10 min forecast = present actual flow * e ^ (drift + random value)

Here, every 10 min data of three days (31 Jan, 01 Feb, 03 Feb) is taken into consideration for calculation and made simulation 100 times each for forecasting of Feb 03. Thus total 144*100=14400 simulations are done to obtain the result. After calculating the average of every 10 min flow from 14400 simulations the forecast is gotten. Then the forecasted value for Feb 03 is compared with the actual value of Feb 03. The result is quite amazing.

Table 2: Observed result from Chi square test

Observed	Normal	Log-normal	Logistic	Log^logistic(2,0.5)	Gamma(15,45)	Gumbel	Beta(2,2)
t-value	4.6057	37.9397	5.1822	396.84018007	426746.38	7.4540	4.0881
p-value	0.9993	0.0039	0.9999	4.17054214E-73	0	0.9857	0.9997

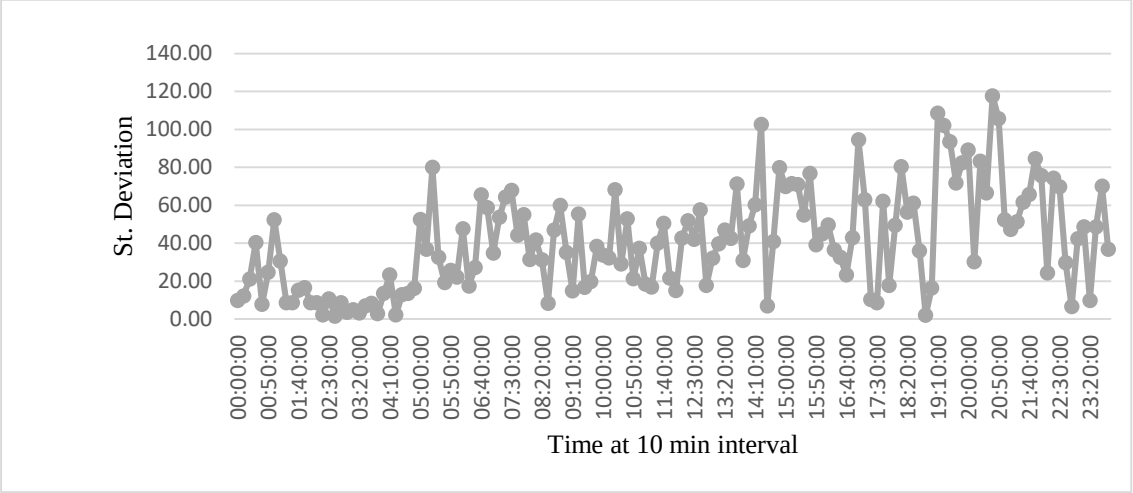

Fig. 3: Time vs Standard Deviation graph

RESULT & DISCUSSIONS

Chi-square method

Using Chi squared test, the traffic flow distribution of 24 hours of 4 days is compared with seven kinds of distribution like as Normal, log-Normal, Logistic, Log-logistic, Gamma, Gumbel and Beta distribution according to the p value. The general assumption was that the normal distribution of random variables follows symmetrical bell shaped curve. While in log normal, logarithm is normally distributed. The gamma distribution is a two-parameter family of continuous probability distribution. Logistic distribution shows a continuous probability distribution. Though It has same shape as normal distribution but it develops heavier tails and high kurtosis. Adding with that the log-logistic distribution is similar to log normal but has heavier tails. Gumbel distribution is used to model the distribution of the maximum or the minimum of the number of samples of various distributions and it is not symmetrical. And at last, Beta distribution is a continuous probability distributions defined on the interval [0, 1] parametrized by two positive shape parameters. Those two parameter that appear as exponents of the random variable and control the shape of the distribution. From the significant p value of Chi squared test, we have found that the traffic flow distribution can be considered as Normal distribution, Log-normal distribution, Logistic distribution and Beta distribution.

Monte Carlo simulation

Taking every 10 min traffic volume of 3 days as input Monte Carlo simulation process has been applied and simulated 14400 results. Then the traffic flow of each 10 min interval is forecasted. In Table 3, the result is shown as 2 hour interval. But figure 04 shows the total forecasting of each 10 min interval.

Table 3: Traffic flow prediction using Monte Carlo simulation

Time	Actual flow	Predicted flow	Error (%)
00:00:00	340	365.42	7.47
02:00:00	63	81.56	29.46
04:00:00	211	186.87	11.43
06:00:00	664	638.99	3.76
08:00:00	1782	1709.52	2.63

10:00:00	1335	1359.37	1.82
12:00:00	1127	1217.18	8.00
14:00:00	1284	1301.52	1.36
16:00:00	1623	1585.80	2.29
18:00:00	1646	1686.42	2.45
20:00:00	946	969.20	2.45
22:00:00	682	635.48	6.82
	Mean Average Percentage	Error =	6.66

From analysis the Mean Average Percentage Error has been found as 6.66% which is highly acceptable.

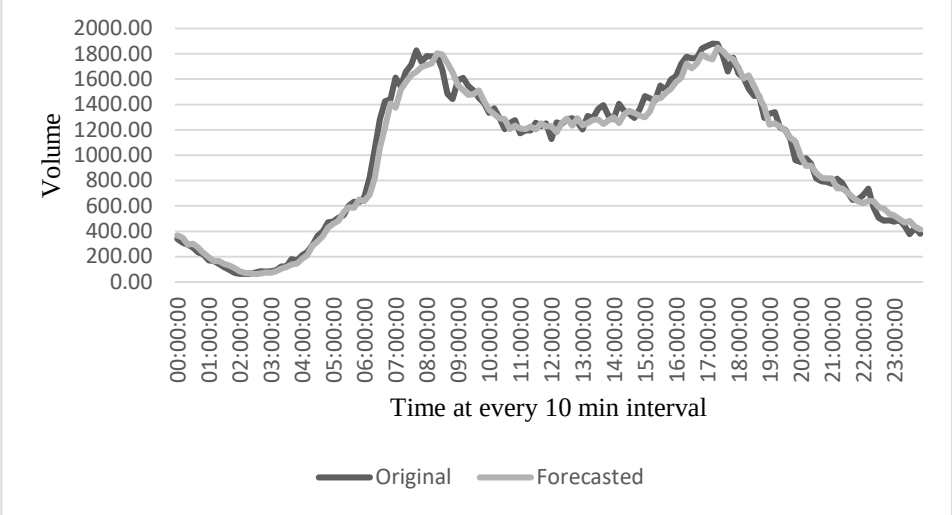

Figure 04: Original vs Forecasted traffic flow at every 10 min interval

CONCLUSION

From the analysis of traffic flow of the study area it has found that the traffic flow distribution of 24 hours a day follows Normal distribution, Log-normal distribution, Logistic distribution and Beta distribution for both normal day and weekend.

Monte Carlo simulation has shown only 6.66% Mean Absolute Percentage Error which is highly acceptable.

So, traffic guidance and management will be now more easy and effective by taking step according to the distribution properties. Also, the traffic congestion can be decreased and traffic control will be easier by knowing the next day traffic volume of each 10 minutes using Monte Carlo simulation.

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EVALUATION OF PUBLIC BUS COMFORT IN DHAKA CITY

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ABSTRACT
Comfort in transport has become a formidable factor to significantly affect the mode choice of commuters, specially for mass transits like public buses. In this study, a combined approach (mechanical and qualitative) was undertaken to evaluate the comfort of public buses in Dhaka city. Measurement of physical parameters, such as, speed, temperature, noise, jerking, etc. using Arduino Micro Controller and subjective parameters through questionnaire survey were carried out. These physical parameters were translated to subjective feelings with numerical values by using multiple linear regression analysis. A comfort model for public bus was thus developed by correlating the subjective opinions of passengers to the objective physical parameters. This research leads to a prime finding where public buses in Dhaka are found 'slightly uncomfortable' or 'uncomfortable'. It was found that speed, temperature, noise and jerking were the most significant physical parameters influencing comfort, however, temperature and jerking had the highest impact on the overall comfort feeling in public buses. The outcomes of the study will aid national level traffic comfort improvement through better design of public buses, along with other modes of public transport, which can help uplift and uphold the overall public transport service quality.

Keywords: Comfort; Dhaka City; Public Bus; Multiple-Linear Regression; Arduino Micro Controller

INTRODUCTION
A transport service is marked by a series of service factors such as comfort, reliability, service programming, and so on. Comfort of rides is considered as one of the top criteria that affect passenger satisfaction with public transport systems (Andaleeb et al., 2007). People often don't use public transport (PT) in spite of having good accessibility due to inconvenience and discomfort (Rivera, 2015). Therefore, improving bus comfort to attract more passengers to PT and further alleviate traffic congestion has gained much more attention for bus operators and authorities (Zhang et al., 2014). Additionally, identifying factors which affect bus comfort may assist policymakers implement focused improvement strategies (Shen et al., 2016).

Several studies have been conducted to measure comfort of public bus in various methods while many theories have been proposed to explain which factors are responsible for affecting it. Public bus comfort studies can be divided broadly into two categories - one is measuring comfort by mechanical approach, and the other one is by qualitative approach. In mechanical approach, the variables that may significantly affect comfort are measured using equipment, and in qualitative approach, the perception of various components of comfort is collected from PT users through questionnaire survey (Marques and McCall, 2005). Lin et al. (2010) used the GPS and 3-axis accelerometer functions of modern smart phones to measure comfort in public transport. Zhang et al. (2014) developed a combined comfort model using environmental parameters, such as, vibration, thermal comfort and acceleration. They used

USB5935 equipment to measure the parameters during 241 bus journeys and they predicted the comfort value of bus using multiple linear regression. Pavlina (2015) identified and quantified the most important factors influencing customer satisfaction with public city transport services in the Czech Republic using structural equation model, a modelling technique that can handle a large number of endogenous and exogenous variables, as well as latent (unobserved) variables specified as linear combinations (weighted averages) of the observed variables. Shen et al. (2016) conducted a two-day survey on public buses in Harbin City, China to express the passenger comfort perception in five levels. They used in-vehicle time under different passenger load factors and showed that both in vehicle travel time and passenger load markedly affects passenger comfort. Some studies have combined both the aspects of comfort studies– mechanical and qualitative. Shek and Chan (2008) measured three thermal parameters - air temperature, relative humidity and air velocity and three air parameters, which are, carbon monoxide, carbon dioxide and suspended particulates, for measuring thermal comfort and air quality in public buses in Hong Kong. They investigated the relationship between the subjective and numerical data and developed a combined comfort model. Hence, similar to other factors of mode choice like, safety, cost and travel time, the effects of comfort in public buses require attention.

Most of the previous comfort studies adopted either qualitative or mechanical approach, but comprehensive studies combining both the method are rare few and far between. Taking Dhaka city, the capital of Bangladesh as its study area, where 46.7% and 14.4% trips are made by public buses and private car respectively though private cars cover 76% of the road space (Rimon, 2017; RSTP, 2015), this manuscript has examined the comfort level of public buses using both subjective (using questionnaire) and mechanical approach. The mechanical data, such as, speed, temperature, jerking and sound pressure level are collected using an Arduino Micro-controller based custom made data acquisition unit and the subjective data, which is the 'overall comfort of the journey', is collected using an on-board questionnaire. After that, the relationship between these components are analysed using Multiple Linear Regression (MLR) followed by establishing a comfort estimation model to determine comfort level of public bus journeys. Finally, the results of the study defined how comfortable the public buses in Dhaka City are and identified the areas of public bus service where improvement will lead to have more comfortable public buses in the city. This research can be considered as one of the pioneering studies to develop a comfort evaluation model for public buses in Dhaka using both mechanical and subjective approach.

METHODOLOGY

The overall workflow diagram for this study is illustrated by Fig. 1.

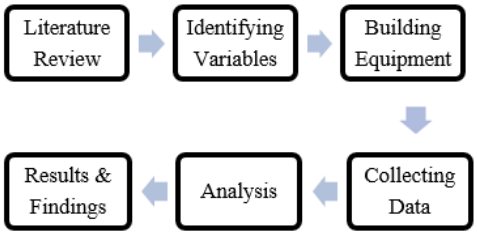

Fig. 1: Work Flow Diagram

Conducting focus group discussions (FGD) and extensive literature review, four variables affecting public bus comfort the most are identified. They are - speed, temperature, jerking (acceleration change) and sound (Velt and Daneen, 2017; Ouis, 2002; Hensher et al., 2003). The mechanical data are collected using Arduino micro- controller equipped with sensors. It consists of several parts: Arduino Mega 2560, GPS sensor, GPS antenna, accelerometer sensor, bread board and SD card slot. The equipment is used to collect the data of GPS location, time and date, speed, acceleration (in 3-axis), temperature, sound pressure level (SPL). The units for the variables are m/s, m/s^2, Degree Celsius and dB for speed, acceleration, temperature, sound pressure level respectively. The questionnaire consists of only one question: "how comfortable was your overall journey?" The passengers gave their response from the following range: very comfortable =0, comfortable = 1, slightly uncomfortable = 2, uncomfortable =3 and extremely uncomfortable =4. A pilot survey is carried out prior to the main survey in Tongi area to

identify the problems associated with the data collection process and necessary corrections were made accordingly.

This manuscript used multiple linear regression (MLR) to analyse the relationship between independent variables which are speed, temperature, jerking, sound with dependent variable comfort. The significance level for the regression model is taken as 5%.
MLR model for this study can be expressed using Eq. (1).

$$y = a + bx_1 + cx_2 + dx_3 + ex_4 + \varepsilon \quad (1)$$

Where, y = overall comfort; x_1= speed; x_2= temperature; x_3= SPL; x_4= jerking; a = intercept; ε = error term; b, c, d, e = regression coefficients. The data used in this study comprise of 45 individual trips made by bus reflecting 45 individual passenger's comfort perception. The data of mechanical variables were stored in the SD card of Arduino.

ANOVA test was conducted to evaluate the equality of mean of two populations where the null hypothesis was: overall comfort was independent of speed, temperature, SPL and jerking whereas the alternative hypothesis was overall comfort depended on speed, temperature, SPL and jerking. Goodness of Fit test was conducted to investigate how the observed value of a given comfort value was significantly different from the expected comfort value. Here, the null hypothesis was: there was no significant difference between the observed and the expected comfort value whereas the alternative hypothesis was: there were significant differences between the observed and the expected comfort value. Line fit plot was produced to display the relationship between overall comfort and each single independent variables. Furthermore, residual plots are drawn to check the appropriateness of the comfort model. The Mohakhali to Abdullahpur route of the city is selected for data collection. The reasons behind this choice are, a huge number of public bus service run along this route, all types of public buses can be found in these areas such as local buses, sitting service buses, gate-lock buses, single decker and double decker buses, long route and short route buses. Another reason for selecting this area is that people from diverse backgrounds use this route. The opinion of passengers from various age, professions, mentalities and classes of the society are taken as feedback. The journeys are made during day and night and also on weekdays and weekends.

RESULTS AND DISCUSSIONS

From MLR analysis it is found that Multiple R is 0.98 which means that the linear relationship is strong and there exists significant dependency of dependent variable (comfort) on the independent variables, speed, temperature, jerking and sound. The R-squared value came out as 97%, which means that all the variability of the overall comfort value is around mean comfort value. The adjusted R square value is 0.96 which is less than R square value (0.97). The standard error value (0.05) is also very low which indicates that the predictions of the model are adequately accurate. The F value for Anova Test came out as 293.24 which means overall comfort is dependent of speed, temperature, sound and jerking. Table 1 illustrates the regression analysis output. The standard error value for each independent variable is also very low which indicates that the prediction of the model is adequately accurate. The T stat value is also larger than +2 or -2 which means that the coefficient is significant with 5% significance level.

Table 1. Parameter estimates of Multiple Linear Regression Model

	Coefficients	Standard Error	T Stat	P- value
Intercept	-1.87	0.22	-8.18	0.000
Speed	-0.02	0.01	-22.5	0.000
Temperature	0.11	0.01	28.64	0.000
SPL	0.01	0.01	2.1	0.04
Jerking	0.15	0.02	6.98	0.000

Using the coefficients of independent variables shown in Table 1 the regression model is established and as follows:

Overall Comfort Value = -1.87 - 0.02*(Speed) + 0.11*(Temperature) +0.01*(SPL) +0.15*(Jerking)

Using this equation, the overall comfort value of any future journey can be estimated by putting the values of that journey's speed, temperature, SPL and jerking in the equation. For data validation, first 22 samples are taken again and a new MLR model is established. It is found from this model that Multiple R is 0.99 which means that the linear relationship is strong. The R-squared value is 97%, the adjusted R square value is 0.96 which is less than R square value (0.97). The standard error value is also very low (0.06) which indicates that the predictions of the model are adequately accurate. The regression analysis output for the data validation model shows that the standard error value for each independent variable is very low which indicates that the prediction of the model is satisfactorily accurate. The T stat value is larger than +2 or -2 which means that the coefficient is significant with 5% significance level. The following regression equation for the data validation is prepared based on the coefficient values of the independent variables using the first 22 samples.

Overall Comfort = -2.15 -0.02*(Speed) + 0.11*(Temperature) +0.01*(SPL) +0.22*(Jerking)

The independent variable values of the last 23 samples are put into the above regression model and overall comfort values are calculated using this model. A MLR model is established with this data and the results show that Multiple R is 1 which means that the linear relationship is strong. The R-squared value is 100%, which shows that all the variability of the overall comfort is around their mean value. The adjusted R Square value is equal to the R Square value. The standard error value is very low indicating the validity of the model.

Line Fit plotting is carried out to determine the comfort values with respect to the independent variables and the results are illustrated in Fig. 2,3,4,5 respectively.

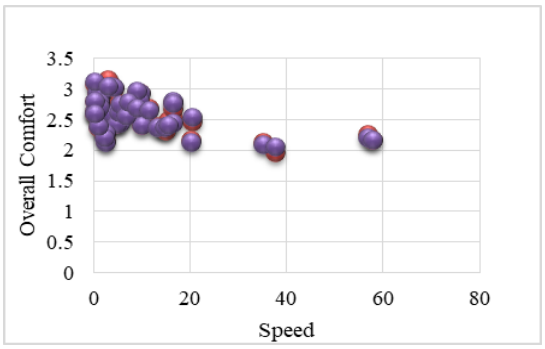

Fig. 2 Speed Line Fit Plot

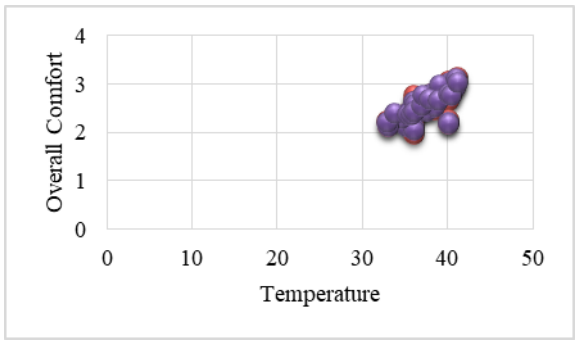

Fig. 3 Temperature Line Fit Plot

From Fig. 2, it can be seen that the overall comfort value lies between 2 and 3, meaning that on average the 45 journeys are slightly uncomfortable to uncomfortable with respect to speed. The Line Fit Plot also shows that with the increase of speed, the journey becomes more comfortable. Fig. 3 shows that the overall comfort value lies between 2 and 3, that means on average the journeys are slightly uncomfortable to uncomfortable with respect to temperature. The Line Fit Plot also shows that with the increase of temperature, the journey becomes less comfortable.

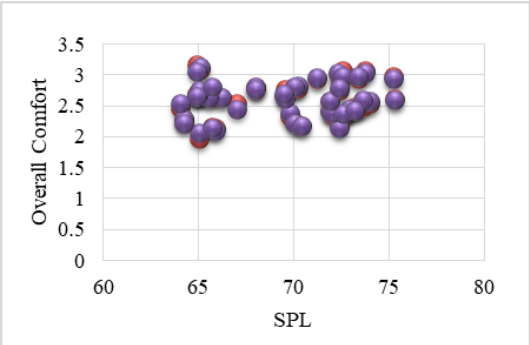

Fig. 4 SPL Line Fit Plot

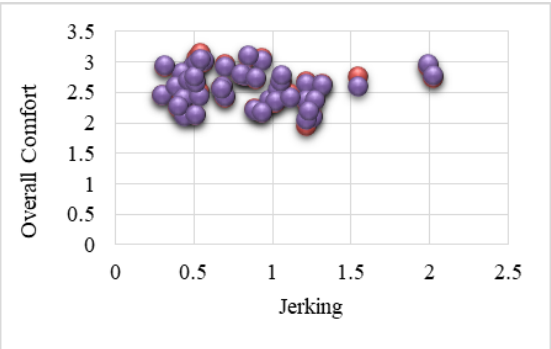

Fig. 5: Jerking Line Fit Plot

It can be seen from Fig. 4 that the overall comfort value lies between 2 and 3 meaning that on average the 45 journeys are slightly uncomfortable to uncomfortable with respect to sound pressure level (SPL). The Line Fit Plot also shows that with the increase of SPL, the journey becomes less comfortable. It can be deduced from Fig. 5 that the overall comfort value lies between 2 and 3 which means on average the journeys are slightly uncomfortable to uncomfortable with respect to jerking. The Line Fit Plot shows that with the increase of jerking, the journey becomes less comfortable.

Residual plots are drawn to check the appropriateness of the comfort model with respect to each independent variable.

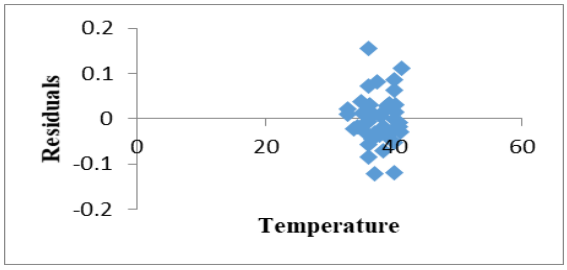

Fig. 6: Temperature Residual Plot

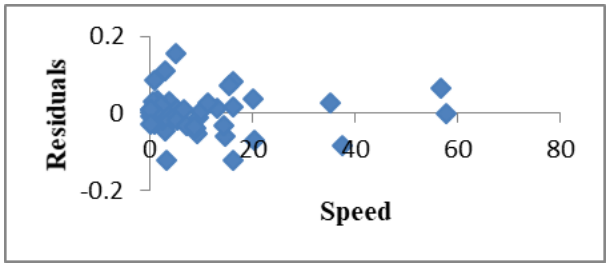

Fig. 7: Speed Residual Plot

The residual plot in Fig. 6 shows that all the points are close to zero. All the points in the residual plot are randomly dispersed around the horizontal axis indicating that the linear regression model is appropriate with respect to temperature .All the points of the residual plot shown in Fig. 7 are close to zero. The points are randomly dispersed around the horizontal axis meaning that the linear regression model is appropriate with respect to speed.

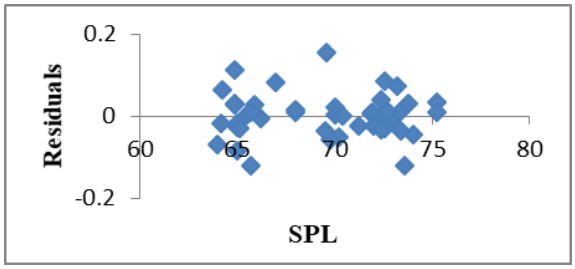

Fig. 8: SPL Residual Plot

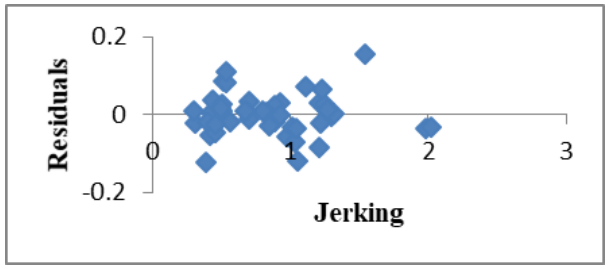

Fig. 9: Jerking Residual Plot

From Fig. 8, it can be seen that the points are almost close to zero. The points are randomly dispersed around the horizontal axis meaning that the linear regression model is appropriate with respect to SPL. Fig. 9 shows that all the points are close to zero and all the points in the plot are randomly dispersed around the horizontal axis meaning that the linear regression model is appropriate with respect to jerking.

CONCLUSIONS

The responses obtained from passengers after conducting the questionnaire survey yielded two very common level of comfort. The comfort level for public buses varied between 'Slightly Uncomfortable' and 'Uncomfortable'. Therefore, in the results, all the values lie between 2 and 3 (higher value means less comfortable). The results corroborate research showing that, when speed increases the comfort of the journey enhance and when temperature, jerking and SPL increases, the comfort of the journey decreases. The results of this study are coherent with its 5% significance level. The study also has some limitations. It measured the comfort level of public buses only. In future, this method can be applied to measure the comfort of other public transport modes i.e., para-transits, rickshaws, CNG, etc. The results of this study can be implemented on a national level to improve the comfort level of public buses thereby improving the overall public bus service quality. This study is expected to pave the way for future researchers to study the influence of different factors and transport modes on the comfort of public bus passengers.

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BEHAVIORAL ANALYSIS OF JOINTED PLAIN CONCRETE PAVEMENT AND JOINTED REINFORCED CONCRETE PAVEMENT USING FINITE ELEMENT METHOD

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ABSTRACT
A study has been undertaken to determine critical pavement responses of Jointed Plain Concrete Pavement (JPCP) and Jointed Reinforced Concrete Pavement (JRCP). Usage of Finite Element (FE) computer package ABAQUS has been made, when the model has been subjected to single axle static load. For the development of JPCP and JRCP model, realistic material properties of the corresponding type of pavement have been incorporated considering the linear behavior of granular base and subgrade to ascertain stress and deformation. Formulating the responsible factors affecting the behavior of the pavement system, vertical deformation at the top of the concrete layer, tensile stress at the bottom of the concrete layer and vertical compressive stress at the top of the subgrade of JPCP and JRCP has been calculated. The analysis has shown that contribution of the reinforcement in JRCP is insignificant. Maximum Surface deflection and maximum vertical compressive stress at the top of the subgrade of JRCP model using reinforcement of 10 mm diameter placed at 150 mm c/c distance reduces by only 1.184% and 0.89% respectively compared to JPCP model whereas maximum tensile stress at the bottom of the concrete layer has increased by 0.21% compared to JPCP model in case of linear characterization.

Keywords: Jointed Plain Concrete Pavement; Jointed Reinforced Concrete Pavement; Finite Element; ABAQUS.

INTRODUCTION
Stress and deformation can be predicted without undertaking any experiment by the Finite Element Method (FEM). It is a numerical approach which divides the structure of any shape into finite number of elements that remain connected through nodes. Accuracy of results depends on number, type and orientation of elements within the structure as well as the modeling of the structure precisely (Sii, 2014). Researcher has been developing three-dimensional (3-D) Finite Element (FE) models for investigating structural problems. Limitations of plate theory assumptions in two dimensional (2-D) FE models ignore influential factors in the development of model which is an impediment towards obtaining correct results (Kuo, 1995). With the advancement made in the field of numerical solution techniques, 3-D FE is capable of addressing complex structural issues (Kim, 2009).

In this study, stress and deformation variation due to the addition of reinforcement in rigid pavement have been investigated undertaking finite element analysis of Jointed Plain Concrete Pavement (JPCP) and Jointed Reinforced Concrete Pavement (JRCP). In case of JRCP, insertion of reinforcement in the concrete slab reduces the number of joints in the transverse direction and holds the cracks tightly so that cracks don't get widened. The study reveals that the addition of reinforcement will not significantly reduce the deformation that would be observed in the case of JPCP. As the concrete slab rests on base

material, this component doesn't act as similar as a slab of the typical building. Though no improvement is observed in terms of vertical deformation, JRCP is expected to perform better under vehicular loading owing to its ability to hold crack. Following the methodology, it will be possible to determine deformation under static vehicular loading.

RESEARCH BACKGROUND

Rigid pavement was first introduced in Bellefontaine, Ohio in 1893. Goldbeck (1919) considered pavement as a cantilever beam and wheel load as a pointed load at the corner. Thus he developed an equation for design purpose. Afterwards, Older (1924) applied this equation in the Bates Road Test. Westergaard (1926, 1927, 1933, 1939, 1943, 1948) conducted rigorous research on rigid pavement to formulate stresses and deformation within the pavement. Later, the advent of finite element method eased the analysis of concrete pavement compared to the complexity lied in the theoretical approach (Huang, 1993).

Numerical modeling is often performed to complement experimental research (Darestani et al., 2006). Huang and Wang (1973) investigated the impact of position of loading, transfer of load and decline in subgrade contact area due to critical stress. For this purpose, they created FE programming language for making it operational in computer. However, a FE program called ILLI-SLAB was developed by Tabatabaie and Barenberg (1978) which included intrinsic aspects of concrete slabs. To determine the stresses and deflections in consecutive slabs lying on elastic foundation, Huang and Deng (1983) developed another FE program named KENSLAB. On the other hand, Tayabji and Collley (1986) developed JSLAB which could analyze concrete pavement sections consisting of up to nine slabs. Chatti et al. (1994) and Kim et al. (2002) modelled concrete slab considering it as a thick plate or thin plate. On the contrary, Liu and Gazis (1999) carried on FE analysis putting beam characteristics in concrete slab and viscoelastic properties in foundation. They developed viscoelasticity by bringing in damper and spring to the model. Loading pattern was also varied to investigate the response of pavement to dynamic loading. For example, Liu and Gazis (1999) considered loading as a moving point load whereas Chatti et al. (1994) and Liu et al. (2000) applied wheel load. Single axle load and tandem axle load were also put into the study by Zaghloul and White (1993), and Kim et al. (2002) respectively. Apart from that, Zaghloul and White (1993), and Chatti et al. (1994) introduced dowels, tie bars and cohesion induced by interlocking of aggregates. Besides, Kim et al. (2002) took into account the effect of damping property. Moreover, Liu and Gazis (1999), and Liu et al. (2000) configured surface roughness into the analysis.

Darestani et al. (2006) investigated dynamic responses of JPCP and JRCP due to applied load by different axle groups and speed which was incorporated with the loading. However, Murshed (2011) analysed the pavement system for linear, non-linear and mixed characteristics of base and subgrade. Thickness and modulus of elasticity were also varied in his study in order to perceive the effect. Later on, Analysis of concrete pavements using ANSYS software had been attempted by Khan and Harwalkar (2014) to compare the stresses of the model analysis with the classical approach of Westergaards and IRC 58-2002 method. However, Kabir (2015) made a comparison between responses due to 11-axles load and 5-axles load using ISLAB2000. Moreover, assessment of the effect of tire configuration, load applied by the Michigan trucks, thickness of the pavement and characteristics of the joints was also made in his study. As the comparison between JPCP and JRCP in the context of stress and deformation has not been made by the researcher, the paper endeavours to investigate the impact of reinforcement in JRCP by comparing its' response under static wheel load with response of the JPCP for similar loading condition.

VERIFICATION OF THE MODEL

To verify the model developed for JPCP and JRCP, a model of flexible pavement is reconstructed as per the study carried out by Kim (2007). Thickness and material characteristics of individual layer which had been used in the study by Kim (2007) for modeling are tabulated in Table 1.

Table 1: Pavement Geometry and Material Properties for FE Modeling verification

Layer	Thickness (mm)	*E* or M_R (MPa)	Poisson's Ratio, υ
Asphalt Concrete	76	2759	0.35
Base	305	207	0.40
Subgrade	20955	41.4	0.45

The load was considered as uniform pressure where static wheel load of 0.55 MPa was implied over a circular area of 152.4 mm radius. Instead of 20-node hexahedron elements, 8-noded brick element was chosen because 20-noded hexahedron element results in greater computing capacity and time than the 8- noded brick element.

Predicted certain critical pavement responses, i.e., maximum vertical deformation at top the asphalt concrete layer ($\delta_{surface}$), maximum horizontal stress at the bottom of the asphalt concrete layer ($\sigma_{h\ bottom\ of\ AC}$) and maximum vertical compressive stress at top of the subgrade ($\sigma_{v\ top\ of\ subgrade}$) are compared in Table 2 with the linear elastic KENLAYER closed-form solutions (Huang, 1993) and results predicted by Kim (2007). The results show in general a very good agreement with the KENLAYER result and the result obtained by Kim. Fig. 1, 2 and 3 illustrate the variation of $\delta_{surface}$, $\sigma_{h\ bottom\ of\ AC}$ and $\sigma_{v\ top\ of\ subgrade}$ during time period of 1 in static step.

Table 2: Comparison of Predicted Responses for 3D Model with Kim, et al. Study Results

Pavement Response (tension in positive)	KENLAYER	ABAQUS with 20- node hexahedron elements (Kim, 2007)	ABAQUS with 8-node brick elements
$\delta_{surface}$ (mm)	-0.927	-0.909	-0.972
$\sigma_{h\ bottom\ of\ AC}$ (MPa)	0.777	0.777	0.574
$\sigma_{v\ top\ of\ subgrade}$ (MPa)	-0.041	-0.040	-0.036

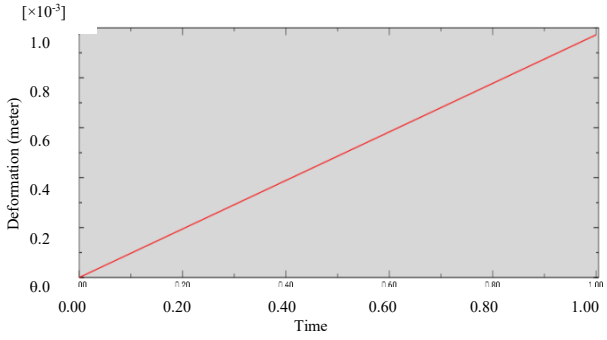


Fig. 1: The Variation of $\delta_{surface}$ during Time Period of 1 in Static Step

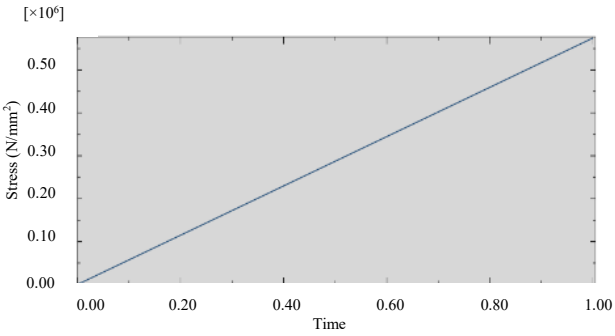


Fig. 2: The Variation of $\sigma_{h\ bottom\ of\ AC}$ during Time Period of 1 in Static Step

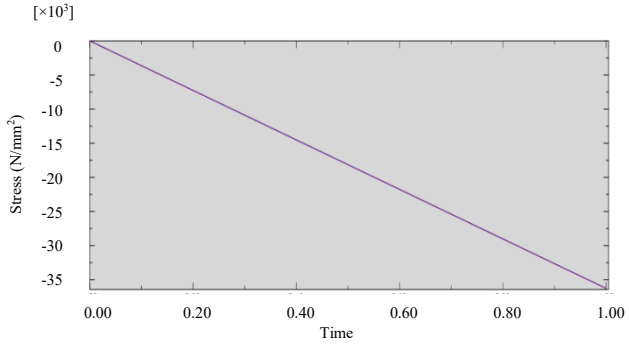


Fig. 3: The Variation of $\sigma_{v\ top\ of\ subgrade}$ during Time Period of 1 in Static Step

DEVELOPMENT OF THE MODEL

The FE modeling of JPCP consists of three components- the JPCP surface, the granular base course material, and the subgrade soil. It also includes the interfaces between any two of these three components of the pavement system. Subgrade, granular base course and concrete slab are modelled with C3D8 element. Among constituent parts, concrete slab contains 6800 elements, base course contains 7272 elements and subgrade course contains 57040 elements. Translation along the normal direction of the surrounding boundary excluding concrete slab surface is restrained. On the other hand, the FE modeling of JRCP is similar to JPCP despite the additional embedded reinforcement which JPCP doesn't contain. In addition to interfaces existing in the JPCP, interaction between concrete slab and embedded reinforcement has also been taken into consideration. T3D2 element is used in this study for modeling reinforcement as strength of reinforcement is comparatively high and it does not reach yield strength in response to vehicular load in our study.

Selection of Parameters and Dimensions of the FE Model

In order to study in detail the behavior of JPCP and JRCP to find out the critical pavement responses due to single wheel load, elastic material properties of constituent layers for the model are provided in Table 3 which have been taken from the study of Murshed (2011). For reinforcement modeling, cross-sectional area of 0.11 in^2 with center to center spacing of 150 mm, Modulus of Elasticity, E_S of 29000 ksi (2×10^{11} N/m^2) and Poisson's Ratio, υ of 0.3 have been selected.

Table 3: Pavement Geometry and Material Properties

Layer	Thickness/ Depth (m)	Modulus of Elasticity, E_S (MPa)	Poisson's Ratio, υ	Unit Weight ($Kg/m^{2)}$
Concrete Surface	0.225	25000	0.2	2400
Granular Base	0.30	120	0.3	2147
Subgrade soil	24	28	0.3	1920

RESULT INTERPRETATION

Results of linear elastic analysis of JPCP and JRCP are tabulated in Table 4. Due to addition of 10 mm bar spacing 150 mm center to center, impact on maximum vertical deformation at top of the asphalt concrete layer ($\delta_{surface}$), maximum tensile stress at bottom of the asphalt concrete layer (σ_i) and maximum vertical strain at top of the subgrade (σ_v) have also been quantitatively compared.

Table: 4 Predicted Pavement Responses for 3D Analysis

Pavement Responses	**JPCP**	**JRCP**	**Difference (%)**
$\delta_{surface}$ (mm)	0.760	0.751	1.184211 (↓)
σ_i (MPa)	0.461	0.462	0.21692 (↑)
σ_v (KPa)	14.7112	14.58	0.891838 (↓)

Fig. 4, 6 and 8 illustrate the variation of $\delta_{surface}$, σ_i and σ_v of JPCP for linear elastic layer characterization during time period of 1 in static step. On the other hand, Figure 5, 7 and 9 illustrate the variation of $\delta_{surface}$, σ_i and σ_v of JRCP for linear elastic layer characterization during time period of 1 in static step.

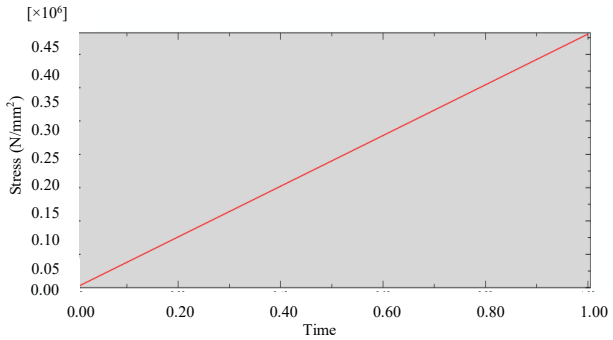


Figure 4: The Variation of $\delta_{surface}$ of JPCP

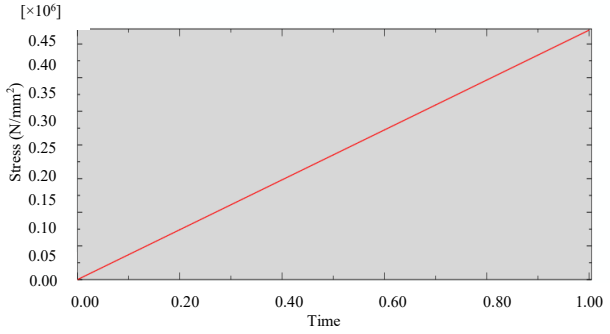
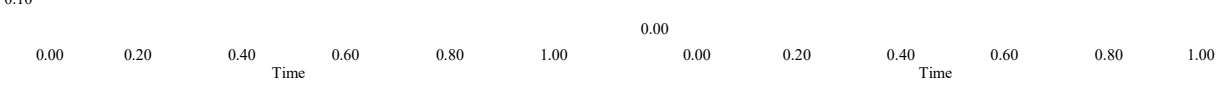


Figure 5: The Variation of $\delta_{surface}$ of JRCP



during Time Period of 1 in Static Step
for Linear Elastic Layer Characterization

during Time Period of 1 in Static Step
for Linear Elastic Layer Characterization

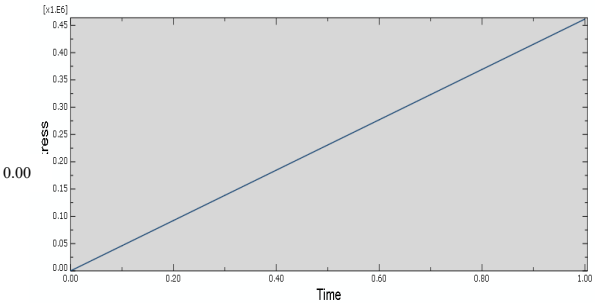


Figure 6: The Variation of σ_i of JPCP
during Time Period of 1 in Static Step
for Linear Elastic Layer Characterization

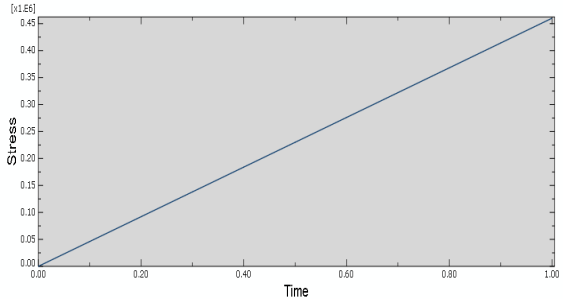


Figure 7: The Variation of σ_i of JRCP
during Time Period of 1 in Static Step
for Linear Elastic Layer Characterization

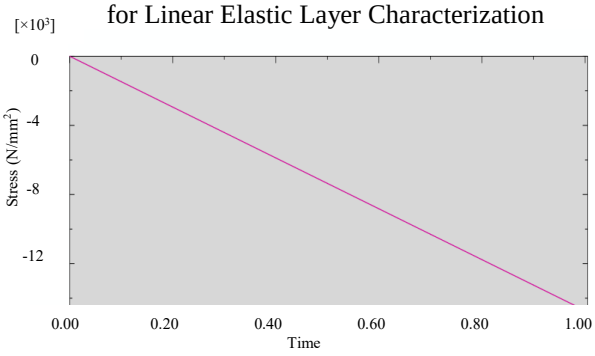


Figure 8: The Variation of σ_v of JPCP
during Time Period of 1 in Static Step
for Linear Elastic Layer Characterization

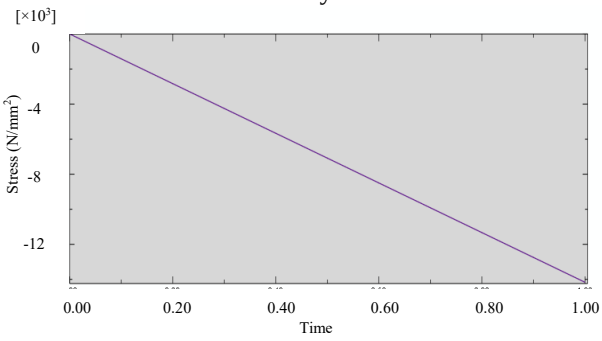


Figure 9: The Variation of σ_v of JRCP
during Time Period of 1 in Static Step
for Linear Elastic Layer Characterization

CONCLUSION

FE analysis of JPCP and JRCP model for linear characterization manifests that the addition of 10 mm diameter reinforcement with 150 mm spacing doesn't affect the deflection and stress value significantly. Maximum surface deflection and maximum vertical strain at top of the subgrade of JRCP decreases by 1.18% and 0.89% respectively compared to JPCP but the maximum tensile stress at the bottom of the asphalt concrete layer of JRCP is 1.21 times than that of JPCP. So it is evident that the addition of reinforcement doesn't add significant load carrying capacity to the JRCP pavement system. As the concrete slab rests on base material, the boundary condition is not as similar as a slab of the typical building. As a consequence, reinforcement in JRCP doesn't reduce vertical deformation and stress at critical locations though JRCP is expected to perform better under vehicular loading owing to its ability to hold crack. Thus, pavement responses for linear as well as non-linear material behavior along with dynamic loading can be numerically determined accurately following the methodology used in this study. This method can also be implemented to assess the effect of load transfer at joints (by aggregate interlock or dowel bars) and presence of water table under the pavement surface.

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ANALYSIS OF TRAFFIC INTENSITY VARIATION IN MAJOR INTERSECTIONS OF A SECONDARY CITY IN BANGLADESH: A CASE STUDY ON PABNA MUNICIPALITY

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ABSTRACT
Intensive traffic flow has become a common scenario in almost every city of Bangladesh which creates severe traffic congestion that brings speechless woe for citizens. This situation challenges transportation planners and engineers to cope with providing sustainable traffic management strategies. From this realization, this study is conducted to analyze traffic intensity variation in major intersections of a secondary city in Bangladesh. Traffic volume Survey, Spot Speed study and Landuse pattern analysis were the main methodological approaches to conduct the study. The data collected were analyzed through the use of ArcGIS 10.3 and statistical computer packages. The study reveals that the flow of vehicles increases on roads during the summer season and normally vehicle's speed tends to decrease significantly at noon and evening indicating serious traffic jam. It also explores that land-use pattern has a great impact on the variation of traffic intensity within the city. This study tries to express the effects of these variables on traffic intensity variation to support the future planning of sustainable traffic management strategies for municipalities with similar profiles.

Keywords: Traffic intensity, Traffic Volume, Spot Speed, Landuse Pattern, Pabna Municipality.

INTRODUCTION
In developing countries, urban migration is increasing so rapidly which creates intensive traffic resulting traffic congestion. According to Gwillian (2011), per year about 3 to 5 percent population growth has occurred over the past decade in African cities due to urban migration. This is huge for exceeding road network capacity.

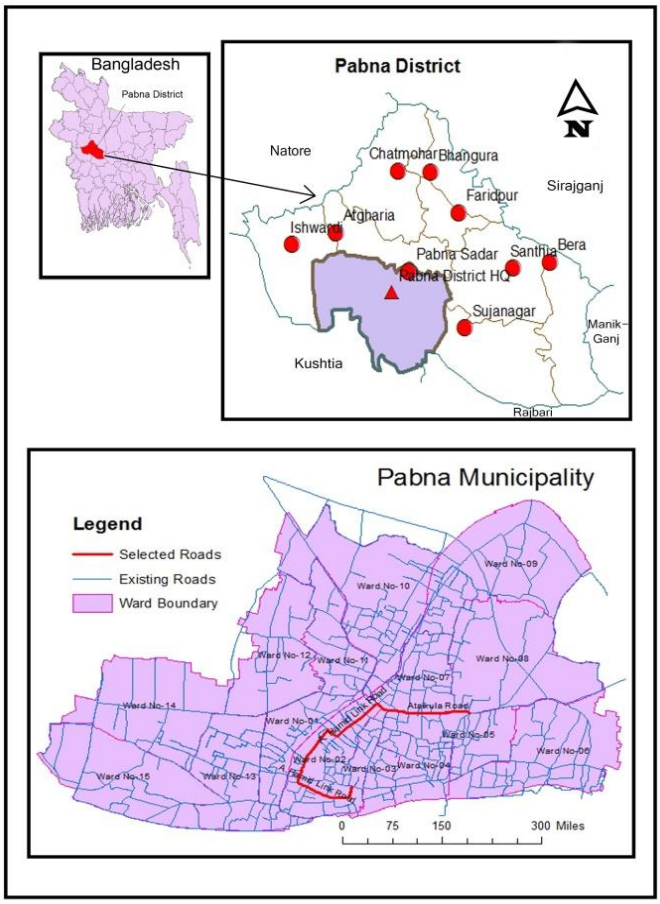
Recently, transport activities have increased for demographic, economic, land use and international development which is essential for the economic and social growth of a country (MinVenW, 2004). On the other hand, transport has many negative effects such as traffic congestion and environmental pollution (Osoba and Samson, 2012). In Bangladesh, for the year 1997 country wise annual economic loss became $79 million due to traffic congestion (Osman, 2010). In addition, annually $3 billion and daily over 8 million works hour is wasted due to traffic congestion resulting from intensive traffic flow in Bangladesh (Gilbert & Perl, 2013 as cited in Chowdhury et al., 2016).

However, severe traffic congestion that brings speechless woe for citizens and this situation challenges transportation planners and engineers to cope peace with providing sustainable traffic management strategies.

Traffic intensity variation analysis provides information about temporal variations of traffic flow, speed distribution with respect to time and economic, social and cultural impact on traffic. This information is necessary to provide steps to reduce traffic congestion of a city.
Thus, this study is conducted to analyze traffic intensity variation in major intersections of a secondary city in Bangladesh i.e. Pabna municipality. It also tries to provide a better understanding insight the functioning of traffic system with temporal variation that may help decision makers in taking necessary strategies to provide fluent transport system within the city.

METHODOLOGY

The study analyzes traffic intensity variation of traffic morr, indira morr along Abdul Hamid road and Chapa-Mosjid morr, pach-matha morr and Kheyaghat morr along Ataikula road under Pabna municipality which is selected as study area. To obtain study objectives temporal variation of traffic intensity and spot speed of vehicles are critically observed. At first, Abdul Hamid road and Ataikula road are selected as the major roads in the city. The five intersections along two roads are seriously affected by traffic congestion which has become a daily scenario. Almost all vehicles passing through the city using the two roads and facing traffic congestion in these intersections.

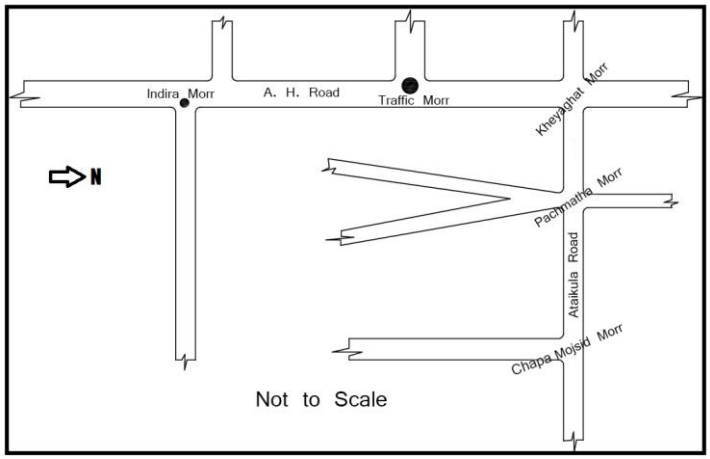


[Fig. 1]: Location of the Selected Roads

The study is conducted based on primary and secondary data. Primary data sources are:

i) Reconnaissance survey: Field visit has been done for observation and selecting study area.
ii) Traffic volume survey: Counting of vehicles has been done manually using passenger car units (PCU) value where one car is considered as a single unit; the cycle and the motorcycle are considered as half car unit; the bus and the truck are equivalent to 3 cars or 3 PCU.
iii) Spot Speed Survey: Spot speeds of vehicles have been surveyed through the direct-timing procedure.

iv) Landuse Pattern Survey: The analysis of existing land uses around the selected roads has been done through a physical survey.



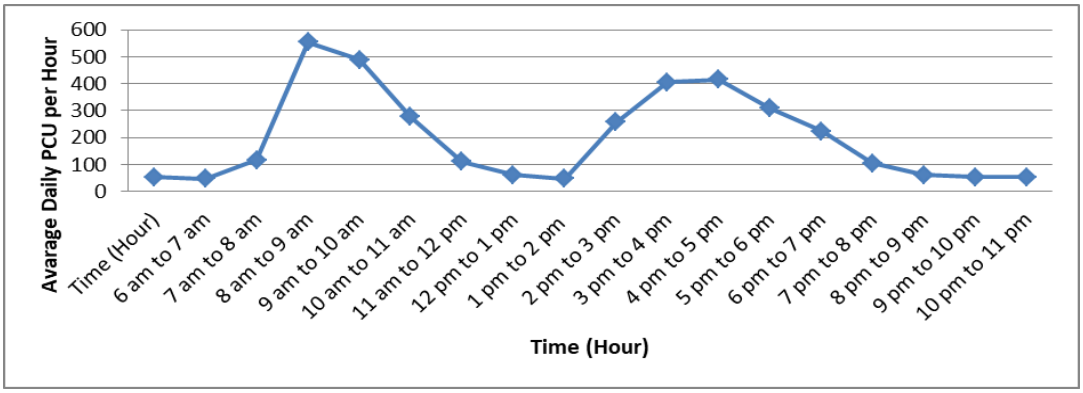
[Fig. 2]: Selected Intersections within the Roads

The secondary data have been collected from journals, books, Pabna municipality etc. The collected data have been analyzed through the use of ArcGIS 10.3 and statistical computer packages.

RESULTS AND DISCUSSIONS

Traffic Intensity Variation With Respect To Time

The five most important sections (e.g. Chapa-Mosjid morr, Pach-matha morr, Kheyaghat morr, Traffic morr, and Indira morr) of Pabna city have been surveyed to show the variation of traffic intensity with respect to time. The temporal variation of traffic has been illustrated in figure 3.

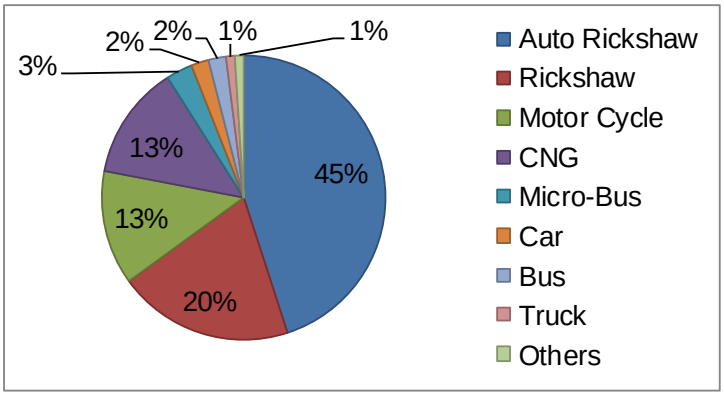


[Fig. 3]: Variation of Traffic Intensity With Respect To Time

[Fig. 3] shows that traffic volume becomes high from 8 am to 10 am in the morning and 4 pm to 6 pm in the afternoon. Intensive traffic flow occurs in the morning for peak hours of office, shopping, school and college as the starting time. Again, the intensive flow becomes high in the afternoon due to the peak hours as the ending time of offices, schools and colleges and also for shopping. In addition, it has been found that intensive traffic congestion occurs during peak hours. Besides the peak hour fact, some other causes have been identified for traffic congestion in intersection points such as due to the lack of regulations, insufficient parking space and footpath, multiple origin and destination points from auto rickshaw trips, moving of both rickshaws and auto rickshaws through access roads.

Traffic Mode Choice analysis during Peak Hours

From traffic volume survey in the five intersections, it has been observed that auto rickshaw is the most preferable mode of traffic (45%) in the city. People prefer auto-rickshaws for fixed routes in short distance within municipality area, multiple origin and destination points, low fare and availability. The following modes are respectively rickshaw (20%), motorcycle (13%), CNG (13%), micro-bus (3%), car (2%), bus (2%), truck (1%) and others (1%).

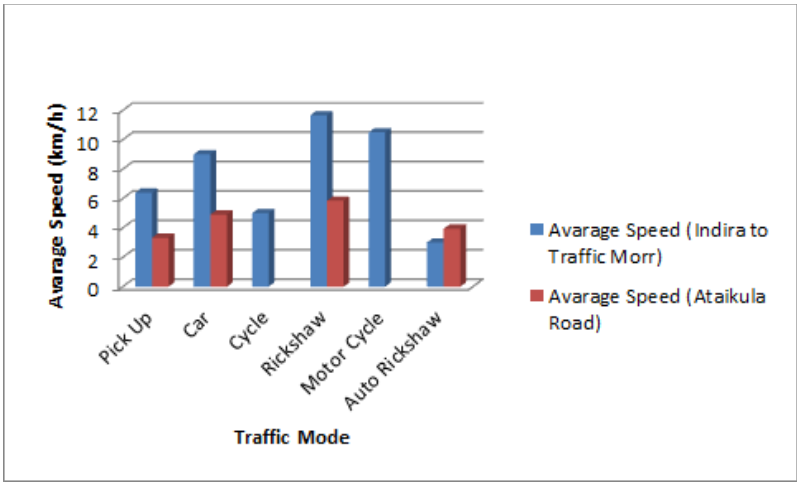


[Fig. 4]: Preferable Mode of Traffic during Peak Hours

General people prefer rickshaws for traveling as the fare is respectively low, destination-based trip facility and availability in Pabna municipality.

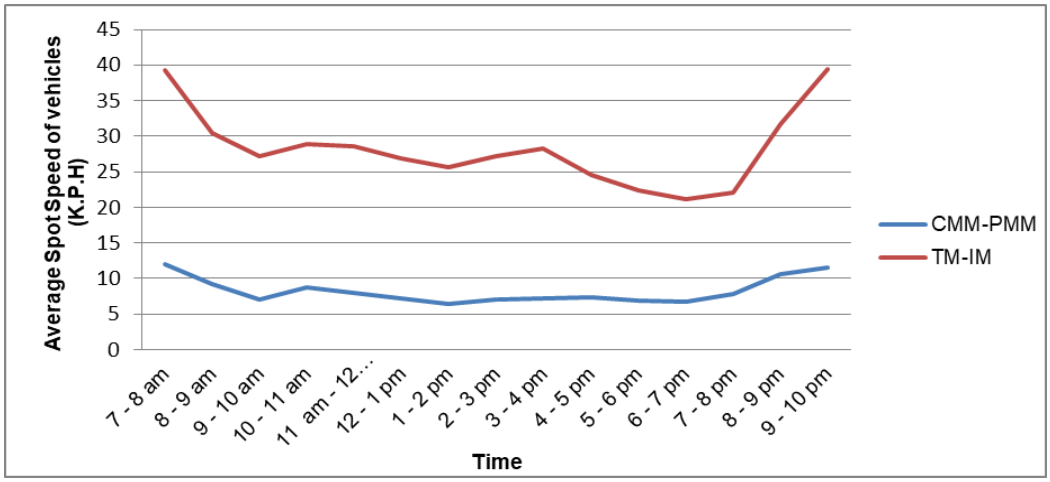
Spot Speed Variations

A survey conducted in 2008 revealed that average journey time within the city was around 20 minutes (MIDP, 2008). In this study spot speed variations of different vehicles during peak hours are analyzed. The spot speed survey has been done through Traffic morr to Indira morr (TM-IM) portion of A. H. road and Chapa-Mosjid morr to Pach-Matha morr (CMM-PMM) portion of Ataikula road.



[Fig. 5]: Spot Speed Variations On The Basis Of Traffic Mode during Peak Hours

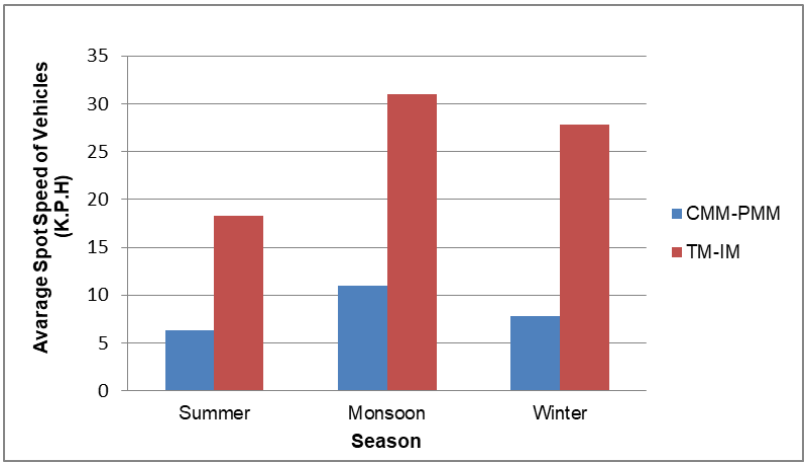
[Fig. 5] shows that the average spot speed of rickshaw and motorcycle is higher than other vehicles. Rickshaws are one way trip generated vehicles that have a fixed origin and destination. In addition, rickshaws are able to bear only one or two passengers in a single trip and due to available passengers during peak hour their average spot speed goes higher. On the other hand, as auto rickshaw can bear at least 6 passengers in single journey drivers try to pick passengers from multiple origin points that create congestion. And hence the average speed of auto rickshaw becomes low.



[Fig. 6]: Average Spot Speed Variation throughout a Single Day

[Fig. 6] exposes the average spot speed of vehicles passing through the selected portion of the two roads in a single day. It reveals that the lowest average spot speed of vehicles is 6.44 K.P.H at 1 pm to 2 pm for Chapa-Mosjid morr to Pach-Matha morr (CMM-PMM) portion and 21.13 K.P.H at 6 pm to 7 pm for Traffic morr to Indira morr (TM-IM) portion. Unavailable frontal space for commercial activities of roadside shops and lack of footpath for pedestrians of CMM-PMM portion decrease the carriage way for vehicles which results in the lowest average spot speed during noon. On the other hand, several banks, offices, service centres, and markets are situated alongside the TM-IM portion of A. H road. These generate numerous trips within TM-IM portion. Again, illegal occupancy of the footpath by hawkers and parking decrease the carriage way area which results in the lowest average spot speed in TM-IM portion during the evening. The study also exposed that the mean spot speeds for CMM-PMM and TM-IM portion are respectively 8.25 and 28.24 K.P.H.

Again, Variation of average spot speed of vehicles is illustrated in figure 7 below.



[Fig. 7]: Average Spot Speed Variation throughout Seasons

[Fig. 7] marks that average spot speed is found low during the summer season for both portions of roads (6.34 K.P.H for CMM-PMM and 18.25 K.P. H for TM-IM). The study shows that the number of vehicles becomes high on roads during the summer season which results in high flow of vehicle and creates traffic jam that decreases the spot speed. On the other hand, the number of vehicles on roads decreases during the monsoon season which results in low flow of vehicles that ensures the highest spot speed for both portions of the roads as well as intersections.

Land Use Pattern Analysis

Table-1 shows the trip attractive landuse alongside the roads.

Table 1: Landuse types that attract trips alongside the Portion of the Roads

Name of Portion of Road	Name of the Road	Landuse types that Attract Trips
Chapa-Mosjid morr to Pach-Matha morr (CMM-PMM	Ataikula Road	Bulbul College, Bookshops, Vegetable market, Hardware & Electronics shops, Banks, Jublitank, Mosque, jewelry shops
Traffic morr to Indira morr (TM-IM)	A.H Road	Two supermarkets, Banks, Medicine stores, Mobile markets, Band shops, training centers, Pabna College, Printing shops

Again table-2 shows that the surrounding area of selected roads is mainly used for commercial purposes (45%). Besides major land use types are services (20%), education (15%) and industrial (7%).

Table 2: Landuse Pattern in the Selected Area

Sl No	**Landuse Type**	**Percentages**
1	Residential	3%
2	Commercial	45%
3	Industrial	7%
4	Educational	15%
5	Religious	3%
6	Service	20%
8	Recreational	2%
9	Mixed use	4%
16	Others	1%
	Total	**100%**

According to a recent study, in Pabna city 25.1% of the total trip is generated for housework purposes, 25% is for education, 16.7% for service, 12.2% for business, 8.5% for personal work, 4.7% for recreation, 4.2% for shopping and 3.6% for other purposes (Rana, Hosssain & Sadat, 2017). The traffic intensity is high on the selected roads as major portions of the surroundings of roads are used for commercial, service and educational purposes. Hence, during office time intensive traffic flow is observed every day. Besides, acute trips are generated during different social, cultural and religious festival.

THE SCOPE OF THE STUDY

According to Adedimila in 1981, “Traffic congestion or traffic jam is the byproduct of using motorized vehicles. Traffic jam is created when the vehicles do not move for a long time which causes huge time wastage and monetary loses”. To protect this loses of country’s economy, at first it is necessary to analyse present traffic congestion and its characteristics. This study may help to perform these purposes as it has analysed the variation in traffic intensity of Pabna town, one of the most ancient towns in Bangladesh. In addition, this study tries to provide a better understanding insight the functioning of traffic system with temporal variation that may help decision makers in taking necessary strategies.

Recommendation

One-way traffic flow can be a possible solution of congestion for the town. But it can be predicted that alternative roadway would be demanded in the nearest future especially for buses, trucks, and microbus. Controlling of traffic flow at intersections can be also a possible way to reduce congestion rate.

However, it has been observed that most of the commercial activities of the town take place within a very narrow space comparing to its total area. Therefore, growth centres should be developed at different important locations of the town to reduce trip generation towards the downtown of the town.

CONCLUSION

Like other cities in Bangladesh, traffic congestion has become a common scenario in Pabna city. Regulating traffic and setting up planned office time may be a temporary solution in reducing the present daily congestion. But expanding of commercial area and constructing alternative road networks will be demanded in near future for the long-lasting solution of the problem.

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INFLUENCE OF LAND USE ON MODE CHOICE BEHAVIOR OF THE CITIZENS OF KHULNA CITY

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ABSTRACT

The information regarding travel behavior of the citizen and understanding why they are making any particular choice in their trip making is gaining vital importance in shaping the traffic management system in any city efficient and competent. Travel behavior pattern of the citizens could have both negative and positive influences on the sustainability issue of any transport system. This paper focuses on the steps of the transport demand model with two types of information- demographic information and travel data. Information regarding trip generation, the pattern of trip variation with housing types, modal choices for various purposes along with changes in income variation of citizens in Khulna City were explored using statistical tools and` techniques, and trip distribution modeling was done to find out the factors affecting the trip making behavior. The findings showed that there is present a salubrious relationship between the income level of the people and their mode preferences. However, the total number of trips has influenced mostly by the income of the households where housing condition has a negative impact on the trips produced. Vehicle ownership and family size do not have that much effect on the number of trips generated. So, the consideration of both positive and negative influential variables on the travel pattern can help to outline a sustainable future transportation plan of Khulna City.

Keywords: Travel pattern; Trip-making behavior; Mode choice; Sustainable transport system

INTRODUCTION

Transportation is the science that seeks to study the problems that arise in providing transportation facilities in an urban, regional or national setting and to prepare a systematic basis for planning such facilities (Kadiyali, 2003). Khulna, the third largest city in Bangladesh, also one of the most prominent industrial domain in the country, where the vehicles, pedestrians, economic and commercial activities, official and administrative activities are increasing rapidly. However, the transportation facilities including the roads and streets, road width, management systems are not increasing, and management measures are not being upgraded as per the increasing demand. Mainly, easy-bikes, auto rickshaws, and tempo service are available as transportation modes in the city. The routes among the urban centers are usually long, and there is no bus service on those routes though it is the cheapest (Rahman & Kabir, n.d).

The objective of this study was to understand the nature of problems that the users face in their everyday mobility throughout the city. The focus was also on the formulation of proposals for safe and efficient movement of goods and people from one place to another place. With that in mind, the whole city was divided into separate parts and areas with most transportation usage was identified. Then it was focused to collect the information on all the factors that are likely to influence the travel pattern of the citizens in the selected areas. From the initial study, 13 wards of Khulna city corporation (KCC) were found busier than the other 18 wards, and the rest of the study was focused on these 13 wards. Ward no. 18, 19, 20, 23, 24, 25, 26, 27, 28, 29, 30, and 31 of KCC were studied to know the travel pattern of the

citizens in these areas. Home interview survey is performed to collect the data. Mainly household and trip data and other data related to the travel behavior of people were collected through the survey. The household information contains information such as address, size of household, age and sex structure of household, occupation, place of work, household income, vehicle ownership and so on. Travel data contains information on all journeys made during the previous 24 hour period, including the origin and destination of the journeys, the purpose of the trip, mode of travel, etc. Finally, a model which has been developed to determine the future number of trips and know the estimated future values of the independent variables. It has been already stated that this research aims to understand the travel pattern of the people of Khulna city and to identify the influences of land use on mode choice and future transport planning of this city. In this study, a mathematical relationship has been developed to synthesize the trip making pattern on the basis of observed trips and the variables related to the trip making behavior.

METHODOLOGY

This study is based on the four-step model. The first three steps have been considered out of the four steps that are trip generation, trip distribution, and modal choice. Network assignment step has just skipped for the low probability to get the actual information about the network path as the people of Khulna city uses para-transit at most often because of their default mode of transport. In the working process, activities are - select study area, determine sample size, prepare the questionnaire, conduct the field survey using prepared questionnaires, analyze the collected survey data, and create a linear model of trips produced by the surveyed households on the basis of the analysis. An unorthodox method was followed using the housing condition of the households. Total number of households in the study area were 42797 (KCC, 2011), and total population was 177588 (BBS, 2011). Total sample size was determined 630 for the whole work. Moreover, that was based on a ratio of 2:1:2 of housing conditions which were Pucca, Semi-Pucca and Katcha accordingly. The total survey work was done based on a unified questionnaire for each household selected randomly in the selected wards.

RESULTS AND DISCUSSIONS

A few analytical procedures were performed, e.g., cross tabulation, linear modeling, and multiple response analysis. These results give significant information on trip generation, the pattern of trip variation with variation in housing, modal choices for various purposes along with changes in income variation of citizens in the study area.

Modes Used by the City Dwellers

From the survey, it was found that about 33% of the people use rickshaw, and mainly the higher income people use this mode frequently because of comfort when they have to travel short distances about 2 to 5 km (Figure 1). Other two modes are walking and easy bike cover about half of the total. About 27% and 25% travel of the dwellers are covered by walking and easy bike respectively. People usually use walking mode for traveling short distances. However, many lower-income people use this mode for saving money. The other modes van, motorcycle, bus, baby taxi and car cover 2%, 3%, 3%, 7% and 0.6% respectively.

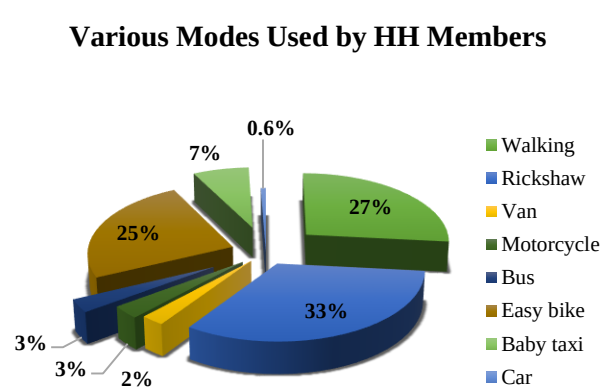


Figure 1 Various modes used by household members

Housing Type and Mode

The very examples can be shown from the figure above or the table below (Fig. 2) which indicates significant differences between the lower end and the higher end of the society according to the income. Moreover, with the change in income level, housing condition has also changed. Most of the people belong to the low-income group lives in Katcha or at most in semi-pucca housing. Moreover, the likes to walk before use any motorized mode for attending works. That is why people from Katcha houses like to walk near about 40% to attend workstation.

Moreover, a portion of using easy bike is vast as most of the family members prefer using it to attend school or other social institutions and meet the basic needs (Figure 2). Although the high-income group prefers to use a rickshaw or personal car, but a portion of using the car is still low in Khulna city. Use of personal vehicles besides cars such as a motorbike, bicycle or personal car is also pretty low in the study area, and so does the use of public transport as there is no adequate public transport system in Khulna.

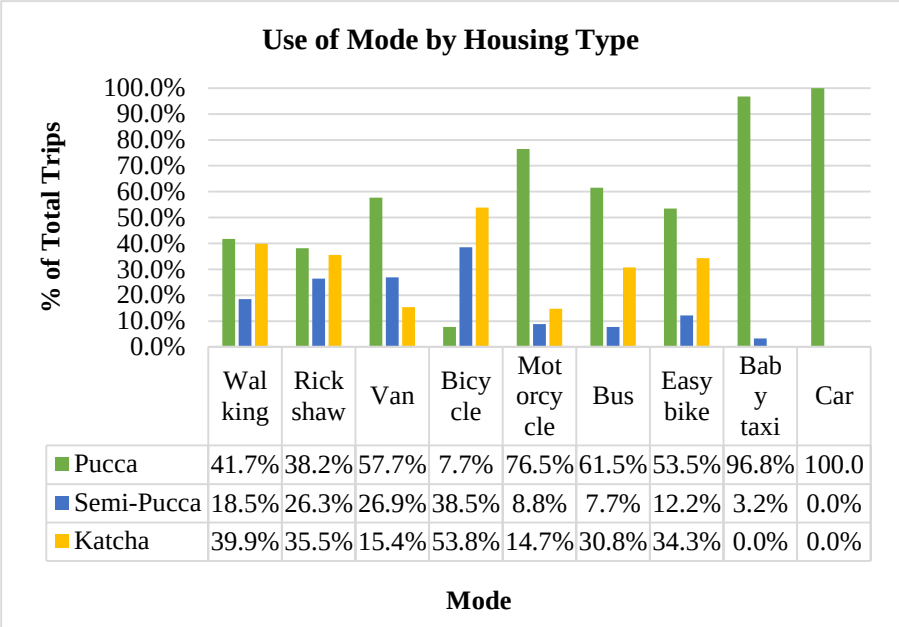


Figure 2 Use of mode by housing type

Trip Purpose and Modes

Use of travel modes changes with the change of purposes of any trip. It has been found that the respondents use different kinds of mode for different purposes.

Table 1: Purposes of travel and used modes

Modes of Travel	Work	School	Shopping	Social	Others	Back to Home	Coaching
Walking	28.10%	10.40%	7.40%	0.80%	8.40%	44.90%	0.00%
Rickshaw	22.60%	18.60%	6.70%	4.30%	7.30%	40.30%	0.20%
Van	34.70%	14.70%	1.10%	0.00%	4.20%	45.30%	0.00%
Bicycle	43.50%	4.30%	2.20%	0.00%	0.00%	50.00%	0.00%
Motorcycle	37.20%	3.80%	9.00%	0.00%	5.10%	44.90%	0.00%
Bus	21.40%	17.50%	1.90%	1.00%	11.70%	44.70%	1.90%
Ethe asy bike	29.10%	11.40%	8.90%	1.90%	6.60%	41.60%	0.60%
Baby taxi	34.60%	25.10%	15.60%	0.00%	3.40%	21.20%	0.00%
Car	33.30%	0.00%	0.00%	0.00%	66.70%	0.00%	0.00%

(Source: Field Survey, 2016)

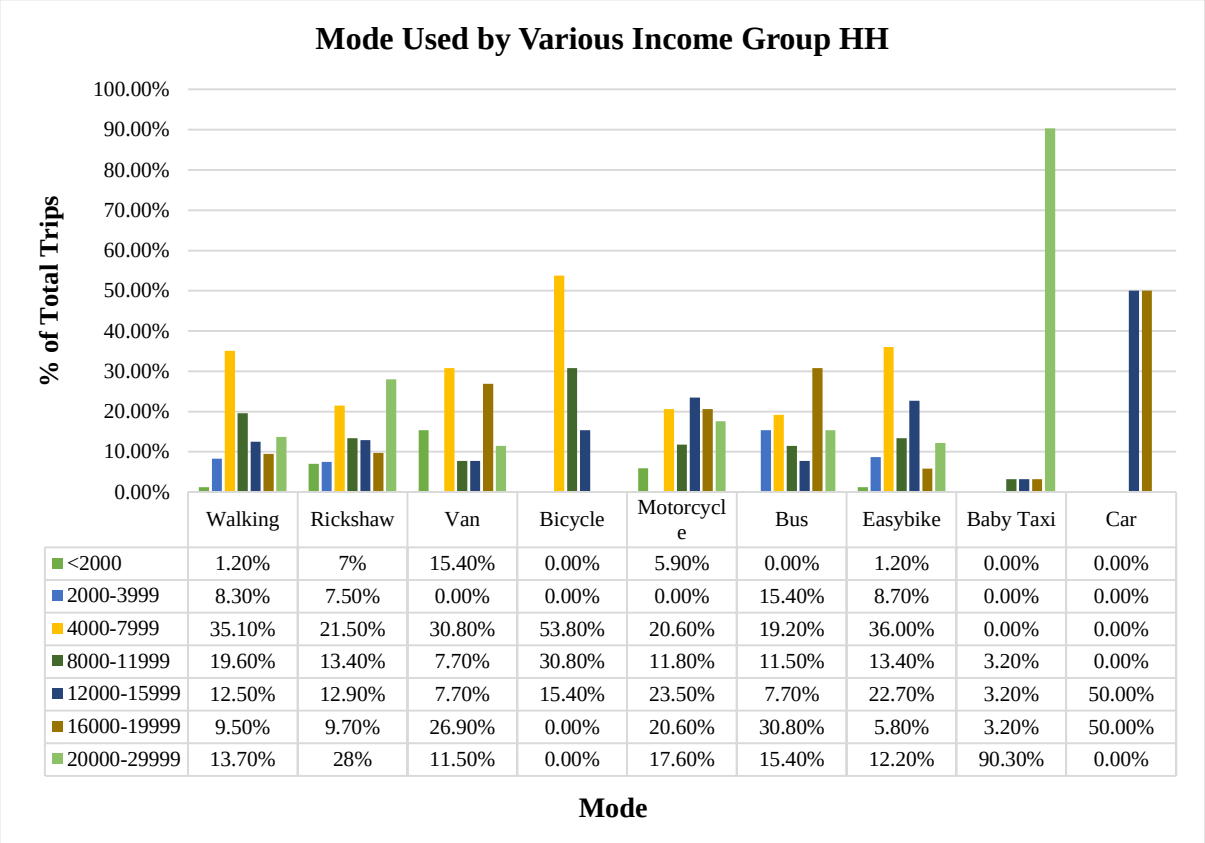
Table 1 presents the purposes of travels and modes used in those cases. From the field survey, people stated that they liked to walk no matter what the purpose is. However, in the case of women or child, they use rickshaw, and easy bike for making any trip regardless of travel distance is significant. It is also considered that people use different modes at different times of the day. For example, the same man can use different modes for two trips one in a morning and one in the evening: first one for going to the office and a second one for returning to the residence. That might be for the cause of stress or tiredness of doing work all day long.

Mode and Income Group

Changes in use of mode are found among the different income groups. A person who has low income usually likes to walk whereas a person with a handsome income tends to choose the motorized mode, e.g., easy bike, personal car or others. In the study area, people who have an income range between 4000-7999 and 12000-15999 have mostly found using vehicle modes. Whereas the income range less than 2000 uses the modes lowly and in some cases, it is found as below 1%. People with a high income (more than 20000) tends to use a variety of modes such as rickshaw, baby taxi, and private cars along with easy bike. Most modes are used by income over 4000 at least, and over 8000 is most prominent to make trips using modes beyond walking. These represent the lower income group people's inability to pay for any trip and the ability of people with higher income for any trip with modes. Figure 3 shows the significance of the collected data to portray the relationship between the income of any household

and their use of modes. The most exciting matter that comes out from the analysis is the use of a car, or private modes of transportation is deficient in number.
Moreover, the presence of car is only in the middle-income group rather than in the higher income group people this may because of the no of trips produced by the high-income group people and their staying time in Khulna. They tend to spend a handsome time outside Khulna. So they prefer other modes rather than private vehicles.

Fig. 3: Mode used by various income group household



	Walking	Rickshaw	Van	Bicycle	Motorcycle	Bus	Easybike	Baby Taxi	Car
<2000	1.20%	7%	15.40%	0.00%	5.90%	0.00%	1.20%	0.00%	0.00%
2000-3999	8.30%	7.50%	0.00%	0.00%	0.00%	15.40%	8.70%	0.00%	0.00%
4000-7999	35.10%	21.50%	30.80%	53.80%	20.60%	19.20%	36.00%	0.00%	0.00%
8000-11999	19.60%	13.40%	7.70%	30.80%	11.80%	11.50%	13.40%	3.20%	0.00%
12000-15999	12.50%	12.90%	7.70%	15.40%	23.50%	7.70%	22.70%	3.20%	50.00%
16000-19999	9.50%	9.70%	26.90%	0.00%	20.60%	30.80%	5.80%	3.20%	50.00%
20000-29999	13.70%	28%	11.50%	0.00%	17.60%	15.40%	12.20%	90.30%	0.00%

Linear Models Using Various Variables

Total number of trips are defined as a dependent variable, and total household size is defined as an independent variable. Total sample size was 630, including 252 pucca, 126 semi-pucca and 252 Katcha households. Basic statistical analysis and linear regression were performed on the collected data (table 2, table 3 and table 4).

Table 2: Correlations between total no of trips and total HH size

Variables	Total trips produced by the HH members	Total family members
Total number of trips produced by the HH members	1.000	.163
Total family members	.163	1.000

Table 3: Description of variables

Variables	Mean	Std. Deviation
Total number of trips produced by the HH members	4.18	2.402
Total family members	3.94	1.304

The analysis shows that the correlation between two different variable total no of trips (dependent variable) and total household size (independent variable) accordingly is 0.163 and it indicates that the relationship between total numbers of trips produced by the Household members and no. of trips produced by the HH slightly correlated. From this value, it is not possible to make a reliable model or plan for transport planning. It is not representing the perfect relationship of vehicle ownership with trip making. In another word, there is no impact of vehicle ownership with produced trips in the study area.

The mean number of trips is 4.16, and the average number of household member is 4.02 in our study area.

Table 4: Correlations among various variables and total no of trips

Variables	Total number of trips produced by the HH members	Total family members	Income range	Housing condition	Vehicle ownership
Total number of trips produced by the HH members	1.000	.130	.415	-.217	.079
Total family members	.130	1.000	.033	.011	.012
Income range of the respondents family	.415	.033	1.000	-.467	.230
Housing condition of the respondents	-.217	.011	-.467	1.000	-.135
If any vehicle owned by the respondent	.079	.012	.230	-.135	1.000

Table 5: Description of variables

Variables	Mean	Std. Deviation
Total number of trips produced by the HH members	4.16	2.449
Total family members	4.02	1.320
income range of the respondent's family	5.03	1.565
housing condition of the respondents	2.05	.892
if any vehicle owned by the respondent	1.74	1.219

The average number of the total trip is 4.16, and from table 2 we get the correlation between total family members and the total number of trips which is 0.130 very close to 0. So, there is no relationship between these two variables. Again, the relationship between the income range of the respondent's HH and the total number of trips is 0.415 which is moderately correlated, but the housing condition is negatively correlated with a total number of trips produced by the HH as the value is - 0.217. Moreover, vehicle ownership is not also correlated with the total number of trips, because the value is 0.079. Besides the housing condition of the respondent negatively (-.467) affects the income range of the respondents. There is a moderate (0.443) relationship between the vehicle ownership and the number of family members and the same type of relationship found between the housing condition and the family members.

From the above data, we can build a linear regression equation involving the variables that influence the total number of variables. The equation can be shown as following using the classical linear regression equation (equation 1)-

The linear Regression equation for the study is-

$$Y = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 \quad (1)$$

Where,

Y=dependent variable (total no of trips)

x_1 = Income range

x_2 = Housing condition

x_3 = Vehicle Ownership

x_4 = Family size

a_0= calibration constant

a_1=calibration factor affecting income= 0.415

a_2= calibration factor affecting housing condition= - 0.217

a_3= calibration factor affecting vehicle ownership= 0.079

a_4= calibration factor affecting family size= 0.130

So, the equation for this study using these variables will be like following-

$$Y_{Total\ no.of\ Trips} = a_0 + 0.415\ income\ range + (-0.217)\ housing\ condition + 0.079\ vehicle\ ownership + 0.130\ family\ size \quad (2)$$

From this Eq. (2), it is easily identifiable that total number of trips is influenced mostly by the income of the households whereas housing condition has a negative impact on the trips produced. Vehicle ownership and family size do not have much impact on the no. of trips produced as they have a very low amount of calibration factor.

Table 6: Correlations between different housing types & Total no of trips

Housing Type	Total number of trips produced by the HH members	Pucca	Semi-Pucca	Katcha
Total number of trips produced by the HH members	1.000	.257	-.061	-.204
Pucca	.257	1.000	-.401	-.659
Semi-Pucca	-.061	-.401	1.000	-.425
Katcha	-.204	-.659	-.425	1.000

The objective of this analysis was to find out the relationship between various housing types and the total number of trips produced by every household. Table 6 shows the correlation between various housing types and no trips. Pucca households correlate around 0.257 which indicates that it has minimal relation or dependence with the no of trips produced. However, both semi-pucca and Katcha housing types have a negative correlation with no trips that indicates that these are not correlated.

CONCLUSION

The travel pattern of Khulna city is more or less quite same to other cities of Bangladesh. There is mixed traffic. People of higher and middle income choose the modes rickshaw and easy bike. Moreover, the van is used by both lower and middle-income people. People of all classes prefer the mode walking to cover the short distance. The people of pucca building travel frequently and use several modes. Then the katcha is in the second position and semi-pucca in third. The people use such kind of modes for various purposes. Back to home, then working are the primary purposes for traveling. The regression model stated that a total number of trips is influenced mostly by the income of the households whereas housing condition has a negative impact on the trips produced. Vehicle ownership and family size do not have that much impact on the no of trips produced as they have a meager amount of calibration factor. So, to make future transport plan for Khulna city, we have to consider the variables that positively and negatively influence the travel pattern of the people of the city otherwise, the plan will not be suitable for Khulna city.

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EMERGING ROLE OF EASY BIKE IN KHULNA CITY: CONTRIBUTION TOWARDS SUSTAINABILITY

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ABSTRACT
Sustainable urban transportation is a crucial aspect in order to ensure the growth and development of any city. Khulna as the third largest city of Bangladesh is far behind to achieve transport sustainability. The improper provision and management of public transport in Khulna city, has led dependency on easy bike. At present, in Khulna city; around 17,000 easy-bike are in active service, which fulfils about 65% of the transport demand. The increased popularity and the ever-increasing transportation demand results in an excessive and uncontrolled number of easy bike within the city, which results in traffic congestion and accidents. Because of these degrading impact of easy-bike, it's role towards sustainability is hardly discerned. Through proper policy formulation and implementation, efficient management and regulated operation; easy bike can be promoted as an effective mode of public transport towards sustainability. Therefore, this study aims to identify the contribution of easy-bike towards sustainability through identifying its' existing route, network and coverage along with its operational service and also recommend some measures towards the efficient management of easy bike as a sustainable public transport within Khulna city.

Keywords: Easy-bike; Operational system of easy bike; Sustainable transportation

INTRODUCTION
In the contemporary world the major cities of developing countries have experienced numerous transport related challenges including pollution, congestion, declination of public transport, energy depletion and lack of accessibility for the urban poor. Study reveals that, in 2002 only 32% people of Khulna city owns personal vehicles and other 68% of the total households had no vehicle of their own (Rahman, 2004). It is now become a major concern to the contemporary urban planners and policy-makers across the world to alleviate these problems in order to ensure urban sustainability (Pojani and Stead, 2015). Khulna, being a major city of Bangladesh with rapid urbanization has to face different challenges regarding proper transportation system to address social, economic and environmental sustainability (Afroze et al., 2010). The transportation system of Khulna city, which is characterized by both public and private transport, often failed to address sustainability. The modal shift of private to public transportation can be a very effective measure to address sustainability along with to reduce road accident, traffic congestion and pollution (Rahman and Kabir, 2011). Public transport is known as a shared passenger transport available for use of general public, and is shared by strangers without any private arrangement. Although the available public transportation of Khulna city includes different motorized and non-motorized vehicles including town service buses, easy bike, auto rickshaw, rickshaws, vans; recently this city is highly dominated by easy bike.
However, because of the mismanagement and unavailability of town bus service people of Khulna city often prefer rickshaw or auto rickshaw as an alternative of bus, although the fare is higher than that of bus (Siddique, 2010; Rahman and Kabir, 2011). Over the time rickshaw was also failed to retain its

popularity because of being a slow moving vehicle. Moreover, the number of rickshaw was insufficient to address the transportation demand. Rather than being a public transport it was more commonly used as a para transit without any fixed route and fixed fare. The negotiable fare is also responsible for reducing its popularity.

In most recent period, battery operated easy bike plays the most dominant role as public transport in Khulna city (KDA, 2012). Lubna et al., 2014 claims that in the most recent period easy bike is the most popular mode of commuting with highest spatial coverage. According to this study, in Khulna city there are approximately 17,000 easy bike is in active service which serves about 65% of the total transport demand. From the statistics of 2011, BBS (2013) claims that, there were only 683 registered easy bike within KCC area. However, because of its' increased poplarity, since 2010, KCC gives license to 6927 easy bikes, whereas KMP stated that, over 25000 easy bike are in active operation within Khulna city (Roy, 2016). Passenger prefer easy bike instead of other mode of public transport because of it availability, comfort and quality of services. Easy bikes, which is a distinct identity of public transport are preferable to travel shorter distance, especially within cities.

Although easy bike is the most popular travel mode within Khulna city, there are still acute shortage of formal policy guidelines regarding the movement and operation of easy bike. Moreover, its' contribution towards sustainability is barely recognized. This study aims to identify the existing operational system of easy bike including route, service coverage and fare along with its potential role towards sustainability to recommend effective operational measures of easy bike within Khulna city.

METHODOLOGY

To attain the aim of this study mixed method approach was implied throughout this research process. Qualitative approach was followed to explore the present service scenario of easy-bike including route, coverage and fare, whereas to measure the potential role towards sustainability following the people's perception quantitative approach was followed. Mostly primary data sources were used to collect data for this study. Existing route, coverage and fare was identified through field survey and their potential role towards sustainability was measured through questionnaire survey, which was conducted on two types of target group, comprises of passengers and easy bike drivers. Passenger survey was conducted to identify all the different aspects of sustainability, whereas to identify the economic aspects including operational cost and economic stability of easy bike drivers, survey was conducted on easy bike drivers. Purposive sampling technology was applied to conduct the questionnaire survey. According to which following sampling equation was adopted to determine the sample size (n):

$$\text{Sample size,} \quad \boldsymbol{n = \frac{z^2 pqN}{e^2(N-1)+z^2 pq}} \quad \ldots\ldots\ldots (1); \text{ where,}$$

p = 50% (0.5) and q = 50% (0.5);
e = 10 % of 'p' = 0.05;
Z = 1.44, considering 85% confidence level; and
N= Population size, which was considered as the active number of easy-bike = 25,000 (Roy, 2016).
Therefore, following the sampling equation [Eq. (1)], the identified sample size, n = 207.36 =207.
Considering, an easy bike driver and four as the average number of passengers, the sample size was divided into 1:4 ratios for determining drivers: passengers sampling size. Thereby, respectively the sample size of easy bike drivers and passengers was identified as 41 and 166. This study considered Khulna city corporation (KCC) area as the area of interest due to the increased popularity of easy bike.

RESULTS AND DISCUSSIONS

Easy Bike in Khulna City: Route, Area Coverage and Fare Structure

Being the cheapest and most available mode of public transport, the operational system of easy bike mostly covers the whole KCC area. Although KDA (2012) identified six operational route of easy bike, in the recent time there are seven easy bike routes are in active use including a number of stoppages and hub. Although none of the stoppages are affirmed by the city corporation or any other legislative authorities, easy bike stoppage developed places based on the passengers' demand. There are 10 major defined stoppages are situated in between the designated seven routes [Fig. 1].

In Khulna city, easy bike provides the highest service area coverage comparison to other mode of public transport. The easy bike stoppages are very much close to each other and almost within the standard

walking distance (500 meter). Even some of these stoppages are within overlapping walking distance which represents the mobility and availability of easy bike within Khulna city.

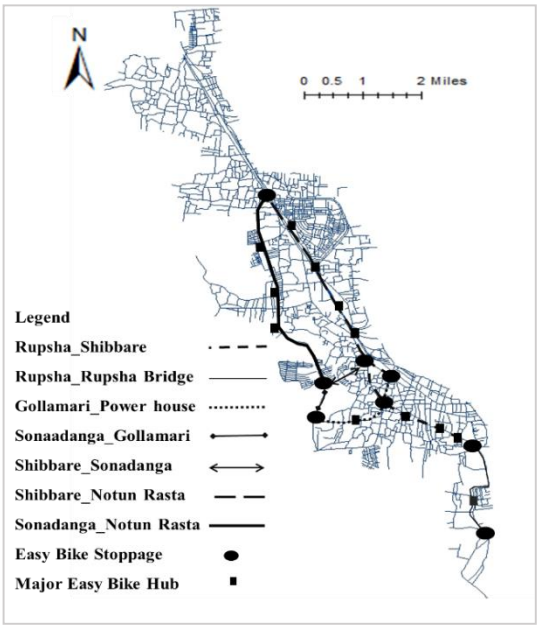

Fig. 1: Routes of Easy-bike within KCC area

Fig. 2: Easy-bike in Khulna City

There is no fixed fare policy affirmed by the authorities to determine the fare structure of easy bike. Fare is usually determined by the easy bike driver. However, the fare is more or less same based on the distance. KDA (2012) acclaimed that per km fare is around 5 tk, which is the lowest fare for any distance travelled by easy bike. Although, easy-bike fare varied among stoppages to stoppages on the basis of distance [Table 1], there is a common pattern of fare on the basis of demand. For instance, in more demanded location, easy-bike fare is comparatively less because of availability of easy bike. Such as, from Rupsha to Rupsha Bridge fare is only 10 BDT, whereas Shibbari to Notun Rasta being less distant area fare is 15 BDT.

Table 1: Easy Bike Fare Structure within Khulna City

Easy bike Route	Distance (Kilometre)	Fare (BDT)
Rupsha to Shibbare	3.9	10
Rupsha Bridge to Rupsha	5.9	10
Gollamari to Powerhouse	3.5	10
Sonadanga to Gollamari	3.2	5
Shibbare to Sonadanga	1.5	5
Sonadanga to Notun Rasta	5.1	10
Shibbari to Notun Rasta	5.4	15

(Source: Field Survey, 2017)

Easy bike: A Sustainable mode of Transportation

Sustainable transportation is a broad aspect of transportation which considers positive contribution towards society from social, economic and environmental aspects (Jeon and Amekudzi, 2005; Schafer, 1998). Easy bike is an ideal sustainable mode of transportation due to its increasing socio-economic role and lower level of pollution, which directly links with sustainability.

Social Aspects of Easy bike towards Sustainability

Easy bike offers a range of activities including comfortable service provision, opportunities of social mix and greater mobility to address the social aspects of sustainability. Most of the passengers are satisfied considering the social aspects, specially mobility of easy bike. Because of the larger service

coverage and well connected service facilities 88% people appreciate the role of easy bike. Moreover, majority of the passengers (56%) think that easy-bike service is comfortable in comparison to other mode of public transport such as public bus, van and rickshaw, whereas only 37% assume that it is not comfortable because of carrying 6 passengers in the same time within its limited space. However, these facilitates the opportunities of social mix, where people of different income group and gender get to meet. Thereby 48% people think it create positive impact and great impact in social mixing. However, majority of the passengers (51%) are not satisfied with the safety aspects [Fig. 3], as they assume that easy bike accident become a regular issue because of uncontrolled movement and mismanagement.

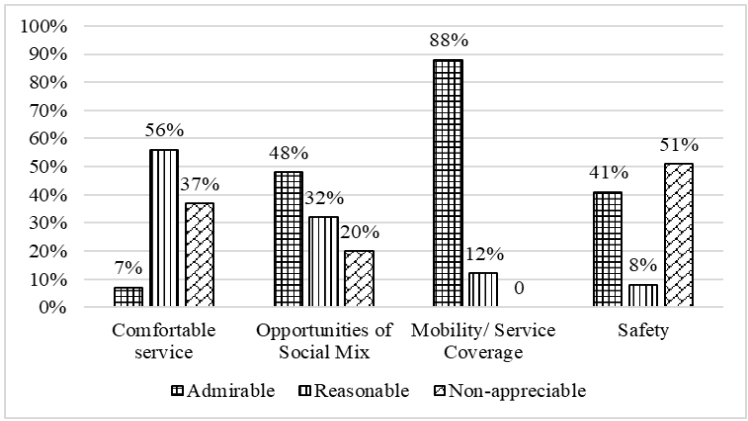

Fig. 3: Perception of Passengers towards Social Sustainability
(Source: Field Survey, 2017)

Economic Aspects of Easy bike towards Sustainability

Easy bike offers very reasonable service charge to its' passenger within the juridical area of KCC, which is on an average only 15-20 BDT per visit and 5 BDT per kilometer (Field survey, 2017). Due to this cheap and cost-effective service provision, people of all income group can easily afford easy bike service for transportation from one corner to another corner of the city, which also increased the accessibility of transportation. Therefore, most of the passengers are satisfied with the offered service charge and assume that the service charge is reasonable and economically accessible [Fig 4].

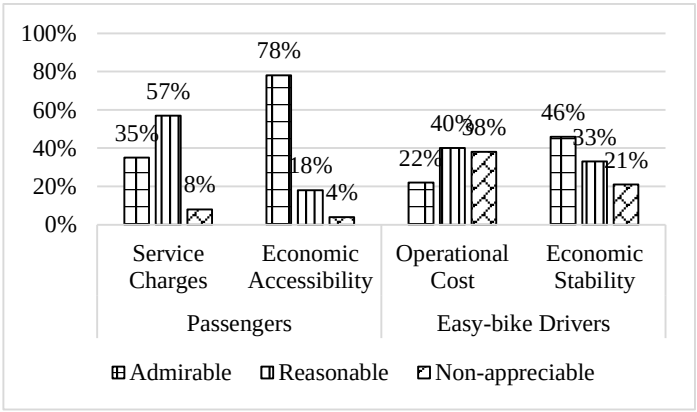

Fig. 4: Perception of Passengers and Easy-bike Drivers towards Economic Sustainability
(Source: Field Survey, 2017)

The initial investment of easy-bike is high for the poor income group of people, which is about 120000 BDT, but it is much reasonable than other diesel-run four stoke vehicles such as tempo. Moreover, the average daily cost of operating including parking and charging battery of easy-bike is only 140 BDT, whereas, the minimum daily income of an easy bike driver is 700 to 800 BDT (Lubna et al., 2014). Therefore, most of the easy bike drivers (about 40%) are satisfied with the operational cost of easy bike. However, because of high investment cost 38% easy bike drivers are not satisfied with the operational cost and thereby, rather than driving own vehicle, run others in rent. Whereas only 22% drivers think it is admirable, as there is not much operational cost after the beginning investment [Fig 4]. Furthermore,

easy bike creates job opportunity for a larger number of unemployed people. People from nearby villages are also work as easy bike driver in KCC area and thereby, improved their economic status from acute poor to poor. 46% of the easy-bike drivers admire this opportunity for improving their economic status, whereas only 21% of them assume that easy-bike doesn't have any positive contribution in improving their living standard [Fig. 4].

Environment Aspects of Easy bike towards Sustainability

Unlike the fuel and diesel run motorized vehicle, easy bikes hardly create any types of pollution. Lubna et al., (2014) denoted easy bike as a green transport. However, due to lack of proper management, proper traffic regulations and impatience of easy bike drivers, drivers are used to press buzzer here and there. Which is why, majority of the passengers (about 61%) held easy bike responsible for creating noise pollution. As easy bike is sensitive towards air pollution and like other motorized vehicle doesn't emit any contagious gas, 83% of the passenger admire the contribution of easy bike towards air pollution [Fig. 5].

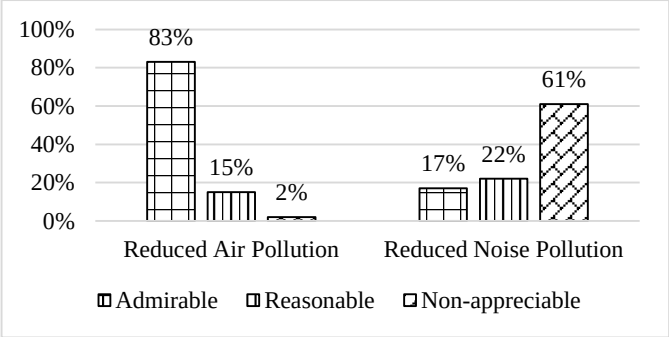

Fig. 5: Perception of Passengers and Easy-bike Drivers towards Environmental Sustainability (Source: Field Survey, 2017)

RECOMMENDATIONS

Only a few aspects that needed to be addressed to promote easy bike as a regular mode of sustainable transportation. Following guidelines should be followed and adopted by the legislative authority to improve the service of easy bike:

- **Easy bike License and Driving License Provision**

The uncontrolled and unauthorized easy bikes are often responsible for creating traffic congestion and accident in Khulna city. To control this, the number of easy-bike should be optimized and there should be proper system of legal provision. Therefore, KCC should provide license to authorize easy bikes and Khulna Metropolitan Police (KMP) should take the responsibility of monitoring and controlling the operation of unauthorized easy bikes and confiscated their operation. Along with vehicle license, driving license should also be provided to the skilled and trained easy-bike drivers to decrease the rate of accident. KCC or Ward Commission should define the age limit of easy bike driver as experience told us that young ages drivers tends to run easy bike in over speed, which causes accident.

- **Development of Defined Stoppage**

The easy-bike stoppages are illegally developed throughout the city including on the major node or nearby the commercial or business hub, where passengers are easily available. There are no proper management of these stoppages, which is why easy bike stops here and there on customer demands without any regulation, which led to traffic congestion and hinders the free flow of other vehicles. In order to control this, KCC should define easy bike stoppage by maintaining proper distance and proper location, where movement of other vehicles will not be interrupted.

- **Operations, Regulations and Management**

Easy bike often seems to operate in the internal streets of neighbourhoods or in the single lane road, which causes congestion and noise pollution. As there is no designated fare along these routes, driver often get the opportunity to negotiate the fare with the passengers. Therefore, ward Commissioner should encourage community not to use easy bike in the internal streets and to use the designated fare by Regional Metropolitan Transportation Committee (RMTC). The movement and the other operation of easy bike should be strictly controlled by KMP.

CONCLUSIONS

Although public transportation plays a significant role towards sustainable urban transportation, in context of Khulna city, before the emergence of easy bike; public transport was hardly popular. Easy bike being a public transport offers cheap fare and comparatively comfortable service for short distance travel with a greater service coverage, which attracts many people to shift modal choices from private to public transport. Although easy bike is a type of public transport, it can further play the role of private transport or para-transit, as passengers can further use the service by reserving easy bike for a time period. However, most of the easy bikes of Khulna city plying on the city street illegally without any proper management. Although KMC already provide license to some of the easy bikes, most of them are illegal. The drivers of the easy bikes are also unskilled and inexpert without any proper training which is responsible for traffic accidents. Furthermore, the excessive number of easy bike is responsible for traffic congestion and increase the rate of traffic accidents, which altogether raised question on the efficiency of easy bike as a sustainable mode of public transportation. Through addressing proper guidelines and managements including license provision, operational systematic management easy bike can be turned into an efficient and mode of public transport, which will be able to contribute the sustainability of transportation sector in Khulna City.

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IDENTIFYING RISK FACTORS ASSOCIATED WITH PEDESTRAIN FATALITY IN DHAKA-SYLHET HIGHWAY

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ABSTRACT
Traffic safety is a key concern for encountering road traffic crashes especially for a country like Bangladesh. Significant rate of pedestrian traffic is involved in fatal highway crashes around Bangladesh along with drivers and passengers each year. Bangladesh is one of the largest contributor in pedestrian fatality among South East Asian countries. As a result, an approach was taken to analyse pedestrian fatal crashes in one of the deadliest highway called Dhaka-Sylhet highway of Bangladesh. Overall, 62% of reported crashes were identified as fatal in Dhaka-Sylhet highway from 2003-2011. Around one third of these fatal crashes were related to pedestrian death in that highway. Binary logistic regression was used to identify risk factors associated with pedestrian fatality in Dhaka-Sylhet highway. Lighting condition, day, time, road surface condition, presence of divider, road geometry, weather and causes of crashes were taken into consideration in analysis. Straight roadway sections were found as one of the greatest contributor in pedestrian fatality in Dhaka-Sylhet highway. Moreover, fair and rainy weather, speeding, overturning, careless driving as well as pedestrian carelessness were also identified most influential factors for increasing pedestrian fatality in that highway.

Keywords: Fatality; safety; pedestrian; risk factors.

INTRODUCTION
Traffic accidents are one of the alarming cause of death, causalities and injuries throughout the world. More than 1.2 million people die each year due to road traffic accidents (WHO, 2017). Approximately, 25% of world's road traffic deaths were observed each year in the South-East Asia region (WHO, 2016). Bangladesh has one of the highest fatality rate in road traffic crashes due to having 56.41 deaths per 10,000 on road vehicles at the year of 2007 (Mahmoud, Hoque and Qazi, 2009). About 38% of total recorded crashes in the year between 1998 and 2007 were spotted in the national highways (Hoque and Mahmud, 2009). Dhaka-Sylhet highway was identified as the most vulnerable highway for fatal accidents in Bangladesh (Rahman, Ahsan & Hadiuzzaman, 2012; Kelly, 2012). Along with drivers and passengers, pedestrian's involvement in fatal crashes were also spotted. According to WHO (2016), 32% of total road traffic fatality in Bangladesh was identified among pedestrians. Whereas, 47% of fatalities among overall fatalities of pedestrian were spotted in the national highway region of Bangladesh (Sarkar et al., 2011). In addition, pedestrian's involvement of about 27% were spotted from overall crashes in Dhaka-Sylhet highway from the period of 2005-2007 (Banik, Chowdhury and Mojumder, 2011). As a result, considerable amount of pedestrian death is being one of the impediment in improving traffic safety especially in highway corridors of Bangladesh.

Different research has been undertaken worldwide to select influential factors of pedestrian injury and fatality related crashes. A research (Ariffin et al., 2011) conducted in Malaysia through binary logistic regression (BLR) identified gender, age, location, pedestrian errors, day, lighting conditions and striking vehicle type were influential factors for increasing injury severity among pedestrian. Another research (Macleod et al., 2010) highlighted that early morning, non-daylight duration, weekend, young male drivers, alcohol usage and suspended license were being identified most important factors through BLR for hit and run pedestrian fatal crashes. Moreover, increase in vehicles and presence of police officer, footbridge, bus stops, solar panel, and waste deposit were spotted crucial through Poison regression model in increasing pedestrian vehicle collisions in Dhaka city (Rifaat et al., 2017). However, an earlier study (Sarkar et al., 2011) based on assessing factors related to pedestrian fatality in national highways of Bangladesh landed into the conclusion that older (age greater than 55) and young (age less than 15) pedestrian, pedestrian crossing location, collisions with heavy vehicles, no traffic control, stop control and rainy season was critically influencing pedestrian fatality. BLR landed into the conclusion that pedestrian age between 7 and 18, crashes with heavy vehicles and rural areas were likely to be effective in inclining pedestrian fatality in Iran (Dovom et al., 2012).

Thus, objective of the study is to identify risk factors associated with pedestrian fatality in Dhaka-Sylhet highway. Though, earlier study (Sarkar et al., 2011) provided an insight of risk factors associated with pedestrian fatality by considering all the national highways of Bangladesh. However, present one will draw the differences among risk factors between entire national highways and Dhaka-Sylhet highway.

STUDY LOCATION & CRASH DATA DESCRIPTION

The present study is focuses on pedestrian fatality in Dhaka-Sylhet highway of Bangladesh. Dhaka-Sylhet highway is a part of the Asian highway network and termed as N2 highway with a length of 272.3 km (Alam, Nahar & Shaha, 2008). The studied highway connects the Tamabil Jaflong location of Sylhet city with the Katchpur area of Dhaka (Alam, Nahar, & Shaha, 2008). Crash data was collected from Accident Research Institute (ARI) of Bangladesh University of Engineering and Technology (BUET). More than 1,250 crashes were spotted in the studied highway based on the information provided by ARI from 2003 to 2011. About, 912 processed detailed crash data including all the required information of a single crash was collected from ARI randomly. Severity of the crashes were identified as fatal, grievous injury, simple injuries and mild collisions. In addition, date, time, lighting condition, presence of divider, weather, road geometry, surface condition, number of deaths regrading passenger, drivers and pedestrian, and causes of the crashes were highlighted in the collected ARI data. Based on the detailed data retrieved from ARI, 62.06% were fatal, 23.68% were grievous injury and 14.3% were mild injury. About, 478 crashes were spotted as being directly related with pedestrian. In addition, 31.03% or 283 crashes in comparison to total 912 crashes were directly related with pedestrian death. High amount of pedestrian fatality was observed if a pedestrian involves in a crash especially in highway region. Only the pedestrian related crashes were taken into consideration for further analysis.

METHODOLOGY

Detailed crash data of Dhaka- Sylhet highway from 2003 to 2011 were taken into consideration for analysis purpose. An appropriate tool such as logistic regression is being deployed to identify risk factors associated with pedestrian fatality in the studied highway. Due to a wide extant of suitability, logistic regression particularly binary logistic regression (BLR) has been used extensively in identifying risk factors involved with crashes (Al-Ghamdi 2002; Yau 2004). Due to analyzing only fatality of pedestrian, BLR would be an ideal tool. Moreover, BLR is a useful tool to establish a relationship between a binary response variable and a set of categorical independent variables (Ramezani, and Ramezani, 2016). As a result, severity of pedestrians in a crash is taken as dependent variable whereas all other associated factors are taken as independent variable in the analysis. BLR is appropriate to depict pedestrian fatality (Y=1) or others (Y=0) as a binary response variable. The governing equation for analysis is as follows,

$$Logit(Y) = g(x) = \ln\left[\frac{P(Y=1)}{1-P(Y=1)}\right] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_i X_i \qquad (1)$$

Where, P (Y=1) describes the probability of occurring pedestrian fatality, x_i represents the independent variable, βi is the model co-efficient that describes the odd ratio involved in the pedestrian fatal crashes. The odds ratio (OR) is equal to exp (βi), so that when an independent variable x_i increases by one unit with all other factors remaining constant, the odds increase by a factor exp (βi) (Hosmer and Lemeshow 2000). The higher the Exp (B) value, the higher the probability of having pedestrian fatal crashes (Seva et al., 2013). Applied regression analysis is considered stepwise and backward stepwise selection of significant independent variable with the context of pedestrian fatality type being applied. In addition, 90% confidence interval is taken as the guideline to run the regression analysis. SPSS statistical package of 23 is being used to identify risk factors of pedestrian fatality in Dhaka-Sylhet highway.

ANALYSIS & RESULTS

Logistic regression was used for detailed spotting of identical independent variables that influence pedestrian fatal crashes on the selected highway. Detailed breakdown of each of the factor involved in pedestrian crashes are presented in table-1. About 59.21% (283) of pedestrian fatal crashes were identified among total 478 pedestrian related crashes. Weekdays and weekend type crashes were separated under day of crash. Weekdays registered more crashes of about 69% than weekend (table 1). Time of crashes were divided into four different sections. Although, more than half (table 1) of pedestrian related crashes were spotted at afternoon (12PM- 6PM) and night time (6PM-12AM). Around 20% crashes were reported at morning period (6 AM- 12PM) as well. In addition, more than 70% crashes related to pedestrian were spotted under daylighted lighting condition (table 1). Whereas, 8.6%, 14.9% and 5.17% were reported under dawn/dusk, night unlighted (Night unl) and night lighted (Night lgt) respectively. Moreover, absence of divider (85.4%) seemed dominating over presence of divider in registering highway pedestrian crashes (table 1). However, straight roadways and dry pavement surface condition were dominating with 92.01% and 74.6% respectively in their designated arena. Few crashes of about 7.99% were reported at the presence of curve or slope involve geometric sections of Dhaka-Sylhet highway. Around one third (25.4%) of pedestrian crashes were reported under wet pavement surface of the respective highway. Fair weather consisted of 67.8% of total pedestrian crashes while rain and fog comprised of 29.4% and 2.77% respectively (table 1). Careless driving of drivers was found most responsible with around 60% crashes in their account among the causes listed for crashes. Pedestrian errors and speeding were accounted of about 16.7% and 12.1% respectively. In addition, bad turning or overturning was responsible for around 10% of total pedestrian related crashes in the studied highway. All other causes listed in the table 1 comprised less than 2 % of overall pedestrian related crashes in the studied highway.

BLR was drawn to identify the crucial factors to pedestrian fatality. The summary of results is presented in table 1. Stepwise backward BLR was executed for pedestrian fatality. All the variables were included in the first step and stepwise reduced the insignificant independent variables to draw a final model. All the variables existed in the final model are only presented in table 1. The reduction of chi square value in stepwise procedure with a p value greater than 0.01 in the last model for Hosmer Lemeshow test of the BLR indicating good fitting of the derived models (Xi, Liu, Cheng, Zhao, & Ding, 2014).

Weather conditions such as fair and rain showed influence on pedestrian fatal crashes as both were listed under BLR model (table 1) due to having p value less 0.1 (90% confidence interval) and positive β value. Though, both weather condition involved in that model, but rainy weather was more influential in conducting pedestrian fatal crashes in the studied highway than fair weather due to comprising higher odd ratio (table 1). It is logical because pedestrian might feel difficulties in judging the distance of the vehicle due to gloomy condition in rainy weather while crossing the roadway. In addition, with low visibility during rainy weather, roadway surface condition such as sleeper roadways might hinder the assumption of braking distance assumed by vehicle drivers. Though, no influence of road surface conditions were identified in the BLR thus the suspicion of drivers barking distance judgement might not be an important one. However, the involvement of rainy seasons in pedestrian fatality of the studied highway complied with the earlier research (Sarker et al., 2011) finding as well. Though, rainy seasons involvement was perfectly matched with the previous research result, but Dhaka-Sylhet highway also showed their alliance with fair weather for pedestrian fatality. In addition, presence of divider did not show any inferentiality towards pedestrian fatality in Dhaka-Sylhet highway as p value greater than 0.01. Only, straight roadway geometry was responsible for increasing the likelihood (β= 1.613 and p value of 0.003) of pedestrian fatality rather than other geometric condition. Pedestrian error was found

most prominent reason with highest odd ratio among all the variables listed in BLR for pedestrian fatality in Dhaka-Sylhet highway. Avoiding crossing the roadways through crosswalk or designated location might driving the numbers of pedestrian fatal crashes. In addition, careless driving with β= 2.680, speeding with β= 27.37 and overturning with β= 3.076 were also found influential to pedestrian fatality at 90% confidence interval. It might be the case that straight roadways were influencing careless driving and speeding phenomenon. No speed regulation techniques or provisions are available in the highways of Bangladesh (WHO, 2016) which significantly causing the life of drivers, passengers as well as pedestrian in the respective highway. Thus, higher pedestrian related crashes were registering in that highway. No other factors were found influential to pedestrian fatality in BLR analysis. Absence of speed control strategy and frequent presence of highway patrol police might not only be increasing pedestrian related crashes but also inclining carelessness driving as well. Presence of posted speed limit signs and highway patrol police can reduce the overwhelming speed and careless driving of the drivers in highways (Afukaar, 2003; Leggett, 1997). However, weather such as fair and road geometry such as straight and curves were also taken into consideration during analysis of overall highway pedestrian fatality (Sarker et al., 2011). Since, they did not prove effective in that previous study (Sarker et al., 2011) but showed inferentiality in the present one for pedestrian fatality thus analysis based on overall fatality of pedestrian in highway corridor might not be representative of Dhaka-Sylhet highway pedestrian fatality.

Table 1: Frequency distribution of crash related factors and summery of BLR model

Factors	**Frequency (%)**	**Factors**	**Frequency (%)**	**Factors**	**Frequency (%)**
Day		**Lighting**		**Road Geometry**	
Weekday	68.83	Daylight	71.3	Straight	92.01
Weekend	31.2	Dawn/Dask	8.6	Curve/Slope	7.99
Time		Night unl	14.9	**Road Surface**	
12 AM- 6 AM	10.61	Night lgt	5.17	Dry	74.6
6 AM- 12 PM	20.31	**Divider**		Wet	25.4
12 PM- 6 PM	35.98	Yes	14.6	**Weather**	
6 PM- 12 AM	33.1	No	85.4	Fair	67.8
Causes				Rain	29.4
Speeding	12.1	Overtaking	1.2	Fog	2.77
Overturning	9.6	Pedestrian error	16.7	**Causes**	
Vehicle defect	0.21	Wrong signal	0.21	Alcohol	0.36
Careless driving	59.2	Road construction	0.42		
Summary of BLR model and model fitting information					
Independent Variable	**Level of Variable**	**Co-efficient (β)**	**P value (Sig.)**	**Odd ratio, Exp (β)**	
Weather	Fair	1.145	0.093	3.142	
	Rain	1.547	0.062	4.696	
Divider	Presence of divider	0.975	0.387	2.651	
Road Geometry	Straight	1.613	0.003	5.020	
Causes	Speeding	3.309	0.000	27.37	
	Overturning	3.076	0.031	21.67	
	Careless Driving	2.680	0.016	14.59	
	Pedestrian error	5.992	0.001	400.2	
Constant		-0.402	0.000	0.669	
-2log likelihood		1673/ 594.2			
Hosmer and Lemeshaw goodness of fir test		**Step**	**Chi Square**	**P value**	
		1	9.251	0.665	
		6	4.601	0.798	

CONCLUSIONS & RECOMMENDATIONS

The key important factors that have been identified are speeding, overtaking, pedestrian errors, fair and rainy weather, and driver own carelessness. In addition, road geometric design plays a vital role as it has been found that pedestrian fatality is terrible influencing by straight roadways. Pedestrian errors being found most dominated one and need to be adjusted as soon as possible for saving life of pedestrian. Only one factor such as rainy weathers involvement went perfectly along with previously found research result.

The research here would be more effective if more factors such as pedestrian demographic information, pedestrian volume and location of the collisions such as roadway, crosswalk or roadside would be included in the analysis. However, from this study following recommendations can be made which will be helpful to reduce vehicle-pedestrian crash as well as traffic accident to some extent:

- Black spots and risk factors of pedestrian-vehicle collisions should be identified separately for each highway.
- More guidance, speed limit and regulatory signage should be installed especially in straight sections to avoid careless driving.
- More pedestrian crossing facilities (crosswalk, pedestrian overbridge etc.) should be installed.
- Deployment of more highway patrol police might be a crucial way to enforce any laws regarding traffic safety techniques.
- An awareness program that focuses on pedestrian carelessness may improve the crossing characteristics of the pedestrians in the studied highway.
- Pedestrian signal control strategy could be a strategic tool to test in high pedestrian crash zones of the studied highway to reduce pedestrian fatal crashes.

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AN IMPROVISED METHOD TO MEASURE REFLECTION OR GLOW OF LIGHT EFFICIENT CONCRETE

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ABSTRACT
Road accident is a common problem in Bangladesh. Visibility is one of the prime factors for this problem. Seeing and being seen is a basic requirement to ensure safety of all road users. The objective of this paper is to describe an improvised method to quantify the amount of light reflected by a product that is made with concrete to reflect light. Light Efficient Concrete has been developed from the concept of BlingCrete and Glow Concrete. The sample is a 1'x1'x0.5" concrete block with patterned silver beads or a glow coat on top. Various samples have been prepared with different light reflecting material to find out which gives the best reflection. The result of this investigation shows that the sample with patterned silver beads reflect maximum light. This is a very promising road safety material for a country like Bangladesh where lights are not always available in the dark.

Keywords: BlingCrete; Glow Concrete.

INTRODUCTION

Light reflecting concrete has been previously made named as BlingCrete™ in the University of Kassel, Germany. This product is a blend of expertise from fields of visual arts, architecture, interaction design, industrial design, experimental physics, and materials research. The BlingCrete project started as a series of artistic experiments with light-reflecting materials and the phenomenon of retro-reflection; to make something artistic for urban city. The material combines positive characteristics of concrete (non-flammable, strong, stiff) with those of retro-reflection. Retro-reflecting surfaces send back the incoming rays of light of sunlight or artificial light in the direction of the source of light. This optical phenomenon is achieved by embedding glass microspheres in the substrate material. Light reflecting concrete has a wide range of uses, starting from Architecture to Transportation Design (Public Transport- tunneling and underground space projects) as well as in Safety-related marking of danger spots in construction (stairs, sidewalks, platform edges and tunnels) (Klussman and Klooster;2008). The objective of this paper is to measure the amount of light emitted or reflected back by concrete sample similar to BlingCrete, made using indigenous materials in Banlgadesh. It is an innovative material that can help improve highway safety in Bangladesh. The reflection or glow emitted from the prepared sample can be used for both: flexible and rigid pavements. This is because it is applied on the sides of footpaths or road dividers, not over the pavement. It will only increase the illumination of the road and eliminate complete blackout. The sample we prepared is named as Light Efficient Concrete.

METHODOLOGY

Samples

Various types of Light Efficient Concrete have been prepared- one which reflects light and one which glows in the dark. The ingredients are Ordinary Portland Cement (OPC) and local sand in the ratio 1:1 with water cement ratio of 0.6. For glow, glow stones and glow coat imported from China were used. For reflection simple silver beads were used. Few of the different kinds of Light Efficient Concrete prepared are shown in the figures below:

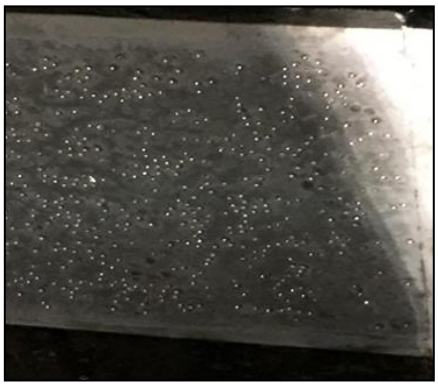

Fig.1 Sample with unpatterned silver beads

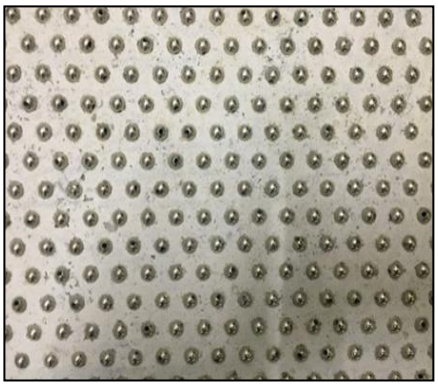

Fig.2 Sample with patterned silver beads

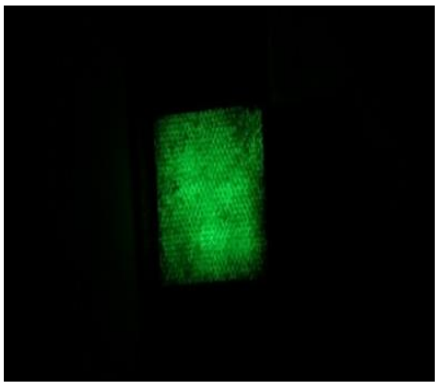

Fig.3 Sample with glow coat

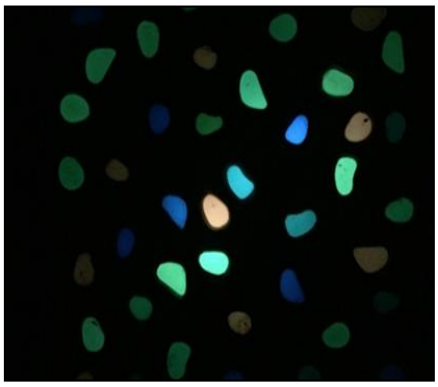

Fig.4 Sample with glow stones

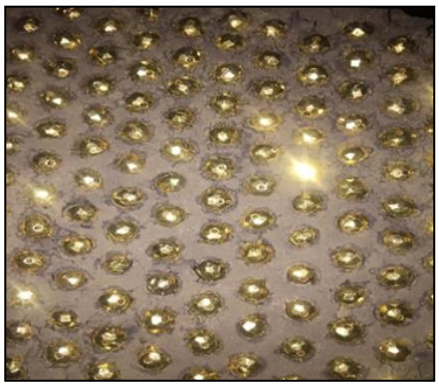

Fig.5 Sample with patterned golden beads

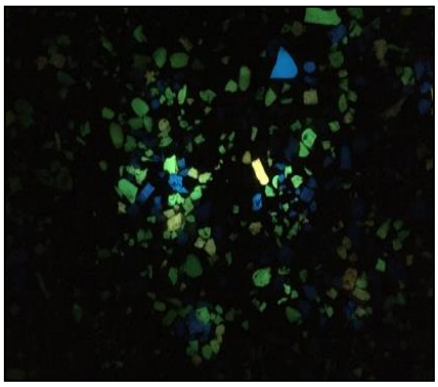

Fig.6 Sample with crushed glow stones

After preparing different types of Light Efficient Concrete, some tests were carried out regarding visibility. Since the objective of the study is to produce a concrete that will reflect light and glow in the dark, strength is not any of the major concerns of the research. Therefore, tests on light and optical phenomena of the material were done to compare it with other similar products in the market. Since, there are still no standard tests to measure light reflected by concrete, improvised methods were used. A device called the lux meter was used to measure the reflected light.

Light Efficiency Test

This is an improvised test to quantify what we can see with our eyes. A wooden box of 1'x1'x1' was made with three holes on the top. It has 3 sides and open at the bottom. To simulate the condition of a dark room, the inside of the box was fully painted black. All possible gaps in the box were sealed with a black tape. Two similar torch lights were used as the light source. They were placed on the two holes on two ends of the box and lux meter sensor was placed on top to take the reading. Initial reading was taken without placing any sample to measure the amount of incident light using a lux meter. Then test samples were placed inside the box to measure the amount of light reflected back by the reflective surfaces.

Fig 7.1: The box used for measuring light efficiency of various samples

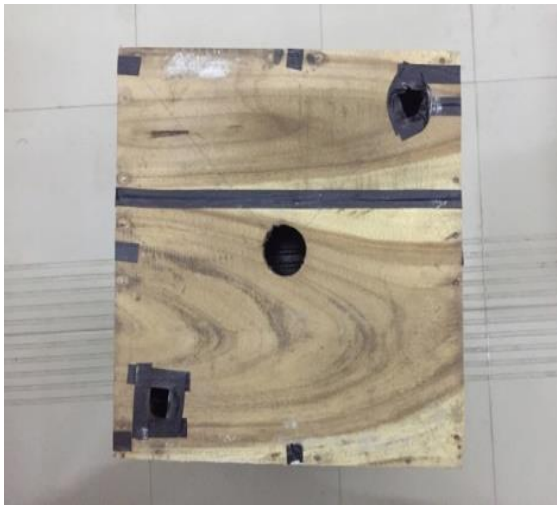

Fig 7.2: The top view of the box (The torch and the sensor of lux meter are placed on holes)

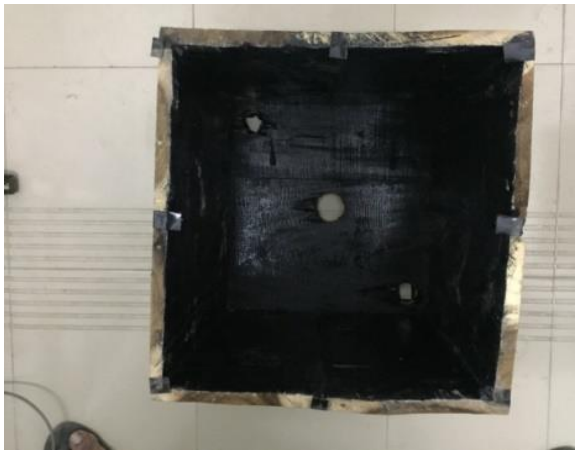

Fig 7.3: Inside wall of the box

Fig 7.4: Lux meter used in the research

Fig 7.5: Torches used for the experiment

Serial	Sample name	Incident light (lux)	Reflected light (lux)	Efficiency (%)
1	Local pavement tiles	198	23	11.6
2	Sample with silver beads	198	60	30.3
3	Sample with silver and golden beads	198	48	24.2
4	Sample with unpattern silver beads	198	42	21.2
5	Sample with glow paint and beads	198	30	15.2

Table. 1: Data obtained from Light Efficiency Test

RESULTS AND DISCUSSIONS

The reflection of four samples are compared against a local pavement tile. Local pavement tiles which is almost the same color to our samples is used.

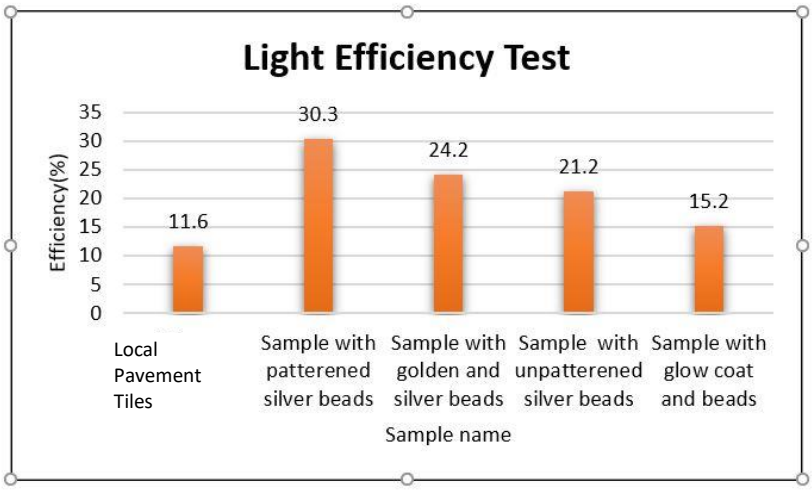

Fig 6: Bar chart illustrating light efficiency of different samples

From the bar graph, it is clearly evident that the sample with patterned silver beads gives the highest reflection and hence the highest efficiency of 30.3%. Second highest is the sample with golden and silver beads followed by the sample with unpatterned beads. The sample with glow coat gives the least efficiency of 15.2%. This may be due to the fact that the sample with glow coat has beads which is covered by the coat. If the surface of the beads is exposed by removing the layer of coat above them, then more reflection can be obtained. Point to be noted is that all of the reflection recorded are not absolutely accurate. It is more of a relative study so that a comparison can be drawn. From this experiment, it is found that all of the test samples give better reflection than local pavement tiles.

CONCLUSIONS

Hence, from the study it has been found out that Light Efficient Concrete gives better reflection than regular pavement tiles. In a country where at least 126 major fatal accidents occur in Bangladesh causing a minimum 612 deaths and 1857 injuries on the highways (Hoque et al., 2003), this can be a solution. Majority of this accidents occur because of poor driving (head on collision, loss of control, rear end). The severity is increased by over speeding and poor road conditions (Hoque et al., 2003). The dreadful conditions of the roads is a major factor but little is being done in that regard (MOMIN, 2015). Ensuring road safety is a major issue in this regard. Unfortunately, with a few notable exceptions, relatively little research has been conducted regarding safety in many developing countries, Bangladesh in particular (Mahmud et al., 2011). Light Efficient Concrete can be applied at the edges of roads to clearly identify the demarcation. Moreover, it can also be used in places where there is no light or limited light for example: tunnels. It can be applied on the edges of footpaths. This will reduce the chances of complete blackout due to load shedding. Not only will the light efficient concrete enhance road safety but will also serve the purpose of decoration.

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COMPARING LEVEL OF COMFORT FOR VARIOUS TRANSPORTATION MODES IN DHAKA CITY

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ABSTRACT
Comfort in transportation, which affects the passenger satisfaction significantly, is now being considered as a major factor for commuter's mode choice. Several studies have been conducted to measure comfort of various modes of transport. However, the focus has mostly been centred around a specific mode that was considered in the corresponding studies. A mode-wide measure of comfort will open the option to compare the comfort level of various transport modes, which will eventually create better understanding of comfort perception held in mind by their users. This research selects Dhaka, the capital of Bangladesh as the study area and collects data on four factors identified through literature review, which are, speed, temperature, noise and jerking using an android application-based questionnaire and a custom based micro controller for ac bus, non-ac bus, auto, rickshaw and private car. Next, the mode specific measure of comfort level in terms of speed, temperature, noise and jerking were calculated and their variations across different modes were discussed. The results exhibit that private car were found to be the most comfortable mode of transport followed by ac bus, rickshaw and auto.

Keywords: Comfort; Transport Modes; Arduino Micro Controller; Android Application; Anova

INTRODUCTION
Comfort has been a top criterion for transport mode choice (Lin et al., 2010). Nowadays commuters are preferring modes which are fast and comfortable (Weinert et al., 2014). Different modes of transport provide different service level and in order to have a broader understanding of transport comfort, and to eventually utilise it to improve the service quality of all the modes, it is necessary to measure and compare the comfort level of different modes (Páez and Whalen, 2010).

Comfort of the vehicle has developed a significant facet that is as important as safety and speed in accessing the physical characteristics of transportation (Prashanth et al., 2013). Most of the comfort studies followed either qualitative or mechanical approach while some studies followed both the methods. In mechanical approach, an equipment is used to collect comfort related data. Cantisani and Loprencipe (2010) constructed a mechanical calibrated model to represent the dynamics of a real vehicle on an uneven surface. They found correlations between subjective perception of ride quality and the international roughness index IRI at various speeds. Alahmer et al. (2012) evaluated thermal sensation and thermal comfort using a Thermal Manikin in different vehicle environments. They found that thermal comfort is affected heavily by relative humidity and concluded that the comfort zone could be reached faster if the relative humidity was controlled. Eboli et al. (2016) stated that kinematic parameters can be considered as significantly affecting passenger comfort. They used A specific smart

phone app named Torque that recorded the acceleration (longitudinal, lateral and vertical accelerations) and speed values by adopting a frequency of 1 hertz, together with the instantaneous bus position (latitude and longitude). Apart from the mechanical approach, subjective approach has been followed where questionnaire survey is used to collect data on comfort (Narayanamoorthy et al., 2008). In this method a set of questions has been made to collect data from the passengers directly and analysed to measure the comfort level of the transport. Eboli and Mazzulla (2007) conducted a survey on 763 students of University of Calabria. Respondents were asked to provide information about their socioeconomic characteristics and bus service quality. They were asked about 16 service attributes and rated on a scale from 1 to 10. Dell'Olio et al. (2011) conducted surveys both on the buses and at the bus stops. A focus group was used to deduce the most significant variables for the users of public transport before beginning the survey. Information about variables of desired quality: waiting time, journey time, vehicle occupancy, level of cleanliness, driver kindness and comfort was obtained. Even though a significant number of researches have been conducted on public transport comfort following either qualitative or mechanical approach, very few studies have evaluated the comfort level of other transport modes following both the approaches.

Taking Dhaka City, the capital of Bangladesh as its study area, this manuscript measured the comfort levels of five different transport modes, which are, non-AC bus, AC bus, auto, rickshaw and private car. The mechanical data, i.e. data on speed, sound, jerking and temperature of the five different modes are collected using an Arduino micro-controller (an open-source electronic platform based on easy-to-use hardware and software) equipped with an array of sensors and the subjective data, i.e. comfort perception of passengers are collected using an Android app-based questionnaire. Next, by correlating both the datasets, comfort ranges for the comfort variables of all the modes are prepared. The one-way analysis of variance (ANOVA) is conducted to determine whether there are any statistically significant differences between the means of the comfort variables for different modes. Finally, this study compares the overall comfort level of the five different transport modes.

METHODOLOGY

After conducting focus group discussions (FGD) and extensive literature review, four variables affecting transport comfort are identified. These variables are speed, temperature, jerking (acceleration change) and sound (Velt and Daneen, 2017; Ouis, 2002; Hensher et al., 2003). Trips for each vehicle is recorded following both subjective and mechanical approach. The mechanical data are collected with the help of Arduino micro- controller, an open-source electronic platform which consists of several parts: arduino mega 2560, GPS sensor, GPS antenna, accelerometer sensor, bread board, SD card slot. This machine is used to collect the data of GPS location, time and date, speed, acceleration (in 3-axis), temperature, sound pressure level (SPL). The units for the variables are m/s, m/s^2, Degree Celsius and dB for speed, acceleration, temperature, sound pressure level respectively. The subjective approach is operated by an Android app questionnaire, created from scratch based on the most significantly impacting parameters (identified variables) with the particular participants' subjective responses towards comfort variables. The storage disc of the Android cell phone is used to store data. The questionnaire followed a scale of measurement from 0 to 2 for speed, jerking, sound, temperature where 0 being comfortable, 1 being uncomfortable, 2 will be extremely uncomfortable. Besides, the participants are asked to rate the comfort level of that trip on the same scale as above. A total of 200 trip are taken as sample in this study including 70 non-AC bus, 50 AC bus, 30 rickshaws, 30 autos and 20 private car trips. The questionnaire survey and mechanical measurement are conducted in between these journeys.

In this study, comfort data are collected in five different transport modes which are non-AC bus, AC bus, rickshaw, auto and private car. Here, AC bus means complete air-conditioned vehicle with limited access to outside environment. Autos are defined by three wheeled automatic vehicles used as a short distance public transport with a capacity of 8 people. The route selected for this study is from Gazipur, Board Bazar to Mohakhali via Abdullahpur. The reason for selecting this route is that the traffic condition and the route nature resemble the general traffic operating condition in Dhaka city.

After collecting both subjective and mechanical data, correlation between the two datasets is carried out to prepare comfort ranges for the comfort variables within each mode. Passengers responded differently in different modes of transport. Passengers gave their responses for 4 comfort variables, which are, speed, sound, temperature, jerking, on 0-2 scale through questionnaire. The sum of each average value of comfort variable of all the journeys shows the overall comfort value of that mode. Therefore, maximum comfort value for each mode can be 8 (2+2+2+2) and lowest value can be 0 (0+0+0+0). Higher overall comfort value indicates more uncomfortable mode and lower overall comfort value indicates more comfortable mode. In this range, value 0 indicates most comfortable mode and value 8 indicates least comfortable mode. Next, three comfort ranges are prepared for each variable within each mode. If passengers responded value 1 when the speed is 30 to 60 km/hour for a specific mode say for AC bus, it is concluded that 30 to 60 km/hour speed level can be regarded as comfortable range for passengers in AC bus. Similarly, if for speed of 0 to 10 km/hour in Arduino, passenger assigns comfort value 2 with it, it indicates that this range of speed has to be considered as 'extremely uncomfortable' for passengers of that particular mode of transport.

For example, in case of AC bus, the data collected directs to a finding that when the subjective response for sound is '0 = comfortable' in questionnaire, sound values from Arduino in decibels ranges from 0-60. When the subjective response for sound is '1 = uncomfortable' in questionnaire, sound values from Arduino in decibels ranges from 61-75 and when the subjective response for sound is '2 =extremely uncomfortable' in questionnaire, sound values from Arduino is over 75 decibels. Table 1 shows the comfort range prepared for AC bus for variable speed based on the given information.

Table 1. Comfort Range for AC Bus

Parameter	Comfortable (0)	Uncomfortable (1)	Extremely Uncomfortable (2)
Sound (dB)	0 - 60	61-75	>75

The one-way analysis of variance (ANOVA) is conducted to determine whether there are any statistically significant differences between the means of three or more independent (unrelated) groups with a view to get a better understanding of the significance of impacting variables. Here the null hypothesis is taken to be such that the mean variance remains same among various modes for a particular variable.

RESULTS AND DISCUSSIONS

Table 2 shows the average comfort variable values as well as overall comfort values of different transport modes.

Table 2. Overall Comfort Value of Different Transport Modes

Modes	Variables				
	Sound (0-2)	Temperature (0-2)	Speed (0-2)	Jerking (0-2)	Overall Comfort (0-8)
Non-AC bus	1.93	1.70	1.58	1.2	6.41
AC bus	1.17	0.97	1.23	0.93	4.30
Rickshaw	1.14	1.07	1	1.35	4.51
Auto	1.3	1.5	1.3	1.4	5.65
Private Car	0.91	0.66	0.5	0.83	2.92

From Table 2, non-AC bus seems to have the highest overall comfort value (6.41) indicating it as the least comfortable mode among the five modes. After non-AC bus, auto (5.65) appears to be the least comfortable mode followed by rickshaw (4.51), AC bus (4.30) and private car (2.92). Here, private car appears to be the most comfortable mode. Table 3 shows the comfort ranges prepared for different modes.

Table 3. Comfort Ranges for Different Transport Modes

Modes	Parameter	Comfortable	Uncomfortable	Extremely Uncomfortable
AC Bus	Sound(dB)	0 - 60	61-75	>75
	Temperature(°C)	22-26	27-32	>33
	Speed (km/hr.)	>40	11-40	0-10
	Jerking(m/sec^3)	0-1.5	1.5-5	>5
Non-AC Bus	Sound(dB)	0-60	61-75	>75
	Temperature(°C)	22-29	30-40	>40
	Speed (km/hr.)	>40	11-40	<10
	Jerking(m/sec^3)	0-1	1-2	>2
Rickshaw	Sound(dB)	<60	60-70	>70
	Temperature(°C)	<32	33-36	>36
	Speed (km/hr.)	20-30	3-20	0-3
	Jerking(m/sec^3)	0-0.6	0.6-2	>2
Auto	Sound(dB)	0 - 60	61-75	>75
	Temperature(°C)	<30	30-35	>35
	Speed (km/hr.)	>35	3-35	0-3
	Jerking(m/sec^3)	0-1.2	1.2-3	>3
Private Car	Sound(dB)	0 - 60	61-70	>70
	Temperature(°C)	20-25	26-34	>34
	Speed (km/hr.)	>45	15-45	0-15
	Jerking(m/sec^3)	0-0.5	0.5-1.5	>1.5

From Table 3, in case of variable sound, for all the modes, 0-60 dB is the comfortable zone. For non-AC bus, AC bus and auto, 61-75 dB is the uncomfortable zone where 60-70 dB is for rickshaw and 61-70 is for private car. For AC bus, non-AC bus and auto, over 75 dB appears to be extremely uncomfortable while for rickshaw and private car, over 70 dB is extremely uncomfortable. The comfortable range of temperatures in degree Celsius (°C) are 22-26, 22-29, <32, <30, 20-25 for AC bus, non-AC bus, rickshaw, auto, private car respectively. Uncomfortable range of temperatures are 27-32°C, 30-40°C, 33-36°C, 30-35°C and 26-34°C for AC bus, non-AC bus, rickshaw, auto, private car respectively. For AC bus the extremely uncomfortable temperature is over 33°C, for non-AC bus it is over 40°C, for rickshaw it is over 36°C, for auto it is over 35°C and for private car it is over 34°C. In case of variable speed, comfortable speed is over 40 km/hr for AC and non-AC bus while the comfortable speed is 20-30 km/hr, >35 km/hr and >45 km/hr for rickshaw, auto and private car respectively. The journey is uncomfortable when the speed is 11-40 km/hr, 11-40 km/hr, 3-20 km/hr, 3-35 km/hr, 15-45 km/hr for AC bus, non-AC bus, rickshaw, auto, private car respectively. The speed is extremely uncomfortable when it is 0-10 km/hr, <10 km/hr, 0-3 km/hr, 0-3 km/hr, 0-15 km/hr for AC bus, non-AC bus, rickshaw, auto, private car respectively. The comfortable jerking values in m/sec^3 are 0-1.5, 0-1, 0-0.6, 0-1.2 and 0-0.5 for AC bus, non-AC bus, rickshaw, auto, private car respectively. The jerking becomes uncomfortable when the values are 1.5-5, 1-2, 0.6-2, 1.2-3, 0.5-1.5 for the same order of modes. The journey becomes extremely uncomfortable when the jerking values are >5, >2, >2, >3, >1.5 for AC bus, non-AC bus, rickshaw, auto, private car respectively.

To statistically test the fact that comfort level changes with change in mode, a Single Factor Anova Test is conducted. Here the null hypothesis is considered as the mean variance will remain the same between various modes of transport for a particular variable among the four comfort variables. The results are shown in Table 4.

Table 4. ANOVA Test Results

Source of Variation	SS	df	MS	F	P-value	F criteria
Sound						
Between Groups	1209.753	4	302.4382	7.170	0.00004	2.465
Within Groups	4091.59	97	42.18135			
Temperature						
Between Groups	1007.792	4	251.948	26.359	7.57E-15	2.465
Within Groups	936.7324	98	9.558494			
Speed						
Between Groups	10422.61	4	2605.651	9.827	9.15E-07	2.461
Within Groups	27044.27	102	265.1399			
Jerking						
Between Groups	9.768671	3	3.256224	1.845	0.14492	2.709
Within Groups	153.5312	87	1.764726			

Here, for sound factor, F value (7.16) is more than F critical value (2.465), for temperature factor F value (26.35) is more than F critical value (2.465), for speed factor F value (9.82) is more than F critical value (2.465). So, the null hypotheses are rejected for these three variables which means that there are significant variations in comfort between transport modes for speed, temperature and sound variables. For Jerking, F value (1.85) is less than F critical value (2.70). So, for jerking factor, null hypothesis is not rejected which means there is no significant variation between transportation groups for jerking factor.

CONCLUSIONS

This study evaluates comfort levels of different modes of transport combining both subjective and mechanical approach for Dhaka city, Bangladesh. The results show that, private car is the most comfortable transport followed by AC Bus, Rickshaw, Auto, Non-AC with respect to speed, temperature, vibration and sound. Among the five modes, non-AC buses are identified as the most uncomfortable mode of transport. Though non-AC buses are the most common way of commuting for general people in Dhaka city, people are facing high discomfort in their daily life traveling on them. Furthermore, this study prepared comfort ranges for comfort variables, i.e., for speed, temperature, vibration and sound within each mode and found at which level passengers feel comfortable. Using a Single Factor ANOVA Test, this manuscript found that there are significant differences in comfort between all the transport modes for speed, temperature and sound variables but no significant difference for jerking. The results of this study will assist to have a clearer and broader understanding of comfort in different transportation modes in Dhaka eventually improving the comfort level of the modes in order to improve the service quality. In future, other modes can be included in the comfort analysis, such as motor bike, two stroke motor vehicle, micro bus, trucks or air and water transports.

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OPTIMUM FLYASH TO INCREASE THE STRENGTH OF SUBGRADE

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ABSTRACT
Stabilization of problematic soils with fly ash not only improves engineering properties of soil but also provides a solution to challenges of fly ash disposal. Approximately 52,000 tons of fly ash produced annually at Boropukuria coal-based power plant in Bangladesh require a huge disposal area and create environmental problems. This paper reports the results of laboratory investigation carried out on expansive soil collected from Rajendrapur area stabilized with fly ash in varying percentages. Here, 4% cement is used as an activator. The effect of cement with varying fly ash contents are correlated with soaked California bearing ratio (CBR) value, swelling index and Atterberg limits of stabilized soil. The study finds that soaked CBR value of the soil improves from 1.73% to 26.07% after adding 6% of fly ash for 14 days of curing. With increasing of more fly ash content, strength decreases. So optimum value of fly ash content is 6% for which highest strength is obtained. Moreover, swelling index of the collected soil with 4-days soaking condition is found to be decreased by 47% when 6% fly ash is added. The outcome of this study will guide road engineers of Bangladesh to use fly ash as a stabilizing agent to improve the properties of subgrade.

Keywords: subgrade, stabilization, fly ash, CBR, swelling index

INTRODUCTION
The Road agencies face challenges while constructing road on areas where natural subgrade is of problematic nature especially if it is expansive soil. Usually, expansive soils do not possess the strength to support road construction activities and traffic load but can be improved by stabilization (Şenol et al., 2005; Bert, 2005). For any pavement, the subgrade layer is very important and it has to be strong to support the entire wheel load (Sumayya et al., 2016). Using Fly-ash, an industrial waste to stabilize the expansive soil will be helpful to the transportation engineers for better economic and stable road construction.
Swelling potential of expansive clayey soils depends on reduction of overburden stress, unloading conditions, or exposure to water and increase in moisture content (Yilmiz, 2009). Fly ash treatment can effectively reduce the swell potential of highly plastic clays and increase the strength (Nalbantoglu, 2004;

Kolias, 2005). In Bangladesh, expansive soil usually occurs in Lalmai Hill areas, Gazipur, Rajendrapur, Cumilla and some portion of Tangail and in the Barind Tract of Rajshahi (Hossain, 2001).
Growing industrial wastes are a great concern for environment and fly ash is one of those wastes. 52,000 metric tons of fly ash are produced annually as a by-product at Barapukuria coal based power plant. Five more coal based power plants are in pipeline and likely to come in production in Bangladesh. In future, it will be difficult to manage the fly ash produced from power plants. Class C fly ash can be used as a stand-alone material because of its self-cementitious properties. Class F fly ash can be used in soil stabilization applications with the addition of a cementitious agent. The study attempts to utilize the fly ash in subgrade stabilization to achieve desirable engineering properties of the soil for road construction and also to minimize the construction cost. Soil improvement is often cost effective because it reduces the cost of the remaining construction (Coduto, 1999)

RESEARCH METHODOLOGY

Sample Collection

For the research work soils were collected from Rajendrapur Cantonment, Gazipur as shown in Photo 1. Soils were collected from approximate depth of 5 ft feet by excavation. Soils were collected from such great depth so that only inorganic soils could be found. Organic soils would hamper the results of the research work.
Fly ash is produced in power plants as a by-product from the burning of coal. Fly ash were collected from Boropukuria Power Plant, Dinajpur. Ordinary Portland Cement (OPC) of a brand was used for the research work.

Photo 1: Sample collection and preparation for tests

Details of Laboratory Tests

To determine the size distribution of soil sample sieve analysis and hydrometer tests were carried out. This procedure was done according to ASTM D6913 and D7928. The specific gravity of soil was was performed according to ASTM-D854.
Atterberg limits tests were done under some different percentages of fly ash with fixed percentage of cement and soil sample according to ASTM D4318. The Modified Proctor test was performed to determine the relationship between the moisture content and the maximum dry density according to ASTM D1557 for various combination of fly ash as it was done in case of lime stabilization by Molla (1997)
CBR test results were the most important parameter of the research work. The test was carried out under different percentages with different curing times. The percentage of fly ash was taken 2%, 4%, 6% with 4% Cement as activator as shown in Table 1. All the tests were done after 7 days and 14 days curing. The swell index for 4 days of soaking was calculated for all combinations to measure the swelling of the

collected expansive soil. After every preparation of CBR mould a swell gauge was set up as shown in Photo 2. The tests were conducted according to ASTM D1883.

Table 1: Laboratory Tests Performed on different combinations

Name of Tests	Combination
Particle Size Analysis ,Specific Gravity, Modified Proctor	Only Soil
Atterberg Limits Test, CBR & Swelling Test	Only Soil Soil + 4% Cement Soil + 4% Cement + 2% FA Soil + 4% Cement + 4% FA Soil + 4% Cement + 6% FA Soil + 4% Cement + 8% FA

Photo 2 Assembly for finding swelling values and soaked CBR value

RESULTS AND DISCUSSION

Physical Characteristics of Collected soil

According to USCS, the collected soil was classified as CL, clay with low plasticity. It is found that 81 % of the soil sample passes through the ASTM sieve no. 200. Particle size distribution for the soil retained on no. 200 sieve is shown in Fig. 1.

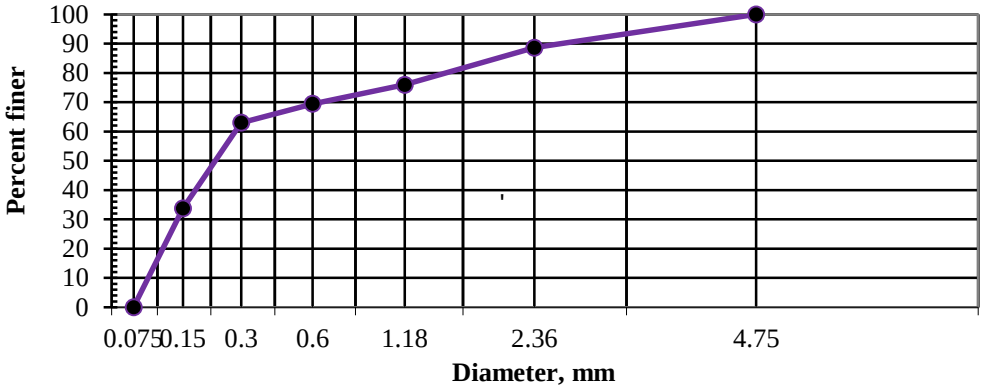

Figure 1 Grain size distribution of the collected soil.

Atterberg Limits

The Atterber limits values for all combinations are shown in Table 2. It is observed that plasticity index of the soil was reduced by 66% from the original.

Table 2 Atterber limits values for different combinations

Combination	Liquid Limit	Plastic Limit	Shrinkage Limit	PI
Soil , 0% Cement & Fly Ash 0%	48.56	29.5	41.24	19.06
Soil , 4% Cement & Fly Ash 0%	50.95	29.88	43.42	21.07
Soil , 4% Cement & Fly Ash 2%	49.2	30.86	36.69	18.34
Soil , 4% Cement & Fly Ash 4%	35.96	25.57	34.58	10.39
Soil , 4% Cement & Fly Ash 6%	24.72	18.29	31.76	6.43
Soil , 4% Cement & Fly Ash 8%	40.31	26.70	37.06	13.6

OMC and MDD

The OMC and MDD are found decreasing after addition of fly ash with the cement-soil mixtures as shown in Table 3.

CBR Values

The dry CBR value of the collected soil sample was found to be 41.4 %. However, the CBR value decreases to 1.73% when the test was done after 4 days of soaking. It proves that strength of the collected soil is highly influenced by moisture contents. Values of CBR are found increasing with addition of cement and fly ash as shown in Fig. 2. After 14 days of curing the soaked CBR value for the treated soil is more than that of 7 days curing. For soil, 4% Cement & Fly Ash 6% combination CBR values are the highest and the values obtained are 22% (7 days) and 26.05% (14 days). The CBR values decrease for soil, 4% Cement & Fly Ash 8% combination and become 12.56% (7 days) and 15.38% (14 days). For 6% fly ash highest strength is obtained. The stabilized subgrade has reached the CBR requirement for Sub-base i.e. 25% according to RHD (General Specifications, 2011).

Combination	MDD(pcf)	OMC(%)
Soil , 0% Cement & Fly Ash 0%	123.7	12.2

Table 3 MDD and OMC values for different combinations

Soil , 4% Cement & Fly Ash 0%	123.5	12.1
Soil , 4% Cement & Fly Ash 2%	123.1	12
Soil , 4% Cement & Fly Ash 4%	122.9	11.8
Soil , 4% Cement & Fly Ash 6%	122.6	11.6
Soil , 4% Cement & Fly Ash 8%	123.15	11.9

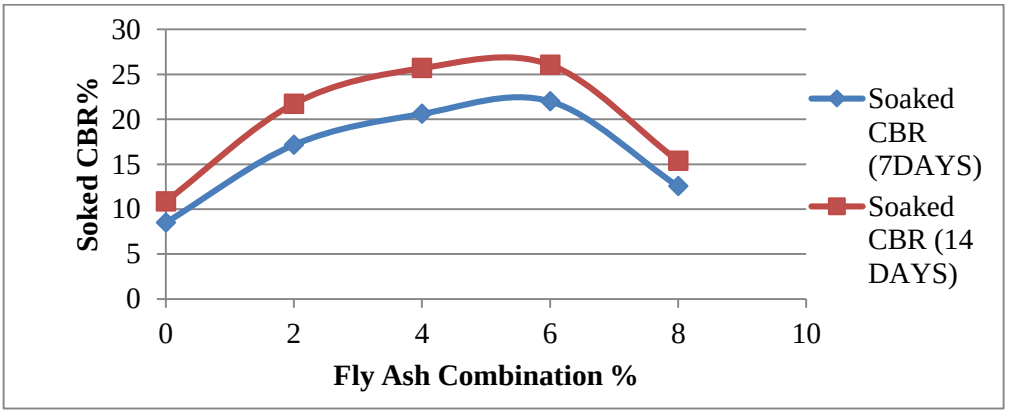

Figure 2 Influence of fly ash contents to CBR of the cement-soil mix

Swelling Index

The collected soil is found to have a swelling index of 4.95% when tested after 4 days of soaking and under a surcharge load of 4.54 kg. With an increase of fly ash content the swelling behavior reduces remarkably as indicated by the swelling index shown in Fig. 3. Swelling value is increasing with addition of more fly ash content upto 6% fly ash and the swelling index is found to be 2.6% .

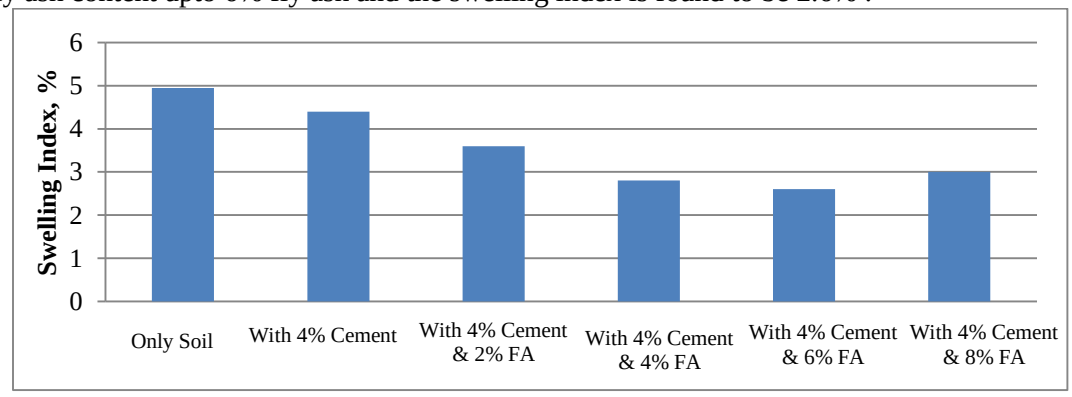

Figure 3 Effect of fly ash contents to swelling index of the cement-soil mix

CONCLUSION

This study was aimed to utilize the fly ash an industrial waste to improve the physical properties of Rajendrapur soil. The investigation was done by adding cement and fly ash with soil at different percentages. Major findings from this study are:

1. From soaked CBR test optimum fly ash content is found 6% for which maximum strength is obtained. The stabilized subgrade has reached the CBR requirement for Sub-base.

2. With addition of fly ash content the swelling index value decreases significantly. The fly ash stabilization has reduced the swelling index by 47%
3. Both liquid limit and plastic limit are found to be decreased at optimum fly ash content. Plasticity index of the treated soil is found to be decreased by 66% than that of the untreated soil.

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ASSESSMENT OF VARIOUS DELAY MODELS AT INTERSECTIONS IN DHAKA CITY

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ABSTRACT
Intersections are the nodal points in transportation system networks and their operational efficiency undoubtedly plays an important role in the entire network performance. In evaluating the performance of signalized intersections, the most vital parameter is traffic delay. In the developing countries like Bangladesh, pretimed signalized intersections are used most commonly if not monitored by traffic police. Capacity analysis of pretimed signalized intersections is highly dependent on the estimation of traffic delay. In spite of having various difficulties in estimating delay at intersection due to large variation and randomness of traffic arrivals and interruption caused by traffic signal controls, a lot of research has been conducted to determine delay by a number of analytical delay models. This study deals with the evaluation of various delay models, those are applicable for under saturated traffic flow, and verification of the applicability of those delay models by comparing with manually estimated field delay at three selected intersections of Dhaka City where degree of saturation was less than 1.0. Variation between the field delay and the delay estimated by different models were graphically represented and the applicability of the intersection delay models for the Dhaka city was analyzed by performing error analysis.

Keywords: *Intersection delay, Delay models, Delay expressions, Signalized intersection, Traffic delay, Under saturated traffic flow*

INTRODUCTION
Delay at signalized intersection is computed as the difference in the departure time and the arrival time of a vehicle. Delay is a parameter that is not easily determined due to the nondeterministic nature of the arrival and departure processes at the intersection. But lot of research has been done in this field to define delay by a number of analytical delay models. In Dhaka city the accuracy of traffic delay is more difficult to estimate because of the maintenance of cycle length and green time are monitored by traffic police at intersections. Even at the pretimed signalized intersections there is no rule forced upon maintaining the lane discipline. In addition, at most of the intersections there are observed unrestricted mixing of motorized and non-motorized vehicle at intersections. Moreover, the static and dynamic characteristics of the vehicles vary widely even if they are under same class. All of the facts in the same right way result in heterogeneous natured traffic stream. In order to design the cycle length, green time ratio or capacity analysis of an intersection it is highly recommended to have broad knowledge on the deviation and applicability of various delay models on that area's intersections.

METHODOLOGY

In order to estimate the intersection delay at low traffic flow when degree of saturation is less than 1.0 ($x \leq 1.0$), the following delay models are more acceptable.

- **Webster's full delay expression:**

$$D = \frac{C(1-\lambda)^2}{2(1-\lambda x)} + \frac{x^2}{2q(1-x)} - 0.65\left(\frac{C}{q^2}\right)^{\frac{1}{3}} x^{2+5x} \quad (1)$$

- **Webster's simplified delay expression (Modified by Hutchinson):**

$$D = \frac{9}{10}\left[\frac{C(1-\lambda)^2}{2(1-\lambda x)} + \frac{x^2}{2q(1-x)}\right] \quad (2)$$

- **Wardrop's delay expression:**

$$D = \frac{\left[r-\frac{1}{2s}\right]^2}{2C[1-y]}$$

(3)

- **Miller's first delay expression:**

$$D = \frac{(1-\lambda)}{2(1-\lambda x)}\left\{C(1-\lambda) + \frac{(2x-1)I}{q(1-x)} + \frac{I+\lambda x-1}{s}\right\}$$

(4)

Where, I = variance to mean ratio of flow per cycle.

- **Miller's second delay expression:**

$$D = \frac{(1-\lambda)}{2(1-\lambda x)}\left\{C(1-\lambda) + \frac{\exp\left[\frac{(-1.33)\sqrt{sg}(1-x)}{x}\right]}{q(1-x)}\right\} \quad (5)$$

- **Newell's delay expression (Modified by Cronje):**

$$D = \frac{C(1-\lambda)^2}{2(1-y)} + \frac{IH(\mu)x}{2q(1-x)} + \frac{(1-\lambda)I}{2s(1-\lambda x)^2}$$

(6)

Here, I is the variance to mean ratio of arrivals and H (μ) is a function given by the following equation:

$$\mu = \frac{sg - qc}{(Isg)^{0.5}}$$

The function of H (μ) was obtained by numerical integration that ranges between 1 at μ = 0 to 0.25 at μ = 1.

Cronje proposed an alternative approximation for H (μ), which is expressed as follows:

$$H(\mu) = \exp\left\{-\mu - \left(\frac{\mu^2}{2}\right)\right\}$$

Where, $\mu = (1-x)(sg)^{0.5}$

To check the applicability of these models to non-lane based traffic conditions in Dhaka City, values obtained by these models are compared with the field observed values. Collection of data on the field was carried out manually. Three intersections were selected in Dhaka city, for the analysis. Simultaneously data on signal timing (i.e. cycle length, green time) and traffic data (i.e. number of traffics arrived, number of traffics departed) was collected manually using stopwatch.

[Fig 1]: Intersections (Top left-Rajarbagh, Top Right –Bijoy Shoroni, Bottom- Gulshan-2 google earth photos)

Intersections type was traffic police controlled pre-timed signalized four-way intersection. Data collection time was selected between 12pm to 2pm, when the rush of traffic flow was limited, so that degree of saturation could be obtained below 1.0.

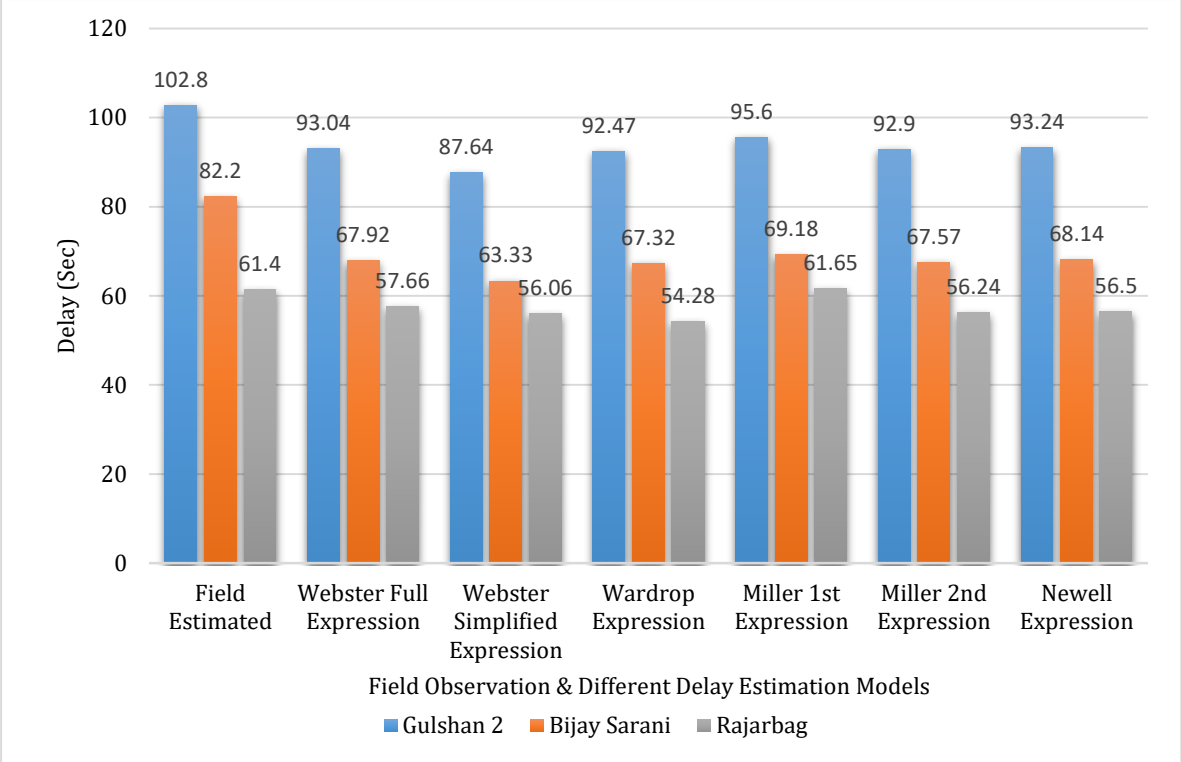
The arrival time and departure time of different traffics, those approached at the intersection at different phases of the cycle, were noted down. Average delay was obtained from the mean value of the delay of those vehicles approached at the intersection at different phases of the cycle at fixed specific interval of C/4. Obtained average delay is the field observed delay.

Using the required information from the collected data, arrival flow rate and saturated flow rate were estimated in PCU per hour. Then green ratio, flow ratio and degree of saturation were estimated. Once delay is estimated by the mentioned delay models using field data, the field observed delay is compared with the delay estimated by the delay models. Once the comparison between field observed delay and theoretical delay is graphically represented, then the Mean Absolute Percentage Error (MAPE) and Root Mean Square Error (RMSE) are determined for each of the models in accordance with the applicability of those models in non-lane based traffic system of Dhaka City.

RESULTS AND DISCUSSIONS

Table 1: Field observed delay and delay estimated by different models at three intersections of Dhaka City**.**

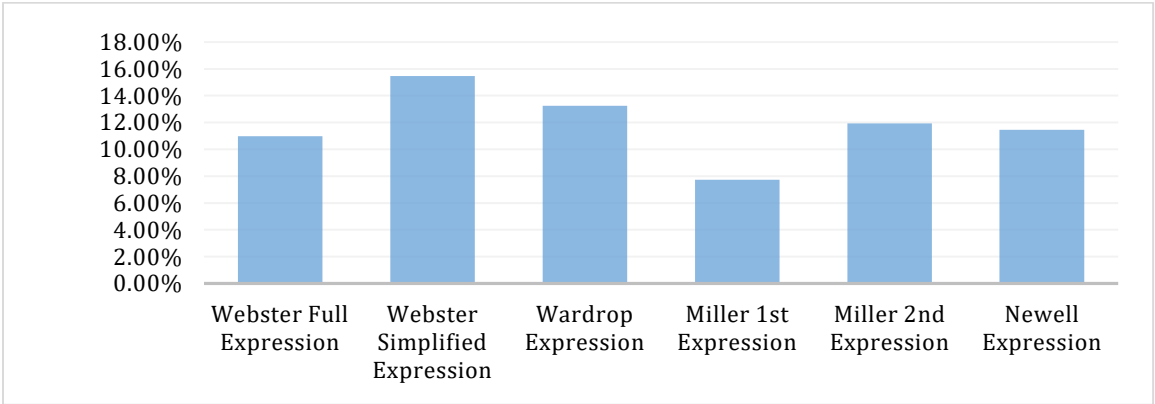
Intersection	Field Observed Delay (sec)	Estimated Delay (sec)					
		Webster Full Delay Model	Webster Simplified Delay Model	Wardrop Delay Model	Miller 1st Delay Model	Miller 2nd Delay Model	Newell Delay Model
Gulshan 2	102.8	93.04	87.64	92.47	95.6	92.9	93.24
Bijay Sarani	82.2	67.92	63.33	67.32	69.18	67.57	68.14
Rajarbag	61.4	57.66	56.06	54.28	61.65	56.24	56.5



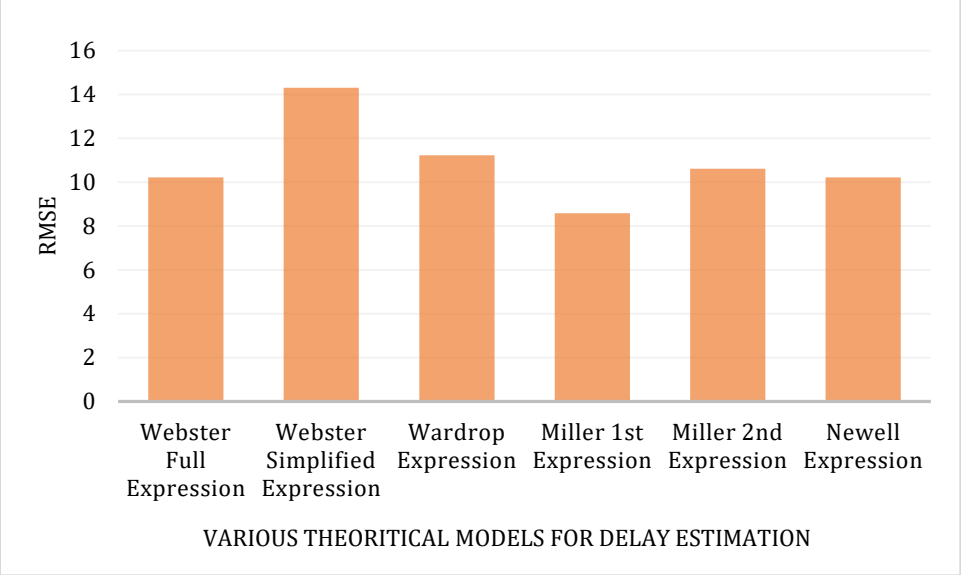
[Fig 2]: Variation of field observed delay and theoretical delay estimated by different delay models

Table 2: Error analysis of different delay estimation models

Error Analysis Method	Delay Estimation Models					
	Webster Full Model	**Webster Simplified Model**	**Wardrop Model**	**Miller 1st Model**	**Miller 2nd Model**	**Newell Model**
Mean Absolute Percentage Error (MAPE)	10.97%	15.47%	13.24%	7.74%	11.93%	11.46%
Root Mean Square Error (RMSE)	10.22	14.31	11.23	8.58	10.61	10.22



[Fig 3]: Mean Absolute Percentage Error (MAPE) of various Delay Estimation Models



[Fig 4]: Root Mean Square Error (RMSE) of various Delay Estimation Models

- Field observed delay at all the intersections are found higher than the delay estimated by different delay models. Violating of traffic signals, negligence of lane maintaining, mixture of motorized and non-motorized vehicles, the effect of right turning vehicle etc. are the main factors affecting the intersection delay.

- Among the specified delay models, Miller's 1st expression of delay model is more applicable for intersections of Dhaka city those are having under saturated traffic flow.

CONCLUSION

Many researches have been conducted with an objective to estimate the intersection delay precisely. As a result, many intersection delay estimation models have been proposed by various transportation professionals. In the developed countries these delay models estimate the delay almost satisfactorily. But in the developing countries like Bangladesh, sometimes the suitability of these delay models is not up to the satisfactory level. Traffic flow in developing countries consists of different types of vehicles, resulting heterogeneous mixture, those do not follow any lane discipline. As a result, analyzing the deviation of field delay from the theoretically estimated delay at intersections of Dhaka city, designing of cycle time, green time ratio and capacity analysis can be carried forward more appropriately.

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AN ANALYSIS ON EXISTING CONDITION OF INTER DISTRICT BUS TERMINALS OF CHITTAGONG CITY

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ABSTRACT
Bus is very important mode of transportation for a city. The significance of integrated and balanced transportation system, especially planned logistics is indispensable for communication efficiency and sustainable development of any country. The inter-district bus terminals, as a key component of transport logistics play a vital role in assuring intra-urban mobility and inter-regional movement competitiveness. Chittagong is the second largest city and commercial capital of Bangladesh. It has two inter-district bus terminals and some prime Bus Stations. Due to the city's location significance, spatial influence and economic role in the national context, the importance of these three bus terminals are crucial in facilitating sound passenger movement from Chittagong to the rest of the country and vice versa. The necessity, therefore, to make these existing terminal facilities more organized, well-served and functionally competent is the demand of the time. With the backdrop, this paper focuses on existing condition analysis of these inter-district bus terminals in reference to their regulatory framework, infrastructure facilities and management system. The outcome indicated deviation of the facility provisions in comparison to prescribed regulations and their inadequacy in relation to the increasing demand of its passengers.

Keywords: Transportation, Inter-district bus terminal, Passenger facilities, Chittagong city

INTRODUCTION

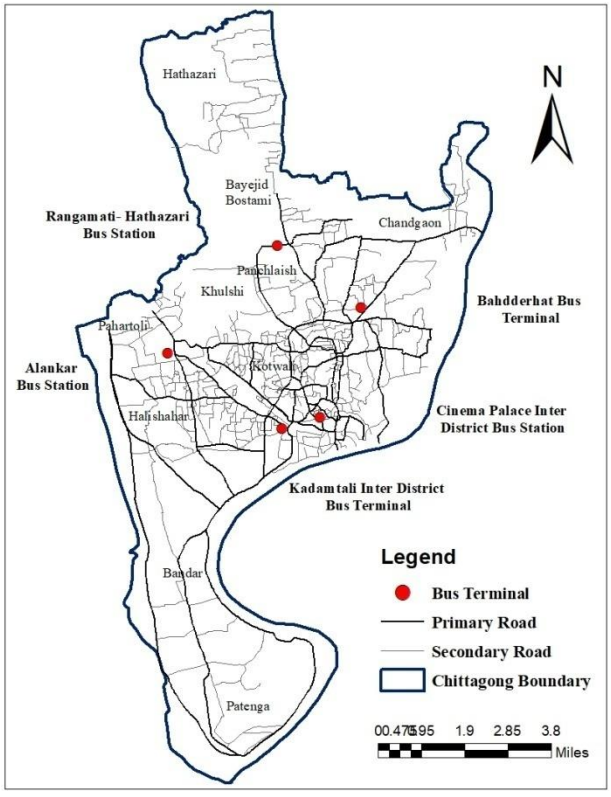
"A bus terminal is defined as an area- way from the general flow of road vehicle, which gives buses and coaches the freedom of movement to set down and pick up passengers in safety and comfort. Intercity, inter-district and sometimes international buses use this structure for the pickup and drop off of passengers." (Hoque, 2011). A bus terminal is very important place for passengers as they stay there for board and alight from buses for their long intercity journey.The location site of a bus terminal is need to consider for better service. "A list of broad infra-structural requirements has been drawn up, through literature review. These requirements are the essential ingredients for planning and designing bus terminals, and have been classified as primary infrastructure requirements and supporting infrastructure requirements."(Gandhi, et al., 2015). The primary infrastructure requirements i. Passenger areas- Ticketing and queuing , Passenger waiting areas, Passenger conveniences (drinking water facilities and toilets), Passenger circulation, Boarding/Departing areas, Facility entry, Tourist information, Security, including CCTV cameras, Retail, concessions and lease space, Dormitories and lodging (if required), Cloak room, Railway reservation ii. Areas for terminal staff- Revenue office, Security and information, Ticketing booth, Resting room, Staff conveniences (drinking water facilities and toilets), Canteen, Maintenance staff (chairs and lockers), Control room (CCTV surveillance), iii. Areas for bus staff- Canteen, Resting areas, lodging areas (if required), Bus staff conveniences (drinking water facilities and toilets). The supporting infrastructure requirements include provision for Feeder infrastructure,

Seating, Landscaping, Lighting, Way finding (Passenger Information Systems (PIS), Signage and Marking), Public art. "The design and provision of services—such as lighting, drainage, firefighting, and information systems—is an essential component of bus terminal design." (Gandhi, et al., 2015) In the report, Hoque divided the required facilities into three categories. For example, The facilities to be provided for passengers (Public toilets, A bus and coach information centers and Cafes nearby, Waiting room facilities, Booking system, Left luggage and lost property offices), The facilities to be provided for staff (Canteen and Toilets, A recreation area, Locker rooms, Pay-in facilities) and Facilities for bus maintenance (Proper inspection and repair, Servicing of buses and coaches, Fuelling, Washing, Garaging facilities). There are some common facilities that people expect to have for a smooth journey. A clean and healthy environment can provide freshness and comfort to the passengers during waiting. The appropriate design and layout of the physical environment can reduce opportunities for criminal actions. (Liggett, Sideris, & Iseki). The Government Authorities don't have any written documents or the details of any of these terminals or stations.This paper aims to analyze the existing condition of infrastructure facilities of these bus terminals and stations.It would be helpful to the further study of the scholars in the related context.

METHODOLOGY

The study conducted base on primary data collected from field through questionnaire survey. The basic information of the study area are collected from the interview of terminal authorities. A comprehensive field survey and user opinion survey have been made as well using questionnaire and checklist to explore the existing conditions including the infrastructure, existing facilities and services, management system and the extent of user's satisfaction level. 100 users of four terminals (25 users from each terminal) have been surveyed randomly.

STUDY AREA PROFILE



Kadamtali Inter District Bus Terminal: Since 1966 it is the largest (around 3000 bus are under 1200 owners in nearly 2.5 acres area) intercity bus terminal which operated by private bus owner committee in Chittagong. The terminal is established along the Dhaka Trunk Road. Alankar Bus Station: Mainly it is a branch of Kadamtali Bus Terminal for a long period of time. Although it is a station but it operates like a terminal. More than 500 buses are allocated for the service.Cinema Palace Inter District Bus Station: This station provides tickets during the day, at night it provides bus services to pick up passengers. About 35 buses pick up passengers from the station each night.

Rangamati-Hathazari Bus Station: Nearly 126 buses are activated in daily service. This station is located in the junction of Bayazid Bostami Road and Chittagong-Rangamati Highway. Bahdderhat Bus Terminal: Although officially it is belong to the Chittagong Development Authority (CDA), but they have their own bus committee responsible for all activities and decisions. The terminal was constructed and funded by CDA. According to the Chittagong Metropolitan Master Plan (1995), "A small fee for the use of the Bahdderhat Terminal is collected from each operator and forwarded to CDA- though the day-by-day management of the terminal now lies with the bus operators' association". Total 400 buses are available under the terminal bus service. The station is located along the Arkan Road (Chittagong-Cox's Bazar Highway). City View Revolving Zia Memorial Complex, Shadhinata Complex, Bangladesh Betar, Kalurghat are situated around the terminal.

LEVEL OF EXISTING FACILITIES OF BUS TERMINALS AT CHITTAGONG CITY

Kadamtali Inter District Bus Terminal: There are no infrastructure facilities available except a prayer place. The bus parking place is located at a few minutes walking distance. The boarding and departure area is the footpath along the road. There are several ticket counters along the road in a row with small waiting room. There are no separate toilet facilities for man and woman. Environment of the area is clumsy, congested and unhealthy. Alankar Bus Station: It has many shops and restaurants all over the place with high price rate. The ticket counters have small place as a waiting room with a toilet within the counter. Passengers pick up and drop off activities all happen on the main road as there are no parking place. Environment is risky and congested. Cinema Palace Inter District Bus Station: There are some shops and restaurants along the main road within the ticket counters. The counters have a small room with toilet facilities. As there are no service activities during the day, the counters are vacuous of passengers. Rangamati-Hathazari Bus Station: The most risky, unhealthy place as a bus ticket counter with no infrastructure facilities. No parking space, no boarding or departure area, no toilets, so passenger sheds. Roads are broken and narrow. As a station it has no minimum infrastructure facilities. Bahdderhat Bus Terminal: It has a structural identification as a terminal. Although there are no waiting room, they have passenger sheds for taking shelter. Separate toilet facilities for man and woman, a beautiful mosque, entry and exit gate, parking place are available. But the environment and the road surface condition is too bad. There are some common infrastructure facilities that need to have in any bus terminal. The checklist provides the information of existing facilities.

Table 01: Existing facilities of bus terminals at Chittagong City

Terminal Facilities	Kadamtali	Alankar	Cinema Palace	Rangamati-Hathazari	Bahdderhat
Facilities for Passengers					
Waiting room	Yes	Yes	Yes	No	No
Shops & Restaurants	Yes	Yes	Yes	No	Yes
Drinking water facilities	No	No	No	No	No
Separate toilets for men & women	No	No	No	No	Yes
Passenger circulation	No		No	No	No
Security including CCTV camera	No	No	No	No	No
Boarding/ Departing area	No	No	No	No	Yes
Recreation system	No	No	No	No	No
Medical facility	No	No	No	No	No
Left luggage & lost property office	No	No	No	No	Yes
Mosque	Yes	No	No	No	Yes
Facilities for Terminal Staff					
Security & information	Yes	Yes	Yes	Yes	Yes
Ticketing booth	Yes	Yes	Yes	Yes	Yes
Resting room	Yes	No	No	No	No
Canteen	No	No	No	No	No
Drinking water facilities	No	No	No	No	No
Toilets & Washrooms	No	No	No	No	Yes
Locker room	No	No	No	No	No
Announcing system	Yes	No	No	No	Yes
Facilities for Bus Staff					
Drinking water facilities	No	No	No	No	No
Canteen	No	No	No	No	No
Toilets & Washrooms	No	No	No	No	No
Locker room	No	No	No	No	No
Facilities for service					
Drainage system	No	No	No	No	No
Fire fighting	Yes	No	No	No	Yes
Lighting	Yes	Yes	Yes	Yes	Yes
Fueling station	No	No	No	No	Yes

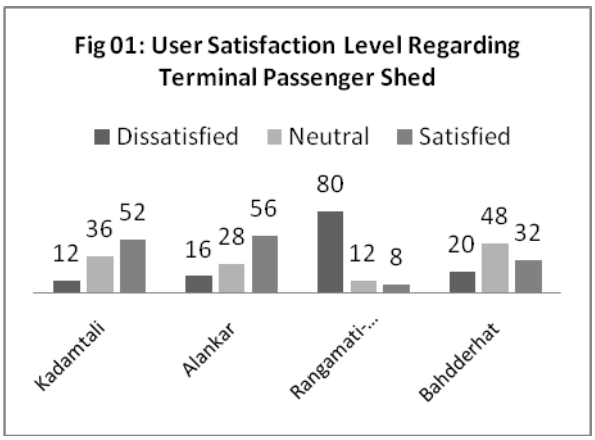
Source: Field Survey, 2018

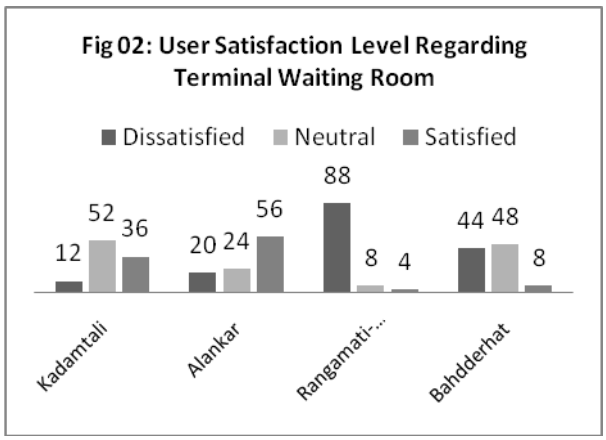
Table 02: Level of user satisfaction at bus terminals of Chittagong City

Terminals / Facilities	User Satisfaction level on Percentage											
	Kadamtali			Alankar			Rangamati-Hathazari			Bahdderhat		
	D	N	S	D	N	S	D	N	S	D	N	S
Provided washroom	4	44	52	44	24	32	84	16	0	52	32	16
Bus parking facility	12	44	44	56	28	16	76	16	8	48	36	16
Environment	84	8	8	44	52	4	92	8	0	76	16	8
Waiting room	12	52	36	20	24	56	88	8	4	44	48	8
Passenger shed	12	36	52	16	28	56	80	12	8	20	48	32
Platform	12	40	48	16	68	16	68	28	4	36	48	16
Information service	12	28	60	16	56	28	16	24	60	0	16	84
Safety & security	24	44	32	32	32	36	88	12	0	60	36	4
Locker Service	32	56	12	64	36	0	96	0	4	76	12	12
Shops & Restaurants	20	36	44	0	0	100	8	32	60	12	48	40
Medicare facility	28	64	8	84	16	0	100	0	0	76	24	0
Mosque	4	68	28	32	32	36	36	40	24	4	32	64
Passenger loading unloading	20	72	8	64	28	8	68	28	4	32	52	16
Ticket counter	4	52	44	0	0	100	4	16	80	0	4	96

D = Dissatisfied **N** = Neutral **S** = Satisfied Source: Field Survey, 2018

"The Dhaka City Corporation has provided some guiding framework to the private sector terminal management authorities regarding provision and maintenance of user facilities in the terminals." (Rahman, Mitra, Yasmin, & Esita, 2007). As there are no standard guiding framework for bus terminals from the Chittagong City Corporation, the standards formed by Dhaka City Corporation has followed. According to the Dhaka City Corporation guiding framework, the set of the service facilities standard given to the paper are Passenger shed, Waiting room, Information service availability from the terminal authority, Toilet and wash room, Lockers, Shops and restaurants, Telephone booths, Medical center, Mosque or prayer room. From the table, a comparison of the existing infrastructure facilities among the terminals can be observed.



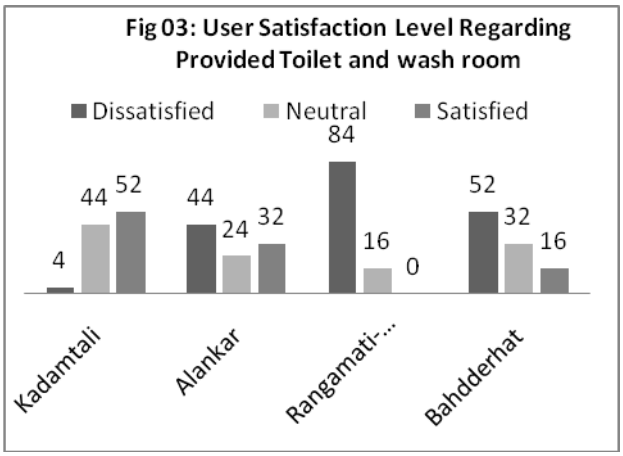


Passenger shed

Bus terminal management authority should maintain a clean, standard passenger shed with sitting arrangement. From Fig 01, it is clear that Kadamtali Bus Terminal and Alankar Bus Station provides passenger shed respectively 52% and 56% although not in a good satisfactory level. Rangamati-Hathazari Bus Station shows the terrible condition of dissatisfaction with 80% response.

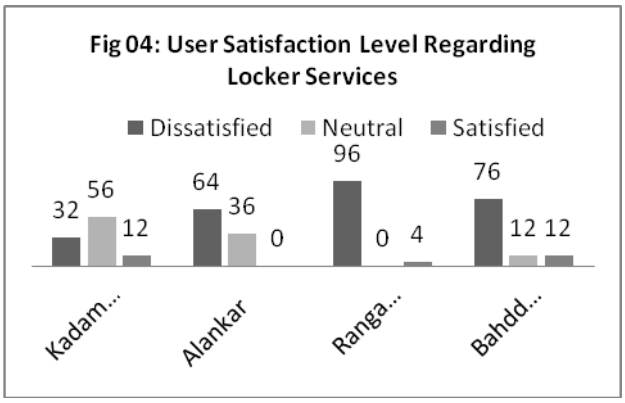
Waiting room

A clean healthy environment to take rest or wait including arrival-departure, origin-destination information a board, wall clock, magazineand newspapershould have in a waiting room for the convenience of the passengers. From Fig 02, 88% dissatisfaction level in the Rangamati-Hathazari Bus Station is the highest. Alankar Bus Station provides good waiting room service at 56% response. Bahdderhat Terminal express a bad condition in waiting room services only 8% are satisfied.



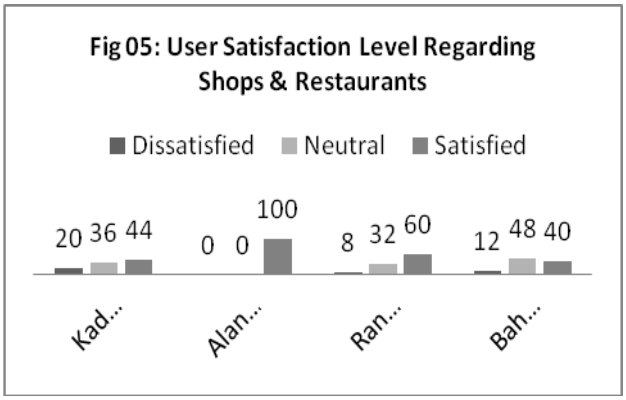
Toilet and wash room

A sanitary toilet facility is very prime consideration to provide odor free, clean toilets and washroom with available water supply. Scheduled toilet cleaning practice must be ensured with delivering soaps, hand wash liquids, cleaning detergents. From Fig 03, the existing condition of Rangamati-Hathazari Bus Station is very terrible in the facility service of toilet and washroom. 16% passengers don't care as they remain neutral and 84% passengers are dissatisfied. Kadamtali Bus Terminal has toilet facilities comparatively good as 52% passengers are satisfied.



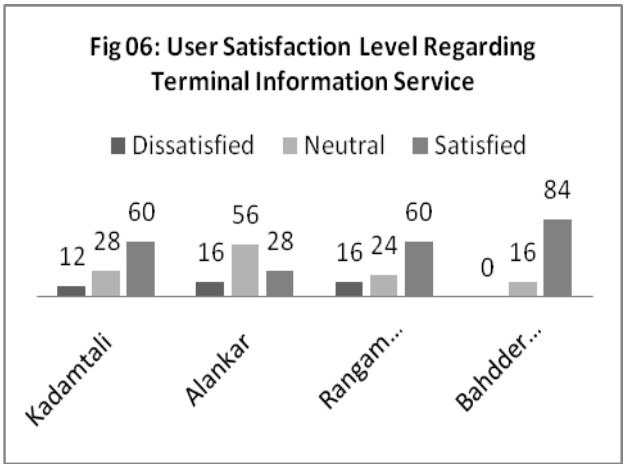
Lockers

Lockers for passengers are important requirements in the terminal waiting building. From Fig 05, Significant dissatisfaction are noticeable in Rangamati-Hathazari Bus Station in 96% response. Kadamtali and Bahdderhat Bus Terminal provide same satisfaction level locker service which is 12%.



Shops and restaurants

Under the terminal management authority, restaurants with fare price, available good quality hygienic food, small utility shop, medical shop need to operate as a part of terminal service. In the terminal area there must not local unauthorized shops, hawkers or counterman be found and a strict law should apply for this. From Fig 05, Alankar Bus Station 100% facilities of food and restaurant services although they don't belong to the Bus Management Authority. Bahdderhat and Kadamtali bus terminal has low satisfactory level which is 40% and 44%.



Information service availability from the terminal authority

The complete and updated information about time, route and bus schedule need to show regularly in a displaying billboard in the waiting room for the passengers. From Fig 06, Bahdderhat Bus Terminal has good performance in the availability of information service with 84% response where Alankar Bus Station is below the satisfactory level because of 28% satisfactory response.

Others facilities

Several numbers of public telephone booths available for passengers for their emergency need to consider. There are no telephone booth services in any Bus Terminal or Bus Stations. A medical center with entitled doctor and experienced nurses for first aid and necessary emergency treatment is must in a terminal for passenger's safety. Medical shop with available necessary medicine should be provided. Bahdderhat Bus Terminal Alankar Bus Station, Rangamati-Hathazari Bus station has no medical service where 8% passenger response in positive way. As a Muslim country, provision for prayer room with adequate facilities are considerable including proper management. Bahdderhat Bus Terminal has good response in satisfaction level that is 64%. Near the Alankar Bus Station there are a mosque which is not belong to the bus management authority for which satisfaction level is 36%.

MAJOR FINDINGS

The study and analysis clearly indicate insufficient provision of terminal facilities in relation to the increasing demand of its passengers. The dissatisfactory condition is also attributable to inadequate distribution of facilities, lack of information about arrival and departure, unorganized ticket fares and payment system, outstation of passenger shade by hawkers and illegal ticket counters, harassment of passengers by bus crews, worse condition of waiting rooms, toilets and other passenger facilities. Further the lack of internal coordination between the terminal maintenance authorities and bus operators causes deficiency of proper services to the passengers. Such irregularities and discontinuities not only cause problems but also fail to mitigate the demand- supply gap. If the desired terminal conditions are to be met there, it is an urgent necessity to overhaul and strengthen the institutional arrangements to implement professionalism in the management of terminals, depots and on street bus operations as well as restructure the terminal and the traffic inside and around the terminal. These are demanded both for better inter district bus service and for problem free traffic flow within the city.

CONCLUDING REMARKS

To make these terminals more effective and useful, the management authority should have to fulfill the present demand by using the potentials of this terminal and prepare a future plan so that present supply can cope with future demand and passengers can enjoy easy access to all possible facilities in the terminal. Thus, the existing terminals will be able to shift into improved and well-equipped logistic support, essential to solve the transportation problem of Chittagong city.

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A TRIP GENERATION ANALYSIS- A CASE STUDY ON CHANDGAON RESIDENTIAL AREA

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ABSTRACT
Study on trip generation is one of the four steps of conventional transportation modelling process, that is trip generation, trip distribution, modal split and trip assignment. Socio-economic and land use characteristics influence trip generation. Applying the trip generation model in the study area of Chandgaon residential area attempt has been made to find out the factors, which are related with trip generation. Based on some selected variables or factors like income, total time, main mode, comfort, fare, reliability etc. used in to find out the correlation of the factor to the total number of trip generation. Then spatial regression analysis has been done to find out the trip generation equation. Then we find out an equation of trip generation by regression equation. The equation will help to calculate total number of trip of the residential area of a family. The study tries to estimate the total number of trips generated from the residential area. Moreover' the impact of trip generation on road transport system is identified in the study to recommend on minimizing its negative impacts for smooth operation of traffic and as well as for proper traffic management.

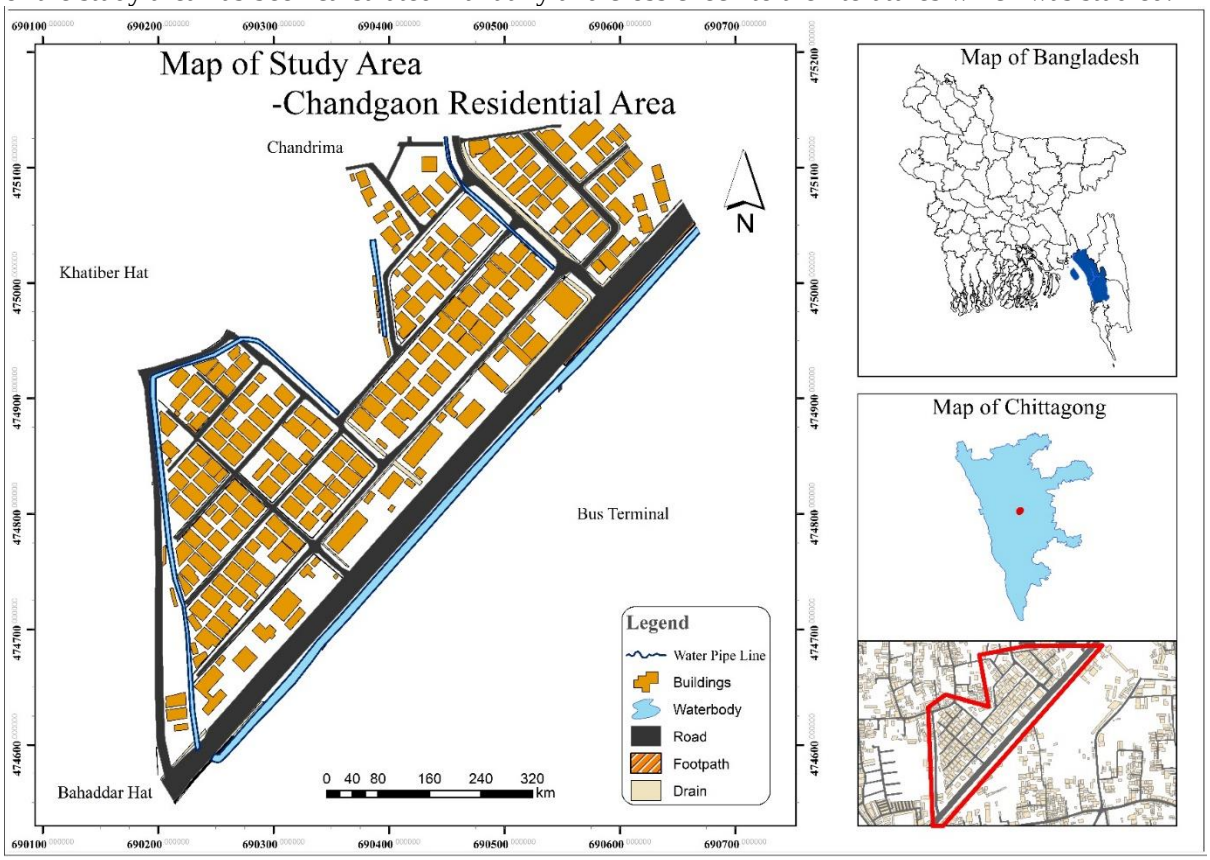
Keywords: Trip generation; Destination analysis; Regression model

INTRODUCTION

Transport modelling has four conventional steps. These Steps are trip generation, trip distribution, modal split and trip assignment (Rahman, 2011; Kadiyali, 2003). Trip generation is defined as the decision to travel for a specific purpose. There can be two types of purpose, one is zonal trip being estimated on Trip purposes and the Other is travel behaviour being also dependent on trip purposes (edu, 2010). The objective of the trip generation stage is to understanding the reason for generating the trips and to produce mathematical relationships on the basis of observed trips, land use data and Household characteristics (Kadiyali, 2003). People who live in the study area belong to different income groups, i.e. higher, middle and low income groups. Socio-economic characteristics and the purposes of traveling influence the travel behaviour of the inhabitant which has a significant impact on the overall transport system, especially to determine the road elements and for efficient transport operation (Rahman, 2011). Chandgaon residential area is being developed in recent years due to housing demand (Rahaman, Hashi, & Azom, 2017). Development of land use affects trip generation and creates a pressure on transport Network as well. Population, Labour force participation rate, work at home or outside and other various factor influence the trip generation which is found and cited by Mifler, (1998) and Rahman, (2011). Trip generation model can help to improve existing transport system by providing sufficient information on total trip generated by people (Rahman, 2011). The aim of the study is to estimate the total number of trips generation from the study area by using spatial regression analysis and analyse the impact of trip generation on transport network.

METHODOLOGY

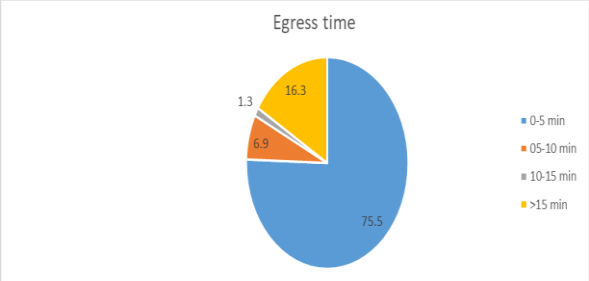
The topic has been selected on the trip generation model of any residential area. We calculated the trip generation rate and analysis the effect of the trip generation condition of the study area. The study area selection is one of the major part of any analyze. In this study, the study area has been selected Chittagong region, the second busiest and the biggest port city of Bangladesh. We select Chandgaon residential area because plan and flat purpose. There have several literature reviews completed for this analysis. In this analysis, all technical and statistical analysis has been conduct according to world class system. The whole data has been collected from both primaries (field survey) and Secondary data source. The primary data are collected from direct field survey by the surveyor about of their all information such as origin and destination of trips, income, and demography profile, travels modes, modes ownerships etc. Secondary data are collected from various sources like CCC, CDA, etc. to prepare the map of study area. To complete the study, we are collected various numbers of journal papers, conferences papers etc. For any study or research work it is an important stage. The collected data are analyzed into various sections. Trip rate analysis, Travels demand, Existing condition of modes users, Demographic profile, Satisfaction and Dissatisfaction level. The collected data has been processed by many scientific and technical systems to get better output of the data. Trip generation rate of the study area has been calculated manually and cross check to the literatures which was studied.



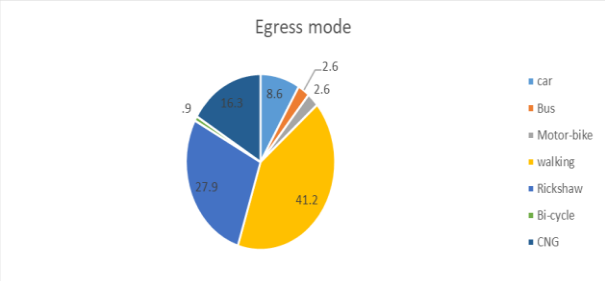
[Fig. 1] Location Map of Study Area

RESULTS AND DISCUSSIONS

[Fig. 2] shows the egress time of the study area. Good transportation connection remains in this study area. People can easily find out their transportation from their house. 75% percentages of people easily get their transport within 5 minutes. Local transportation system is available in this study area. 6.9% percentages of people needed 5-10 minutes to get their transport. 16.3 percentages of people needed above 15 minutes to get transport because some of the roads are not well constructed. As a result, few time is spending for getting transport. And for accessing to the main mode they use egress mode which is shown in *[Fig. 3]*

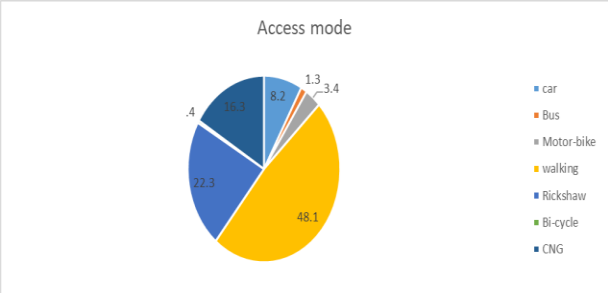


[Fig. 2] Egress time

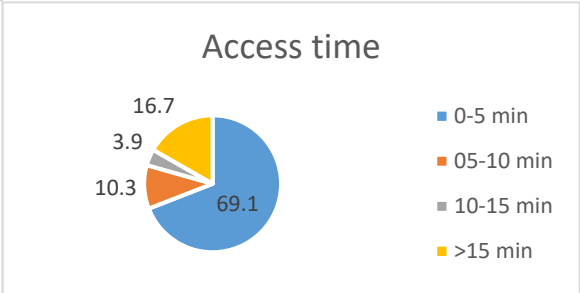


[Fig. 3] Egress mode

Most of the people of this area are job oriented, and most of the commercial place of Chittagong stay belong the road. As a result, people, can easily egress by walking. 41.2% of people completed their egress by walking. 27.9 % people need rickshaw. There are also some several modes for egress. 16.3% need CNG. Car, motor-bike, Bi-cycle also need for egress but in few percentages.



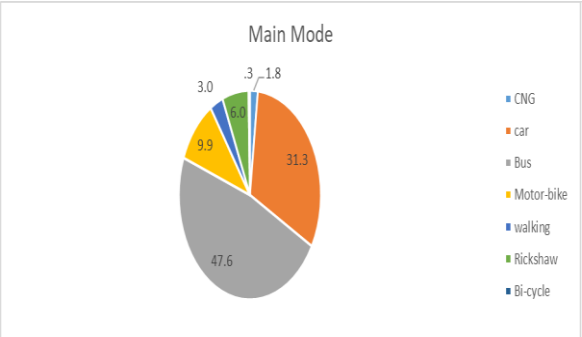
[Fig. 4] Access time



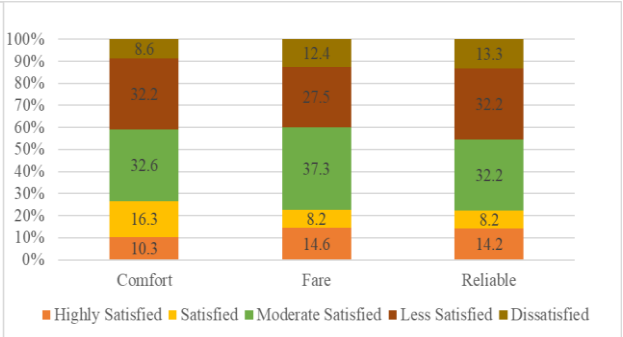
[Fig. 5] Access Mode

There are several transports system remains in this area, but walking and rickshaw are main access mode of this area. From figure no 8 we can see that 48.1% of people completed their access mode by walking. 22.3% people have opportunity of rickshaw. 16.3% people need car and very percentages of people need bus, rickshaw, motor-bike, bi-cycle for accessing. Local highway road has gone beside the area; as a result, people of this area can easily access the transport by walking.

[Fig 4] and *[Fig 5]* shows the access time and mode of the study area. People of this area are highly accusable to get transport for their daily need.691% people can easily get main mode within 5 minutes. 10.3% people spend 5-10 minutes for access.16.7% need above 15 minutes to get transport. Few percentages of people spend 10-15 minutes for main mode.



[Fig. 6] Main Mode

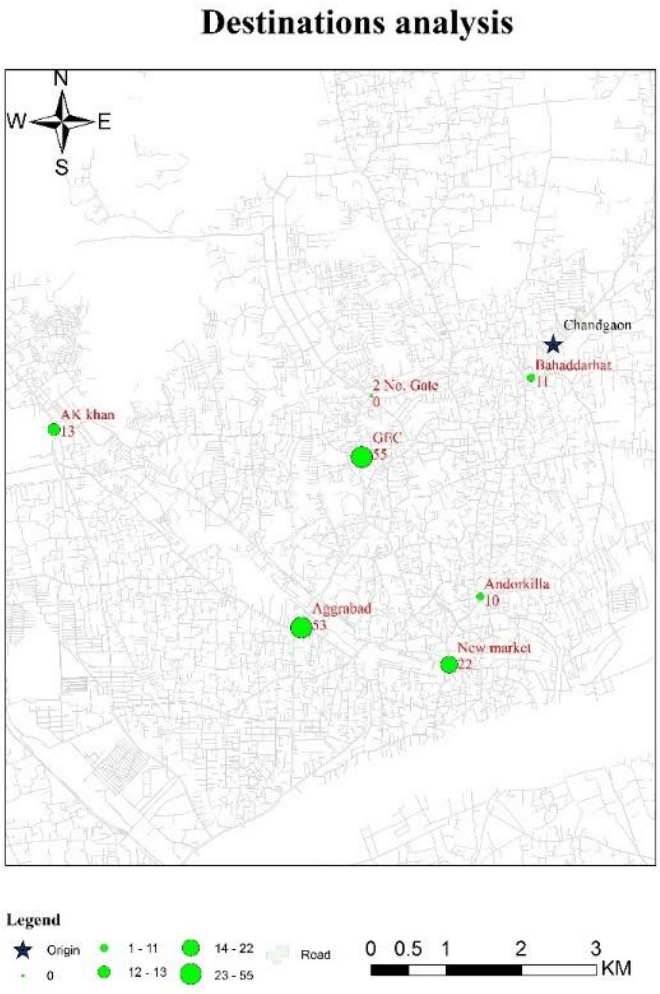


[Fig. 7] Comfort status

[Fig. 6] shows the main mode of the study area. The people of this area are mainly job oriented, for this

purpose they need to go here and there. Local transport system mainly bus is the main transport system for them. Almost half of the people area chose bus is the main mode for trip. 47.6% people chose bus for their main mode. 31.3% people chose car for main trip. Commercial road such as G.E.C., Agrabad etc. can easily access by bus, car, CNG, Bike from the study area. 9.9 % people use motor-bike for main mode. A few percentages of people need rickshaw, Bi-cycle as a main mode.

[Fig. 7] shows the comfort status of these mode. Satisfaction level is mixed up in this area. Some people are highly satisfied, some are dissatisfied. Overall satisfaction comes from transport which is moderately satisfied. 32.6% people are moderately satisfied on transports system. 32.2 % people are less satisfied on transport system. 16.3% people are satisfied on transport system and few percentages of people are highly satisfied and dissatisfied on transport system.
There is also some mixed satisfaction level in transport fare. 37.3% people are moderately satisfied on fare. 27.5% people are less satisfied on fare for transport use. 14.6% people are highly satisfied on transport on transport fare and few percentages of people are satisfied and dissatisfied on transport fare.
There is also some mixed satisfaction level in reliable on transport system. 32.2% people are moderately satisfied. 32.2% people are less satisfied. 14.6% people are highly satisfied and few percentages of people are satisfied and dissatisfied on transport system.



[Fig. 8] Destination analysis

From *[Fig. 8]* we can see that the destination status of the study area. Mainly this area is educated and well qualified. The people of this area are mainly job and business oriented. So, they have to go many important commercial place of Chittagong city. Agrabad, GEC are the main commercial place in Chittagong. Around 53 and 55 percentages of people go Agrabad and GEC for their job and business purpose. The study area people also go 2 No. Gate, A.K.Khan, Andorkilla, Bahaddarhat, Cholkbazar and Newmarket. But these places are not busy places as like as Aggrabd and GEC. From this above analysis, it can be said that the people of the study area are mainly oriented in commercial activity because of high education belong in the area people.
Table 1 shows the cross-table relation within income category and total trip. Lower class income people mainly generated few trips per day which are 0-5 times and 5-10 times. Percentages of those trips are 51.1% and 42.6 %. According to total trip 10-15 times trip conducted by lower income category people,

Table 01 Income category * Ownership Cross tabulation

Income \ Frequency		Total trip category				Total
		0-5	5-10	10-15	15-20	
<30000	% within income category	51.1%	**42.6%**	6.4%	.0%	100.0%
	% within Total trip category	20.9%	18.5%	33.3%	.0%	20.2%
30000-50000	% within income category	43.8%	**52.7%**	3.6%	.0%	100.0%
	% within Total trip category	**42.6%**	**54.6%**	**44.4%**	.0%	48.1%
50000-80000	% within income category	**50.0%**	41.2%	5.9%	2.9%	100.0%
	% within Total trip category	14.8%	13.0%	22.2%	**100.0%**	14.6%
>80000	% within income category	**62.5%**	37.5%	.0%	.0%	100.0%
	% within Total trip category	21.7%	13.9%	.0%	.0%	17.2%
Total	% within income category	**49.4%**	46.4%	3.9%	.4%	100.0%
	% within Total trip category	100.0%	100.0%	100.0%	100.0%	100.0%

which is 33.3%. Lower income class category people conduct their maximum trips 5-10 times which is 52.7%. According to total trip lower all trips are generated in similar percentage without 15-20 times trips. Higher middle class income people generated their maximum trip 0-5 times which is 50%. 5-10 times trip also conducted by this income people which are 41.2% According to total trip 15-20 trips generated by them and the percentage is maximum 100%. Higher income class people also conduct their maximum trip 0-5 times per day and percentage is 62.5%. According to total time there is no huge difference is seen. Overall all income class people conduct their maximum 0-5 times per day which 49.4%

Table 2 Correlation among Dependent and independent variable:

	Total trip	Total time	Income	Fare	Reliable	Comfort	Egress time	Access time	Family size
Total trip	1	.290	-.137	-.053	.082	-.073	.173	.067	.395
Total time		1	-.162	.055	.220	-.107	.159	.213	-.020
Income			1	-.249	-.268	-.084	-.028	-.074	-.045
Fare				1	.794	.661	.055	.075	-.057
Reliable					1	.600	.105	.135	-.023
Comfort						1	.115	-.056	-.037
Egress time							1	.592	-.096
Access time								1	-.074
Family size									1

Table 2 shows the Correlation status among dependent and independent variable. In this table, Total number of trip is the dependent variable and others are the independent variable. This table shows the correlation between total trips with others. The table shows that which independent variables are highly correlated with dependent variable. Family size is highly correlated with total trip, and then total time egress time and income are highly correlated with dependent variable that is total trip. Other independent variable also correlated with total trip but these variables are not highly correlated with the dependent variable. For that reason, these four independent variables are used for analysis.

Four Independent variable were selected. They are Family size, Total time, Egress time, Income

We select the independent variable based on 4 criteria. They are

"(1) Must be linearly related to the dependent variable. (2) Must be highly correlated with the dependent variable (3) Must not be highly correlated between themselves (4) Must lend themselves to relatively easy projection" (Elizabeth & Comiskey, 2015).

Table 03 Value of R^2

Regression Statistics	
Multiple R	0.84
R Square	0.71
Standard Error	2.22

From the Table 3 we can see the relationship of independent variable to the dependent variable. And the value of R defines the relationship weather it is strong or not. When R^2 value is close to 1 then the relation is stronger. And from the table we can see that the value of R^2 is .71 which is much reliable for making a regression equation.

We know the regression equation is, $Y= a + bX$

So, in this case the regression equation becomes

$Y= a + bX1 + cX2 + dX3 + eX4$

The above table shows the regression analysis among dependent variable and highly correlated independent variables. From the analysis and regression statistics an equation is established which name is regression equation. From this above equation four independent variables are coming which are X1, X2, X3, X4. These variables are mainly the value of family size, total time, income and egress time. Here a, b, c, d, e is the constant of the equation. Here Y is the dependent variable which is total trip. The value of Y changes when independent variables are changes.

For this study,

a = 1.065004, b = 0.714545, c = 0.025349, d = -0.000001, e = 0.170526. So, the equation becomes,

$Y= 1.065004+0.714545\ X1 + 0.025349X2 - 0.000001\ X3 + 0.170526X4$

If we the value of X1,2,3,4 then we will be able to know the total number of trip of that family. Where, X1= family size, X2= total time, X3= income, X4= egress time.

Now by putting the value to the equation total number of trip of a family can be found. And this model can predict around 84% of the trip that will be generated in the study area.

CONCLUSIONS

Trip generation model has significant effect on overall transport system. This model can be used for better and efficient transport system. This study tried to find a trip generation model by regression model. It has been found that due to increased development and increased population of this area trip generation has been increased. Based on some socio-economic and transport variable a trip generation model has been developed and different trip related analysis has been done. But all the factor was not possible to incorporate in the model which effect the trip generation, which is the main limitation of this study. So, further study is requiring for developing better trip generation model.

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ISSUES RELATED TO INTRODUCTION OF ELECTRIC VEHICLES IN BANGLADESH FOR SUSTAINABLE TRANSPORTATION DEVELOPMENT

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ABSTRACT
Globally, fossil fuel resource is decreasing and GHG emission is increasing. Countries are feeling the necessity of converting energy economy from a chemical to an electrical base. Recently, "Electric Vehicle" has been chosen by investors and governments of developed countries as a means of reducing GHG emissions and reliance on fossil fuel. This paper investigates the growth of vehicle ownership in Bangladesh and explores the issues for replacing conventional vehicles by EVs and undertakes benefit analysis for this replacement. In Bangladesh, natural gas reserve is depleting fast. On this backdrop, the projection analysis reveals that vehicle ownership is increasing rapidly. In 2041, number of private vehicles will be 25.9 million which will be a major concern for carbon emission. Further analysis reveals that fossil fuel consumption can be lessened through introduction of EVs. Electric powered "Easy-Bikes" have already been introduced here informally which are being operated through illegal charging connections mostly and these easy bikes do not maintain any standard road safety features with the resulting serious safety concern. Policy makers should give serious attention for introducing EVs in a planned way avoiding recent unsafe informal EV introduction for reaping the probable significant benefits as manifested by recent global initiatives.

Keywords: Electric Vehicles; Vehicle Ownership Growth; Replacing Conventional Vehicles; Carbon Emission; Easy Bikes.

INTRODUCTION

According to the air quality index prepared by the US Environmental Protection Agency, Dhaka is ranked fourth in a list of the most polluted cities in the world with an index value of 195 (*www.thedailystar.net/frontpage/dhaka-air-among-the-worst-1550239*). Every year huge amount of fuels is being imported from abroad. Natural gas reservation is currently a big concern of Bangladesh government. So, if the conventional fuel and CNG based vehicles keep increasing with the current rate and may be even at a much faster rate with the predicted accelerated economic growth, both environment and economy will suffer to a great extent. Bangladesh like other emerging economies is on the brink of experiencing an exponential automobile ownership growth with the predicted faster economic and personal income growth. The increased total countrywide vehicle fleet size and city based concentration of large automobile fleet will be a serious concern alarming level of urban air pollution if current conventional fossil fuel based fleet is continued. Following the recent global trend of introducing electric vehicles at an accelerated percent holds an opportunity for countries like Bangladesh to avoid looming alarming level of GHG emissions and urban air pollution. This paper discusses the issues of electric vehicles introduction in Bangladesh comparing the current easy bikes

and the predicted future scenarios of private electric vehicles; and is presented covering the following three aspects: (1) Growth rate of vehicle ownership; (2) Benefits of electric vehicles; (3) Current scenario of easy bikes operation.

METHODOLOGY

Firstly, vehicle ownership growth is predicted by Gompertz S curve analysis and then GHG emissions affecting the environment is assessed through estimation of GHG loadings from road transport sector. Savings in CNG is also calculated with the corresponding electric vehicle penetration.

Growth of motor vehicle population, especially through growth of passenger car ownership is identified as a complex socio-economic phenomenon in various researches (Wu, T. et al, 2014). Relationship between economic growth and vehicle ownership growth is done using Gompertz S curve analysis (M. Wang et al, 2006) considering its suitability in similar emerging economy situation. Gompertz curve analyses can successfully incorporates features of the vehicle market in explaining economic factors to estimate vehicle ownership. It is shown that the Gompertz function fits the historical data better than the Logistic or Richards functions (Huo and Wang, 2012). It is tested for several functional forms, and result shows that the Gompertz function is somewhat more flexible than the Logistic model, particularly in allowing different curvatures at low and high-income levels (Dargay and Gately, 1999). The Gompertz equation is stated below:

$$X_{gt} = a \times e^{-b \times e^{-c * g_t}} \quad (1)$$

where, X_{gt} = vehicle ownership (per 1000 people) in a country in the year t; a = represents the ultimate saturation level of vehicle ownership (vehicles per 1000 people) of country. And b, c are economic factors (two negative parameters) which determine the shape of the S curve and g_t is considered as the nominal GDP per capita.

The saturation level of vehicle ownership per 1,000 people is a key factor in estimating total vehicle population. On the basis of historic trends in HWV growth in developed countries, it has been established three scenarios where the third is a low-growth scenario, with a saturation level of 400 HWVs per 1,000 people (Wang, M. et al 2006). For Bangladesh, considering the quantity of land and low income trend of people, the saturation value, is taken 300 vehicles per 1000 people. The value of b has been set 5.5 after some trials as it gives more acceptable output for Bangladesh and the value, c is taken as 0.000156 as per the South Korean pattern due to the similarities in the quantity of land and economic growth pattern between South Korea and Bangladesh.

Analysis of Vehicle Ownership Growth in Bangladesh

The latest update from Bangladesh Road Transport Authority (BRTA) shows that in the first two months of the year 2017, 69,198 registered vehicles have been listed. In 2015, GDP per capita was USD 1210. Then in 2017-18, the GDP per capita is estimated USD 1754. In 2025 and 2041, the GDP per capita is predicted to be USD 4200 and USD 12000 respectively according to the government plan. So, in 2041, the vehicle ownership per 1000 people is predicted to be 129 using the Eq. (1). The predicted relationship between vehicle ownership and nominal GDP per capita is plotted below:

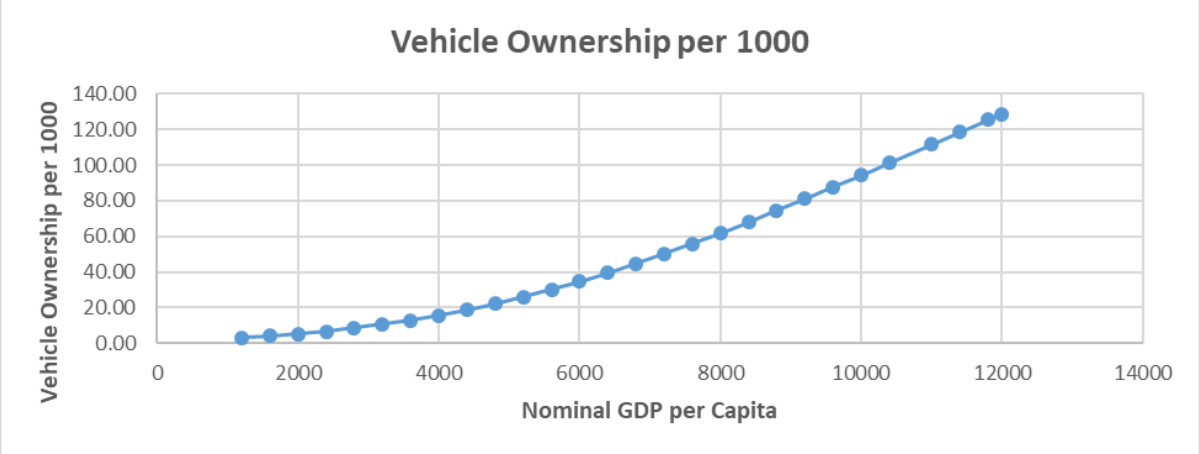

Fig 1. Estimated Vehicle Ownership Vs Nominal GDP per Capita (USD) in Bangladesh

From the above analysis, we can predict the total number of vehicles in a certain year. In 2016, the population was 159.3 million and GDP per capita was USD 1458.85. In 2021, the population is predicted 169.1 million and GDP per capita will be USD 2193.02. Similarly, in 2041, the predicted population will be 201.3 million and GDP per capita is predicted to be USD 12000. So, total number of vehicles will be 25.9 million. The total automobile fleet growth prediction is presented in figure 2 below.

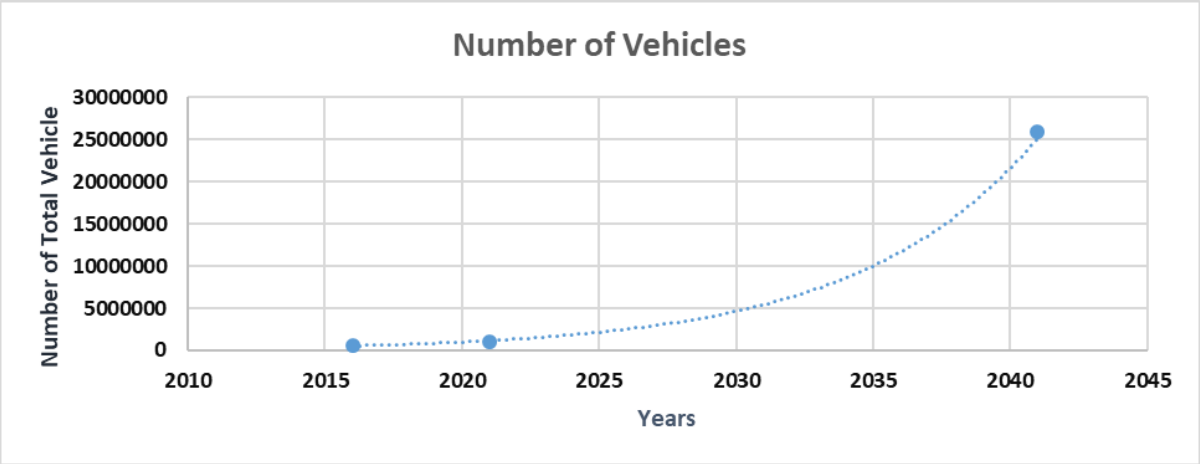

Fig 2. Estimated Total number of Vehicles Prediction up to 2041

So, this huge number of vehicles cannot be let run using fossil fuels/CNG. To save fossil fuels and natural gases, and to tackle the exponential growth of GHG emissions and urban air pollution at least a portion of this huge number of vehicles will have to be replaced with electric vehicles.

Penetration of Electric Vehicles and Electricity Consumption

EV penetration scenario in the upcoming years can be assumed following the trend shown in Table 1 and Table 2. It is assumed that every 5 years, EV penetration will be increased by 5% in case of slow penetration and 10% if the penetration rate is considered fast of total conventional vehicles. Average electricity consumption has been taken as 22 kWh/100 km (Energy Matters 2017). The electrical energy consumption for different level of EV penetration in future years is shown in the following Table 1 and Table 2.

Table 1. Slow penetration policy

Years	Total Vehicles (million)	% EV Penetration	Number of EVs (million)	Electricity Consumption (GWh/year)
2018	0.55	10	0.055	88.33
2025	2.5	15	0.37	594.22
2030	5	20	1	1606.00
2041	25.9	30	7.77	12478.62

Table 2. Fast penetration policy

Years	Total Vehicles (million)	% EV Penetration	Number of EVs (million)	Electricity Consumption (GWh/year)
2018	0.55	20	0.11	176.66
2025	2.5	30	0.75	1204.5
2030	5	40	2	3212
2041	25.9	60	15.54	24957.24

Benefits from Penetration of Electric Vehicles

Watt-hour per km capacity of vehicles is 250 Wh/km (Mokariya et al, 2015). Thus from analysis it has been found that monetary savings is possible and at the same time, CO_2 emission can be decreased because of the less fuel consumption which is presented below in Table 3 and Table 4.

Table 3. Benefits due to slow penetration

Years	% EV Penetration	Fuel Saving (million Barrel)	CO_2 emission reduced (million kg)	CNG Saving (m^3)
2018	10	0.176	61.56	28,044,500
2025	15	1.2	419.76	191,212,500
2030	20	3.2	1119.36	509,900,000
2041	30	24.69	8636.56	3,926,230,000

Table 4. Benefits due to fast penetration

Years	% EV Penetration	Fuel Saving (million Barrel)	CO_2 emission reduced (million kg)	CNG Saving (m^3)
2018	20	0.35	122.43	56,089,000
2025	30	2.4	839.52	382,425,000
2030	40	6.41	2,242.21	101,980,000
2041	60	49.83	17,430.53	7,923,846,000

Taxation Policy

Going through different countries' policies, it has been found that all the developed countries are emphasizing on converting to electric vehicles. In Norway, electric cars are exempt from the 25% VAT on car purchases. In China, exemptions from purchases and additional taxes is ranged between CNY 35,000 and CNY 60,000. In Japan, a new subsidy scheme introduced in 2016 grants gradually higher subsidies as the battery range increases, with the maximum subsidy set at JPY 850 000. The US federal government and a number of states offer financial incentives, including tax credits, for lowering the upfront costs of plug-in electric vehicles. The UK will offer up to 35% of the purchase price of an EV, or up to a maximum of £4,500. In Canada, the Government of Ontario offers a subsidy of up to $14,000. Table 5 shows the current taxation policy for regular and hybrid cars in Bangladesh. The less the tax will be imposed on, the more the people will be encouraged to buy electric vehicles.

Table 5: Supplementary Duty on cars in Bangladesh

Car CC	Supplementary Duty on Regular Car	Supplementary Duty on Hybrid Car
1500	45%	30%
1501-2000	100%	60%
2001-2700	200%	150%

Informal EV Growth in Bangladesh

Easy bikes are 3-wheeler electricity charging based para transit. Usually in Bangladesh, they are charged using electricity from the national grid. There are about 1,000,000 easy bikes over the country which transport 2.5 crore passengers every day in both townships and rural areas and have created job for 30 lakh people; and the growth is increasing every year rapidly. (*https://www.thedailystar.net/business/easy-bikes-outgrowing-limitations-1469200*).

About 55% of the population have access to electricity from the national grid. Electricity production from solar energy is free from fossil fuel use and thus greenhouse gases (GHGs) are not emitted. The cost of charging is found to be Tk. 14.08/km for a charging time of 6 hours and if the bikes are charged using grid electricity, the cost of solar charging is found to be Tk. 7.44/km at an electricity cost of Tk. 7.6/kWh; besides, if the electricity cost passes Tk. 17/kWh, easy bike charging from solar energy is cost competitive compared to charging from conventional grid electricity (Rahman, MM. et al, 2016).

Energy Consumption in kWh by 3 types of Easy Bikes

There are 3 types of easy bikes considered here. They are vehicle-1 which is relatively old, vehicle-2 which is new and vehicle-3 which is medium aged. The average consumption by these easy bikes are 10.92, 8.15 and 9.79 kWh/day respectively (Rian, MZ and Rahman, ANM, 2014).

Related Government Policy

It seems Bangladesh Government has no clear-cut policy for this informal EV population till now even though their number has surpassed one million by unauthenticated estimates. Due to this in-decision from government agencies their number are mushrooming enjoying the benefits of zero tariff on vehicle sales, registration, road tax and arguably free charging from illegal electricity connections.

Environmental Issues by Easy Bikes

The grid electricity emission factor for Bangladesh is 0.637 kg-CO2eq/kWh (Brander, M et al, 2011). Based on the average distance travelled by an easy bike, the GHG mitigation potential is found to be 1860.5 kg-CO_2/easy bike in year (Rahman, MM. et al, 2016).

Safety Concern

It is argued that about 30% of road accident actualities are due to these informal EVs as they run alongside standard MVs on highways. All these informal EVs lack in safety features like brakes, speed adjustment, turning ability, and substandard communication system.

In Bangladesh, there are various structural issues with these battery-powered vehicles, primarily because they are assembled locally. This is done without caring for the centre of gravity, its weight to passenger ratio, construction material and certification by any third party for its safety and proper speed. Sometimes they also put high-powered batteries in these rickshaws, which can take them to a speed of 30 kmph or more which is very dangerous for pedestrians. These vehicles, meant to seat only four, are seen plying with seven to eight passengers. To earn more, a driver overloads the vehicle. This makes the vehicle lose its balance and can lead to accidents.

RESULTS AND DISCUSSIONS

From the Table 3 & 4, it is clear that monetary savings can be possible if electric vehicles are penetrated gradually. Within 2050, it will be a great achievement if 30% EV penetration is made possible. If formal electric cars are introduced here in Bangladesh with a penetration of 30% around the year 2041, 3.9 billion cubic meters of CNG can be saved and if the penetration is 60%, the saving in CNG will be around 7.9 billion cubic meters. 24.69 million barrels of fuel can be saved with 30% penetration respectively around 2041. This saving can be almost 50 million barrels if the penetration is 60%. This also denotes that, less fuel consumption by the vehicles which will ensure better environment and less pollution. 8,600 million kg of CO_2 emission can be reduced if 30% electric vehicles are penetrated and emission of 17,400 million kg of CO_2 can be reduced if 60% electric vehicles are penetrated around the year 2041. So, it is clear, for more percentage of EV penetration, the economic scenario will be more beneficial. At the same time, taking advantage of introducing electric vehicles, easy bikes will be operated at roads. If these easy bikes are operated with connection from national grid, owners of these bikes will try to charge the bikes with illegal connection which will be a bad practice for our electricity sector. So, solar charging station should be constructed to prevent this problem.

CONCLUSIONS

Clearly, vehicle ownership grows exponentially with country's economic development and rise in personal income level. But it will not be sustainable if people keep buying conventional vehicles in terms of GHG emissions and urban air pollution. Again, taking the advantage of introducing EVs, informal illegal para transits (easy bikes) can be operated. In terms of benefit analysis, the sustainable solution seems converting to electric car. It is high time Government started planning to save CNG because Bangladesh will soon deplete its natural gas reserves and has already started importing gas. Alternatively, with huge saving in fossil fuel consumption, CO_2 emission will be decreased to a great extent, which is very important to make the transportation sector eco-friendly. To encourage people for

converting to electric vehicles, government should ease the taxation policy following the policies of developed countries. On the other hand, the uncontrolled growth of informal EVs (Easy Bikes) should be controlled as these are using illegal connections for getting charged and are responsible for road accidents. But they can be operated with proper license and permission. Recently, a solar charging station has been inaugurated in Keraniganj, Dhaka for the purpose of installation of 21.0 kWp for 20 nos. of Easy Bike or equivalent vehicles' battery charging. Such solar charging stations can stop illegal use of electricity for charging the easy bikes. Apart from this, proper government policies must be implemented for these easy bikes; otherwise, charging and safety issues will turn a major headache for the authority in near future. About formal electric vehicles, all the developed countries have already planned to introduce electric vehicles replacing the conventional vehicles. So, for a greater purpose, introduction of formal electric vehicles will be a sustainable pathway for Bangladesh transportation sector.

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ASSESSMENT OF TRAFFIC CONGESTION AT NOTUN RASTA TO GOLLAMARI MID-BLOCK, KHULNA

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ABSTRACT
Traffic congestion is considered as one of the major urban transportation problems all over the world. In most cases, congestion occurs when the volume of traffic running on a particular road exceeds its capacity. It causes delay and loss of working hours. In a developing country like Bangladesh, traffic congestion is a common scenario. Like the other major urban cities of Bangladesh, Khulna is also suffering from this problem. To assess this congestion, Notun Rasta to Gollamari Mid-block is selected as the study corridor for this study. The data collection for the assessment is performed through different traffic surveys and speed surveys on both weekdays and weekends. The whole study area is divided into five segments. The speed performance index has been selected as the evaluation indicator of road state and the traffic state has been divided into four categories: heavy congestion, mild congestion, smooth and very smooth. Based on the traffic state classification standards, road network congestion index has been computed and this index is used to measure the congestion degree of road segments. Also, the level of service (LOS) is measured to assess traffic congestion. The smaller value of speed performance index and the larger value of the level of service (LOS) indicate the poor condition of the road. From the speed performance index analysis it is found that Khulna Medical College to Shonadanga Bus Terminal portion has scored 0.025 and 0.322 on weekdays and weekends respectively. It has the lowest score among the five sections. Again, Khulna Medical College to Shonadanga Bus Terminal portion has scored D in the level of service (LOS) analysis. Hence, it is the most congested part of the study area.

Keywords: Traffic, Congestion, Assessment, Segment Congestion Index, Speed Performance Index, LOS.

INTRODUCTION
Now a days traffic congestion is one of the major urban transportation problems. Traffic congestion has no globally accepted definition (Downs, 2004). Scientists have developed different measures to identify the magnitude of traffic congestion (Aftabuzzaman, 2007).
When the demand for travel exceeds the capacity of an existing road system, traffic congestion occurs (Rosenbloom, 1978). The delay of travel time delay or delay light or obstruction of free-flow travel condition, is called traffic congestion (Lomax et al., 1997). Congestion can be defined as the situation when traffic is moving at speeds below the designed capacity of a roadway (Downs, 2004). By analysing all these experts' definition it can be said that traffic congestion happens when the capacity of a road is less than the demand of the road. Due to traffic congestion, more travel time is required than free-flow traffic. It causes delay and loss of money.
Various phenomena work behind traffic congestion. Among them urbanization, vehicle ownership etc. are the most common. Due to urbanization, people move to cities from outside. As a result, they increase pressure on the movement of traffic. Rao et al., (2012) highlighted different micro and macro factors

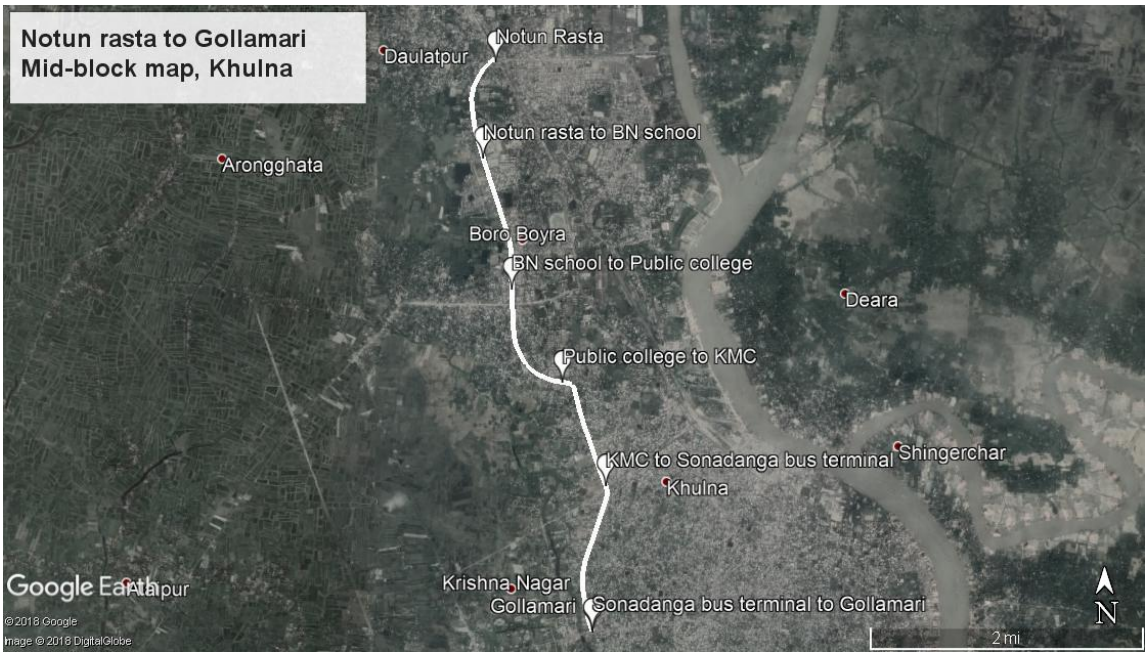
causing traffic congestion. People's movement at a single moment is considered as a micro-level factor. Infrastructure construction, land use, economic growth etc. are macro level factors. Smaller capacity of the road than traffic volume, maintenance of the road, accidents are also responsible for traffic congestion (Boamah, 2010).

In a developing country like Bangladesh, traffic congestion is a common scenario. Dhaka, Chittagong, Khulna, and Rajshahi are the major urban cities suffering from traffic congestion. In Dhaka due to traffic congestion 3.2 million working hours are lost per day (Daily Star, 2017). USD 3 billion is costed a year and over 8 million work hours are lost by cities daily (Osman, 2010). As a 3rd largest city, Khulna is also suffering from traffic congestion problem. It is the 2nd port entry of Bangladesh. The capacity of the existing roads of Khulna city is low for the number of vehicles (The Independent, 2015). As a result, people can hardly reach their destination at their scheduled time.

Scharnk et al., (2005) identified the travel rate index (TRI) which compares peak period travel condition to free flow travel condition. Lindley, (1987) developed the congestion severity index (CSI) to measure freeway congestion in terms of total delay of VMT. VMT means vehicle miles of travel. After that, principal arterial street delay was added to CSI for further modification by Turner, (1992). Lomax, (1990) invented a corridor mobility index. It is calculated for measuring congestion at freeways in urban areas. Cottrell (1991) developed the lane mile duration index (LMDI).

In this study, various congestion indices and level of service (LOS) are used to identify the traffic congestion level at study area of Khulna city.

STUDY AREA



[Fig. 1]. Study Area (Source: Google Earth, 2018)

Khulna is the 3rd largest city of Bangladesh. It is a port and industrial zone. The total area of Khulna City Corporation is 40.79 square kilometer and the population is 770498 in 2011 (BBS, 2011). This paper divides the road Notun Rasta to Gollamari into five segments. The brief description of these roads is given below:

Table 1: Dimensions of study area (Source: Google Earth, 2018)

Name of the segment	Length (km)	Width (m)	Existence of median
1. Notun Rasta to Khulna BN School and College	1.67	15.07	Yes
2. BN School and College to Khulna Public College	1.72	14.81	Yes
3. Khulna Public College to Khulna Medical College	1.44	15.09	Yes
4. Khulna Medical College to Shonadanga Bus Terminal	1.37	15.26	Yes
5. Shonadanga Bus Terminal to Gollamari	1.60	16.60	Yes

METHODOLOGY

Maximum Speed:
Maximum speed or spot speed of various vehicles like auto rickshaw, private car, bus, motorcycle etc. are measured at four times in two days. One at peak hour (9:00-10:00) and other at off-peak hour (15:00-16:00) in each day. To calculate spot speed, a suitable distance of 100 meters at every link is selected where the vehicle has a free flow. The speed of a particular vehicle was measured by how much time the vehicle takes to cross the certain distance. This data was taken five times for each interval at every segment and the average speed was calculated from the data.

Travel Speed:
Moving observer method was used to collect data for journey speed and delay study. The survey was conducted on a weekday at 3 different periods (2 peak periods and 1 off-peak period). Peak hours were 8:30-9:00AM, 5:30-6:00PM and off-peak hours were 3:00-3:30PM. For the study, a car is used as a test vehicle. At the beginning of the survey, the journey is started from the two terminal points of the study route. The tasks of the four observers in each direction were:
(1) One observer recorded the total journey time, section wise journey time, delay time, delay type and location of delay.
(2) The second observer counted the number of vehicles overtaking the test vehicle.
(3) The third observer counted the number of vehicles overtaken by the test car for all the section.
(4) The fourth observer counted the vehicles coming from the opposite direction for each section.

Speed performance index
For measuring road traffic state vehicle speed is an important indicator. Vehicle speed data are collected by field survey. Based on those data, the speed performance index, expressed in Eq. (1), is calculated. The index value reflects the ratio between vehicle speed and the maximum permissible speed. This study uses the speed performance index to measure the road traffic state. It adopts three threshold values (25, 50, and 75) as the classification criteria of urban road traffic state, as shown in Table 2. Based on this evaluation measure, the road segment congestion index and the road network congestion index are identified to analyse traffic congestion of urban road network. (He et al., 2016)

$$Rv = \frac{v}{Vmax} \qquad (1)$$

where,
Rv denotes the speed performance index;
v denotes the average travel speed, km/h;
Vmax denotes the maximum permissible road speed, km/h.

Table 2: The evaluation criteria of Speed Performance Index for the study corridor

Speed Performance Index	Traffic State Level	Description of Traffic State
[0,25]	Heavy congestion	The average speed is low, road traffic state is poor.
[25,50]	Mild congestion	The average speed is lower, road traffic state is bit weak
[50,75]	Smooth	The average speed is higher, road traffic state is better.
[75,100]	Very smooth	The average speed is high, road traffic state is good.

Road segment congestion index
In order to measure the degree of road segment congestion, road segment congestion index is calculated. The average duration of road segment congestion state and the duration of the non-congestion state in the observation period is used to define this index, expressed in Eq. (2) and Eq. (3).The non-congestion state includes two traffic states: smooth and very smooth. The value of the road segment congestion index *Ri* ranges between 0 and 1. The smaller the value of *Ri* indicates the more congestion of road segment. (He et al., 2016)

$$R_i = \frac{R_v}{100} \times R_{NC} \qquad (2)$$

$$R_{NC} = \frac{t_{NC}}{T_t} \qquad (3)$$

where,
Ri denotes the road segment congestion index;
Rv denotes the average speed performance index;
RNC denotes the proportion of non-congestion state;
tNC denotes the duration of the non-congestion state, minute;
Tt denotes the length of the observation period, minute.

Level of service (LOS)

Level of service (LOS) gives a qualitative measure of traffic service quality. There are six categories of LOS ranging from A to F, designed in a descending order. The aim of LOS is to categorize traffic flow and identify the quality level of a specific road. Interrupted flow means obstruction in free flow traffic due to some reason. This can be shown in both signalized and unsignalized intersections. For signalized intersections levels of service (LOS) are defined based on the average amount of delay.
In this study, the delay time is recorded by moving observer survey for each section of the segment. Then the data is compared with the standard delays of LOS to find out the LOS for that section.

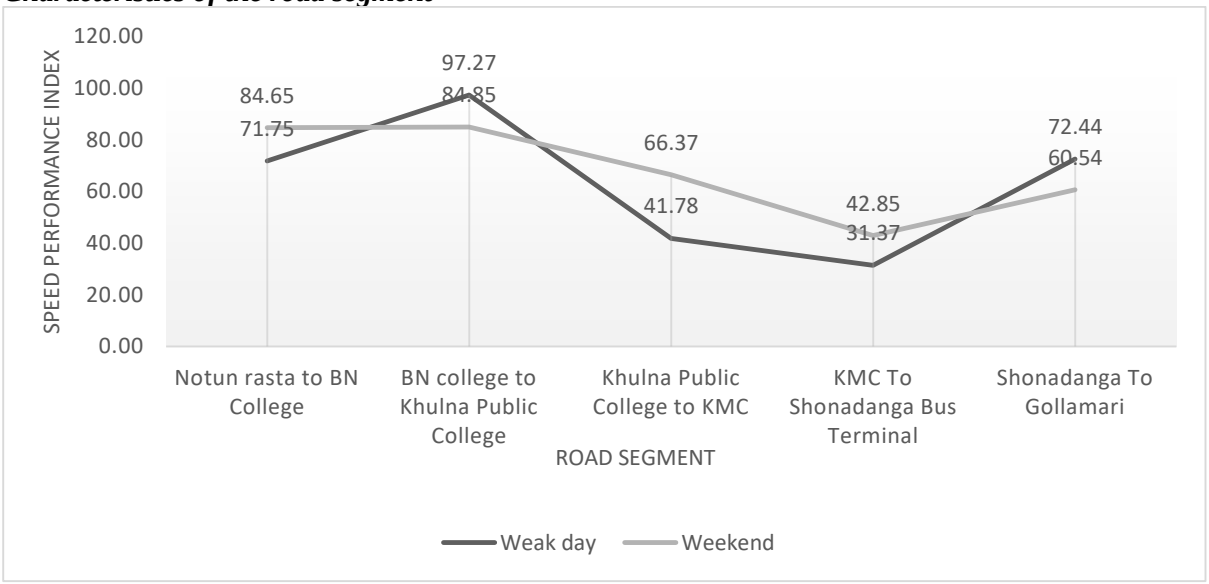
Table 2: Level of Service according to the delay time

Delay Time (sec)	Level of Service (LOS)	Description
<= 10	A	Free flow of traffic
11-20	B	Stable flow but different users are present
21-35	C	Stable flow but different users affect the speed
36-55	D	Stable flow with high density
56-80	E	Flow is near capacity level
>80	F	Breakdown of flow

(Aftabuzzaman, 2007)

RESULTS AND DISCUSSIONS:

Characteristics of the road segment



[Fig. 2]. Road segment wise speed performance index

[Fig. 2] illustrates the speed performance indices on weekdays and weekends against the segments considered. From the analysis, it is found that the speed performance index of Notun Rasta to BN College road segment is 71.75 on weekday and 84.65 on weekend. According to the evaluation criteria of table 2, they range between 50-75 and 75-100 which indicate smooth and very smooth traffic state respectively. The average speed is higher in this segment and road traffic state is good. After that, the BN College to Khulna Public College segment adopts the speed performance index as 97.27 on weekday

and 84.85 on weekend. Both of them portray very smooth traffic state as they range between 75-100. This is the least congested road segment of the study area.
Again, the speed performance index of Khulna Public College to KMC road segment is 41.78 on weekday and 66.37 on weekend. They range between 25-50 and 50-75 which indicate mild congestion and smooth traffic state respectively. The average speed is lower and road traffic state is weak in this segment. Next, the KMC to Sonadanga Bus Terminal segment adopts the speed performance index as 31.37 on weekday and 42.85 on weekend. Both of them portray mild congestion of traffic state as they range between 25-50. This is the most congested road segment of the study area. Finally, the speed performance index of Sonadanga Bus Terminal to Gollamari segment is 72.44 on weekday and 60.54 on weekend. Both of them portray smooth traffic state as they range between 50-75. The average speed is high and traffic state is good in this segment both in weekday and weekend.

Segment Congestion Assessment

Table 3: Road Segment Congestion Index for the individual road segment

Road Segment	**Road Congestion Index, R**	
	Week day	Weekend
Notun rasta to BN College	0.489	0.347
BN college to Khulna Public College	0.353	0.251
Khulna Public College to KMC	0.530	0.376
KMC To Shonadanga Bus Terminal	0.025	0.322
Shonadanga To Gollamari	0.534	0.576

Table 3 exhibits the road congestion index for various segments of the study route. From the analysis, it is found that the most congested segment of the study area is Khulna Medical College to Shonadanga Bus Terminal on weekdays as here the index value is 0.025. During weekend days, the index value at BN College to Khulna Public College segment is 0.251. So it is the most congested segment on weekend. Sonadanga to Gollamari road segment is least congested both on weekdays and weekend, as here the index value is 0.530 and 0.576 on weekdays and weekend respectively. Other segments are also partially congested during weekdays and weekend.

Level of service (LOS)

Table 4: Segment wise Level of Service (LOS)

Name of the road section	**Delay time (sec)**	**LOS**
Notun rasta to BN College	23	C
BN college to Public College	29	C
Public College to Khulna Medical College	10	A
Khulna Medical College to Sonadanga	36	D
Sonadanga to Gollamari	7	A

From the analysis, it is quite clear that Khulna Medical College (KMC) to Sonadanga bus stand segments portrays the worst traffic service condition. It has the highest delay time (36 seconds) amongst all the other routes. The level of service of this segment is D which refers unstable flow with high density. Both segments from Notun Rasta to BN College and BN College to Public College possess a level of service C. It shows the flow is below the speed limit. Drivers need more consciousness to drive and as a result, they feel uneasiness. Public college to Khulna Medical College and Sonadanga to Gollamari have a level of service A. Between them Sonadanga to Gollamari has the least delay time which is 7 seconds. Public college to Khulna Medical College possess the second lowest delay time which is 10 seconds. In both of the segments the operating condition is the best and traffic moves freely. In the Notun Rasta to BN College segment and BN College to Public College segment delay times are 23 seconds and 29 seconds respectively. In both of the segment level of service is C. Here the traffic flow is stable flow but different users affect the speed.

CONCLUSIONS

Traffic congestion is considered as one of the major urban transportation problems all over the world. It causes delay and loss of working hours. In a developing country like Bangladesh, traffic congestion is a common scenario. The speed performance index can be used as the road network state evaluation indicator and the traffic state can be divided into four categories: heavy congestion, mild congestion, smooth and very smooth to identify the severity of traffic congestion. Based on the traffic state classification standards, road network congestion index can be proposed and this index can be used to measure the degree of congestion of the road segment. Also, the level of service (LOS) can also be measured to assess traffic congestion.

The analysis of Notun Rasta to Gollamari road block provides an accurate and clear scenario of network traffic operation status in Khulna city. This analysis provides important information for future traffic management. According to road network congestion assessment and road segment congestion assessment, the most congested part is Khulna Medical College to Shonadanga Bus Terminal portion. According to the level of service (LOS) analysis, the most congested part is also Khulna Medical College to Shonadanga Bus Terminal. So, it can be concluded by saying that the section Khulna Medical College to Sonadanga Bus terminal is found to be the most congested road segment of the study corridor.

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BICYCLING AS A MODE OF TRANSPORT IN DHAKA CITY – STATUS AND PROSPECTS

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ABSTRACT
This study aims to find out the current status and prospects of using a bicycle as a mode for commuting within Dhaka city. Bicycling is a very sustainable mode of transport but unfortunately is used very less by the commuters of Dhaka. There has been a lot of factors affecting the choice of bicycle to commute. This study was aimed to find out what factors could motivate the commuters of Dhaka to use a bicycle as a mode of transport. For determining the motivators, a survey was administered among the commuters of Dhaka city in which the respondents were asked to answer how certain factors would affect their choice to use a bicycle to commute. A Likert scale was used in the survey and the responses were analysed, from which the top motivators were found. The Motivators were then grouped together using exploratory factor analysis to support possible policymaking. Four factors were extracted using the method. The factors were named Additional Perks, General benefits, Personal Benefits, and Infrastructural benefits

Keywords: Bicycling; Dhaka; Motivators; Principal Axis factoring.

INTRODUCTION

The population of Dhaka has been increasing exponentially which has led the city to be tagged as one of the most densely populated cities in the world with a density of 1100 people per square kilometer (Chowdhury et al., 2015). The population of Dhaka is estimated to increase up to 35 million people by 2035 from the current 20 million people (BSS, 2017). The number of motorized cars has increased from 28,764 registered vehicles in 2000 to 1,72,484 in 2011 while on average about 7,000 casualties are reported per year (Ahmed et al., 2014). With increase in population, transportation problems like traffic jams, noise pollution, accidents and other environmental and subjective problems has become a major problem for the city dwellers. For solving these transportation problems bicycle poses to be a sustainable mode of transport (Verma, et al., 2016). Bicycling as a daily travel option also helps in individual as well as environmental health with the cost being nearly negligible (Cavill & Davis, 2007). Bicycling offers an affordable transportation system, less congestion, less pollution and can be used for distances that are long to walk for city dwellers. Despite all these advantages only about one percent of the total dweller in Dhaka city uses bicycle as a mode to commute (Hoque & Alam, 2002).

The deterrents of bicycling include long trip distances of commuters, harsh weather conditions, difficulty to use it in nonutility trips, infrastructure unavailability, extreme traffic conditions, and lack of health and environment consciousness among people (Verma et al. 2016). In the Bangladeshi context, very few researches have been done to understand what acts as motivator or deterrent to bicycling for the people in Dhaka. Bicycle as a medium hasn't been a subject of serious study for the researchers in Dhaka. This study aims to find out the possible motivators that could motivate the commuters of Dhaka to bicycle.

LITERATURE REVIEW

Pucher (Pucher, 1997) stated that the main difference in the bicycling mode share between North American cities and the European cities was because of the public policy. Few bike lanes, unmaintained traffic lanes and no respect behaviour for bicyclists were one of the major reasons for not using bicycles (Pucher, 1997) which is pretty similar to the reasons said by the people who are willing to bicycle in Dhaka. Dill and Voros (Dill & Voros, 2006) identified roads having too much traffic and absence of bicycling lane as two most important barriers for people to bicycle in the Portland region. Quaium (Quaium, 2013) conducted a poll among cyclists of Dhaka and found out that lack of safe parking places, bicycle theft and safety on roads are the three main problems faced by the cyclists in Dhaka city. Dey et al (Dey et al., 2014) conducted a survey among the non-cyclists of Dhaka city and found out six main reasons acting as deterrents for non-cyclists. They were safety, security, parking, long distance travel, social acceptance and discomfort.

Pucher et al (Pucher et al., 2010) reviewed the bicycling policies of different countries and stated that programmatic interventions aim to increase bicycling through promotional activities, media campaigns, educational events, and other means. Bandhan Bandhu Majumdar and Sudeshna Mitra (Majumdar & Mitra, 2015) conducted a study in the Kharagpur city and found out that Physical fitness, Environmental awareness, Travel reliability, Travel flexibility, Psychological safety, Affordability and Desire for pollution free road were the main motivators to bicycling in Kharagpur city of India. Heinen et al (Heinen et al., 2011) conducted a survey among the residents of different cities and conducted a factor analysis concluding that awareness, direct trip-based benefits and safety were the 3 most important motivators to cycling. Verma et al (Verma et al., 2016) conducted a survey among the residents of Bangalore and concluded that stoppage of bicycle during a commuter's childhood was the most important deterrent for commuters to stop using vehicle. They also concluded that cycling lanes and signals at intersections would be strong motivators for people to cycle. Winters et al (Winters, Davidson, Kao, & Teschke, 2011) conducted a survey among 1402 residents of metro Vancouver with 73 possible motivators and deterrents of cycling and grouped them into 15 factors. The most important factors were safety; ease of cycling, weather conditions, route conditions, and interactions with motor vehicles. They also concluded that location and design of bicycle route were the most important factors.

METHODOLOGY

An extensive literature review was done first to identify a suitable analysis method to conduct the research. Based on the literatures of (Verma, Rahul, Reddy, & Verma, 2016) and (Mahmud, Gope, & Chowdhury, 2012) it was decided that exploratory factor analysis was to be used for this research. The possible motivators and deterrents were then identified. Various literature were reviewed and possible motivators were identified.

Next a two sectioned questionnaire was designed and administered from among various potential respondents throughout Dhaka city. The first section of the questionnaire consisted of the socio-economic profile of the respondents while the second part was a five point Likert scale questionnaire of 17 possible motivators and deterrents. The questionnaire was administered in two ways – Firstly a pen and paper survey was conducted throughout Dhaka city among various age group of people. Secondly a questionnaire in the format of Google form was sent out electronically to various potential respondents. The responses were then compiled and sorted. Finally 426 responses were deemed accurate. The likert scale was then given values in the following manner - The rating of "Will strongly motivate me" was given a score of +2, the rating of "Will motivate me" was given a score of +1, the rating of "Neutral" was given a score of 0, the rating of "Less likely to motivate" was given a score of -1 and the rating of "Doesn't matter" was given a score of -2. IBM SPSS Statistics 20 was then used for conducting exploratory factor analysis.

EXPLORATORY FACTOR ANALYSIS

The exploratory factor analysis was done on a five-step exploratory factor analysis protocol developed by Williams et al (Williams, Onsman, & Brown, 2010).

Step 1: Checking the suitability of data for analysis

The suitability of data was determined using the Kaiser-Meyer-Olkin (KMO) measure of Sampling Adequacy/Bartlett's Test of Sphericity. KMO values between 0.8 and 1 indicate the sampling is adequate (Cerny & Kaiser, 1977). Our KMO value of 0.833 indicated sampling was adequate.

Step 2: Selection of factor extraction method

William et al (2010) mentioned that for behavioural responses where no priory theory exists, Principal Component Analysis or Principal Factor Analysis is generally used. Based on this, the factors were extracted using the method of Principal Factor Analysis.

Step 3: Selecting Criteria for Factor extraction

There are many criteria for selecting criteria for factor extraction-: Kaiser's criteria (eigenvalue > 1 rule), the Scree test, the cumulative percent of variance extracted, and parallel analysis (Williams, Onsman, & Brown3, 2010). In this research the Kaiser's criteria that is eigenvalue less than 1 rule was used. Base on this rule 4 factors were extracted.

Step 4: Selection of Rotation Method

Rotation is used to maximize high item loadings and to minimize low item loadings. This produces a solution which is more interpretable. Oblique rotation are used in research involving human behaviours. This paper uses the Oblique rotation for factor extraction.

Step 5: Interpretation and labelling of factors

After extracting the factors, the factors are labelled appropriately for easy interpretation. Variables with higher loading are considered more important than others.

RESULTS AND ANALYSIS

The Socio-economic characteristics of the respondents are shown below-:

Table 1: Socioeconomic profile of respondents

Gender	
Male	62.68%
Female	37.32%
Age	
Less than 18	2.35%
18-30	72.3%
30-45	24.18%
45 or more	1.17%
Bicycle Ownership	
Own a Bicycle	23.94%
Doesn't own a Bicycle	76.06%
Knows How to Ride a Bicycle	
Yes	84.98%
No	15.02%
Mode of Transport Currently Used	
Bicycle	3.52%
Others	96.48%

Based on the responses of the respondents, the mean was found for each motivator for all the respondents. The factor that "Cycling will protect the environment" was found to be the major motivator with a mean score of +1.63. This was followed by the factor that "Cycling would keep the respondent physically fit" which had a mean score of +1.62. The third most important motivator was that the respondent would cycle if the cycling route had less traffic and air pollution with a mean score of +1.5.

Results of Exploratory Factor Analysis

An Exploratory Factor Analysis was done in IBM SPSS Statistics 20 for the recorded response. The Principal Axis factoring method was used for factor extraction while oblimin rotation was used as Rotation technique.

Based on eigenvalues greater than one, four factors were extracted. The factors were named Additional Perks, General benefits, Personal Benefits, Infrastructural benefits. The eigenvalues were 6.504, 1.838, 1.281 and 1.005 respectively. All loading values below 0.3 were not taken into consideration. Additional Perks had the greatest eigenvalue indicating that commuters will be more motivated towards cycling if they are given perks like separate lane, free parking etc. that are not available in other modes of transport. This factor clearly indicates the willingness of commuters to use bicycle. The second factor "General benefits" had an eigenvalue of 1.838. This indicates that people are willing to cycle as it provides environmental benefits as well as other benefits such as less accidents and less traffic prone areas. The third factor extracted was "Personal Benefits" which had an eigenvalue of 1.281. These are the benefits a cyclist would get if he has the facilities to cycle. The last factor extracted was the Infrastructural benefits which are two very important factors for design and should be taken into account while building cycling friendly roads.

Table 2: Exploratory factor analysis results
Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.

Factors (Eigenvalues)	Variables	Loading Value
ADDITIONAL PERKS (6.504)		
	The cycling lane will protect cyclists from rain	.807
	The cycling route will have very good pavement surface	.767
	There are cloth changing facilities at bicycle parking	.710
	There are separate parking spaces for bicycle	.652
	There is a separate lane for bicycle	.547
	The bicycling route has less intersections	.497
	The parking for bicycle will be free	.393
GENERAL BENEFITS (1.838)		
	The cycling route will have less traffic	.682
	Cycling will keep me physically fit	.629
	Cycling will help to protect Environment	.544
	The cycling route is less accident prone	.366
PERSONAL BENEFITS (1.281)		
	Cycling will reduce my travel cost	.786
	Cycling will reduce my travel time	.582
	I will be able to travel flexibly using bicycle	.473
	Bicycle is psychologically safer than other modes	.332
INFRASTRUCTURAL BENEFITS (1.005)		
	The cycling lane is smooth	.727
	The cycling lane is wide	.658

DISCUSSIONS

This paper tried to find motivators that could motivate the commuters of Dhaka to bicycle. The paper identified 17 possible motivators and asked respondents to respond how likely he factor could motivate the respondents to bicycling. It should be noted that most of the commuter's (85%) in Dhaka knew how to ride a bicycle and have rode a bicycle but no longer ride a bicycle. This might be because of the weak infrastructural facilities or lack of people around bicycling. One of the most important way to motivate people to bicycling is to motivate people to keep on bicycling even as they grow older.

From the exploratory factor analysis it can be seen that giving perks to bicyclists could motivate people more to bicycle. Options like free parking to bicyclists, separate lanes etc. could motivate commuters to bicycle.
The second most important factor that could motivate people to cycling was General benefits. This included factors like environmental awareness, physical fitness, Traffic & air pollution free roads, and accident free routes. If policies are made to motivate people cycling, the number of commuters using bicycle in Dhaka would increase.
The third most important factor was Personal benefits. This included travel cost, travel time, travel flexibility and psychologically safer roads. If cycling lanes could be made efficient to reduce travel time and make them psychologically safe, a lot of commuters would be motivated to cycling.
The last factor that was extracted was Road conditions. This factor consisted of speed barrier free roads and wide lane. If the cycling lanes are made wide enough and without any interruptions, People would be motivated to bicycling. Policies should be made in such a manner that while constructing roads, road width and interruption free road conditions be enforced.

CONCLUSIONS

This paper tried to identify the different motivators that will impact the choice of commuters to use bicycling as mode of transport for commuting in Dhaka city. Four different motivators were identified from the research. The motivators are Additional Perks, General Benefits, Personal Benefits and Infrastructural Benefits. The following conclusions can be made -:

- Although 85% of the respondents learnt to bicycle in their younger days, only 3.6% of these respondents use bicycle as a mode to commute at present. Further research needs to identify the reason for this decline.
- Providing Additional Perks to Bicyclists will be a major factor to motivate non-bicyclists to cycle. These perks include better road pavements, separate parking facilities, free parking and many more. These factors should be considered the most in future urban planning.
- It was identified that general benefits and personal benefits itself will act as motivators for commuters to bicycle. Running well organised campaigns and promoting bicycling itself might act as motivator to commuters.
- A better Infrastructure facility will also motivate the commuters of Dhaka. A separate bicycling lane which is smooth as well as wide will highly motivate the commuters of Dhaka to bicycle. Urban planners, engineers and policy makers need to change their designs and policies accordingly to promote bicycling.

Dhaka has a very less mode share for bicycles unlike countries like Netherlands, Germany and Canada. The transportation system of Dhaka city is termed as worst in few cases. Integrating bicycling as a mode of transport within the current transportation system might be of great impact. Very few studies were found regarding bicycling as a mode of transport in Dhaka city. Further research on bicycling is needed to unearth potential of bicycling in Dhaka city.

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MOISTURE RESISTANT FLEXIBLE PAVEMENT USING PORTLAND CEMENT AS ANTI-STRIPPING ADDITIVE

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ABSTRACT
The bitumen coated aggregates and mineral fillers cannot preserve the rigidity of highways since water enters the aggregates and causes cracks to occur due to developed tension. Using cement as a substitute for mineral filler of granular aggregates reduces the percentage of air void rendering a resistivity to crack and damage due to the hardness achieved from the reaction of cement with water. This paper aims at investigating the effect of cement on durability and water susceptibility of flexible pavements of Bangladesh through performing tests for indirect tensile strength and Marshall's stability on both dry and water treated samples. e. Laboratory Marshall samples are prepared for testing using presently used aggregate gradation for national highways. Comparison of results for two situations of dry and moisture treated samples reveals significant improvements in tensile capacity with the lowering of the percentage of air void and increase of density. Implementation of cement added flexible pavements in Bangladesh can result in moisture resistant highway development which needs to be substantiated by real life road section experiments.

Keywords: Portland Cement; Stability; Indirect Tensile Strength; Mineral Filler; Rigidity

INTRODUCTION
Coarse and fine aggregates along with asphalt binders are commonly used in flexible pavements. Coarse aggregate acts as the main infrastructure of the pavement while mineral fillers reduce the air voids and in control the mechanical properties of the mixture. Various mineral fillers such as concrete dust, crushed stone dust, hydrate lime, Portland cement are used in order to increase the strength and durability of the pavement based on several studies performed on effect of mineral filler on strength and durability. In order to meet the gradation requirements of the minerals, reduce the optimum content of the asphalt binder by filling the voids in the granular skeleton, to stabilize the mixture or to improve bond strength within asphalt and stiffen it, mineral filler is used with asphalt.(Diab and Enieb, 2018) For harsh climatic condition crumbling due to heavy traffic, exhaustion breaking, rutting, raveling occurs, the effects becoming more profound with the increment with poor materials, lacking control over traffic and absence of proper drainage system for water which acts as the main offender for the corruption of black top solid asphalts. Water causes loss of attachment at the bitumen– aggregate interface. Water enters the interface through diffusion across bitumen films and access directly in partially coated aggregate which causes separation, dislodging, unconstrained emulsification, pore weight, and pressure driven scour(Iskender et al., 2016). For countries like Bangladesh, where heavy rainfall causes roads to be immerged under water for several weeks during the monsoon, durability of roads have become a major concern.

Study constrained to the measures of damage due to water by wet dry conditions in laboratory conditions shows that the loss of the adhesive bond between aggregate and asphalt can lead to stripping and ravelling, while a loss of cohesion can lead to a weakened pavement that is susceptible to premature cracking and pore pressure damage(Kringos and Scarpas, 2008). Feipeng et al.(Xiao et al., 2010) performed an investigation where the moisture susceptibility of the HMA mixtures containing moist aggregates are studied. The experimental results indicated that the ITS values were less for mixtures with wet aggregates compared to the mixtures without moisture.
Implementation of rigid concrete pavement instead of flexible pavement might solve this problem. But most of the heavy rainfall countries belong to the lower economy band which hinders the idea of implementation of rigid pavement. Instead rehabilitation and reconstruction of existing pavements are in practice. Operating traffic is another obstruction towards the introduction of instating rigid concrete pavements. The aim of this paper is to propose the use of Portland cement as mineral filler with the crushed stone dust which has proved to enhance the quality control by maintaining adequate Marshall stability (MS), Indirect tensile strength (IDS), Air void percentage (AV) and retained tensile strength (TSR) for minimum cost increase.

METHODOLOGY

Marshall Stability Test:

Marshall Stability is the maximum load carried by a compacted specimen at a standard test temperature of 60℃according to the specification of AASHTO T-245. The aggregates and mineral filler (including cement) is heated up to 140℃ for proper mixing of the materials. Two types of blow are provided depending on the traffic load. 25 blows for the light traffic load and 75 blows for the heavy traffic load are provided by the standard hammer specified. 4 inch diameter and 2.5 inch molds are made for conducting this test. 4.8% bitumen content is ensured. Air voids, unit weight, strength and flow are measured to compare the effect of additional anti-stripping additives (OPC) with the untreated specimens.

Tensile Strength Ratio (TSR) test:

To evaluate the moisture susceptibility tests are done by comparing two tensile strength of a Dry set of sample and Wet set of samples (conditioned for 24 hrs at 60℃ water). A set of hot mix compacted asphalt is saturated with water while maintaining 7% air void to achieve 80% saturation which is deemed to be the standard according to AASHTO T-283. The loss of ITS is a measurement of the stripping resistance of the conditioned sample than the dry sample. The ITS value can obtained be by equation [1]
The level of water damage is called Moisture susceptibility which is a function of environmental behaviour, types of the aggregates used, construction, pavement design etc. This moisture susceptibility can be evaluated by the TSR value which in turn can be determined from the equation [2]

Tables

Asphalt binder &Aggregates used for the study are summarised in Table-1&Table-2 respectively.

Table-1: Physical Properties of Asphalt

Test	Specification	Results	Standards
Penetration (25ºC)	AASHTO T49	68	60-70
Softening Point (ºC)	AASHTO T53	53	45-52
Ductility (25ºC)	AASHTO T51	100+	Min 100
Flash Point (ºC)	AASHTO T48	286	280-300
Specific Gravity	AASHTO T229	1.016	1.01-1.05

Table-2: Aggregate Gradation by the guideline of AASHTO T11.

Aggregate Gradation (AASHTO T11)					
		% Passing by weight			
Types of the Aggregates	Sieve (mm)	Specification	Blend	Individual Retain (%)	% of CA, FA, MF
Coarse	19	90-100	95	5	64
	12.5	71-90	80.5	14.5	
	9.5	56-80	68	12.5	
	4.75	35-65	50	18	
	2.36	23-49	36	14	
Fine	1.18	14-43	28.5	7.5	31
	0.6	8-29	18.5	10	
	0.3	5-19	12	6.5	
	0.15	4-15	9.5	2.5	
	0.075	2-8	5	4.5	
Mineral Filler	Cement + Crushed stone dust				5

Equations

$$\boldsymbol{ITS = \frac{2000 \times P}{\pi \times h \times D}} \text{..... [1]}$$

Where,
ITS = Indirect tensile strength (Nmm^{-2}/ Psi)
P = Maximum load (N/ lb)
h = Specimen height (mm/in)
D = Specimen diameter (mm/in)

$$\boldsymbol{TSR = \frac{S_w}{S_d} \times 100} \text{..... [2]}$$

Where,
TSR = Tensile strength ratio (%)
S_w = Strength of the Wet specimen (Nmm^{-2}/ Psi)
S_d= Strength of the Dry specimen (Nmm^{-2}/ Psi)

RESULTS AND DISCUSSIONS

Figures

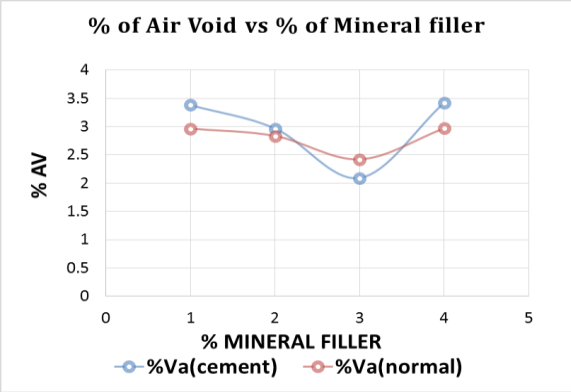


Fig-(a) Effect of % of mineral filler on air void.

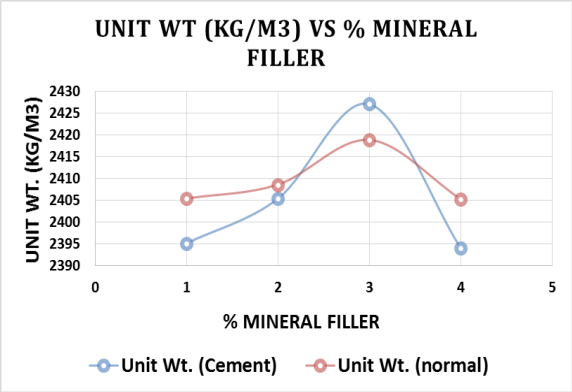
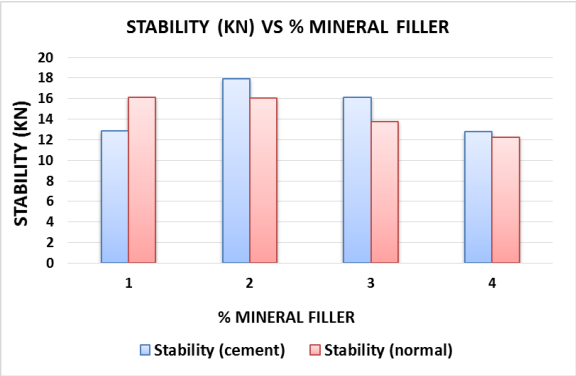
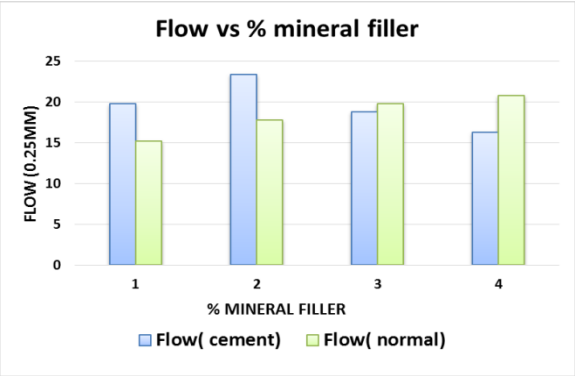


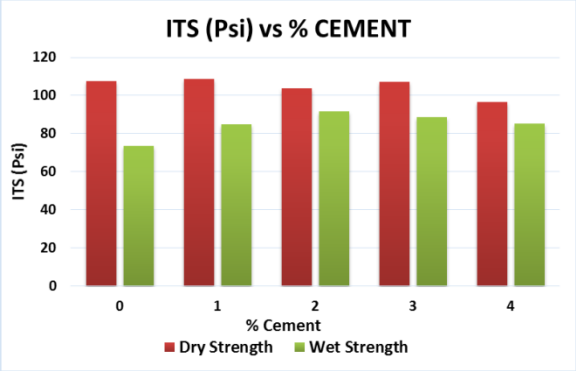
Fig-(b) Effect of % of mineral filler on unit wt.



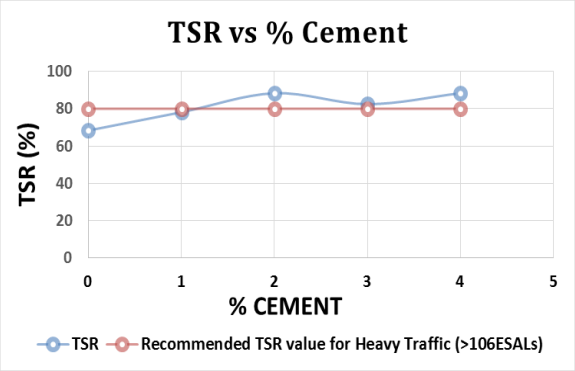
(c) Effect of % of mineral filler on Marshall Stability.



(d) Effect of % of mineral filler on Flow.



(e) Effect of % of cement content on ITS



(f) Effect of % of cement content on TSR.

Marshall Stability and Flow:

Marshall Compaction were done by 75 blows for Heavy traffic (>106 ESALs). After compaction the specimens were kept 24 hrs and then AV, unit wt., stability was measured.

Fig-(a) shows that 1% and 4 % cement content can reach the minimum air void (up to 2% which is more than the reduction caused by the crushed stone dust) criteria for heavy vehicle loading (3% -5%). Reduction of air voids are required for moisture susceptibility. The air void is reduced to minimum at 3% cement because the air voids in the main skeleton in filled with small grain of the cement. But after applying 4% cement the void increases as the cement enter into the available voids and extra grains increases the volume of the main skeleton coarse aggregate increasing the percentage of air void between the coarse aggregate.

Fig-(b) shows that initially at 1% cement content, the sample has lower unit weight compared to the same amount of crushed stone dust content sample. But with the increase of cement content the density of the mixture increases up to 2427 kg/m3 under the consideration that it has 3% cement content. High Unit Wt. indicates better compaction of the mixture and lower air void which resist water entrapped into the pavement, leading to lower moisture damage. Application of extra OPC up to 4% reduces the unit weight as the air void at 4% air void increases which reduces the unit weight.

Fig-(c) indicates the significance of Marshal Stability Test. The addition of 2% cement content in the specimen the maximum stability reaches up to 18 kN which is higher than same amount of specimen with crushed stone content. All the specimens of different cement content crosses the minimum stability value for heavy traffic i.e. 6.672 kN recommended by AASHTO. Stability is directly proportional to the strength of the mixture. Higher strength mix of better compaction prevents crack formation during heavy loading and vice versa. It reduces gradually under submerged condition as water enter into the pores of the aggregate and weakens its strength. The application of cement of various percentages

renders the stability value to be much higher than minimum required criteria. So, cement introduction of 1%-2% with the crushed stone dust as mineral filler could be a more moisture susceptible solution. The Flow values are shown in Fig-(d). Initially flow value increases up to 2% cement content then the flow values decreases with the increase of cement content rather the flow value increases with the increase of crushed stone dust. Higher flow value causes the problem like corrugation or shoving. So, from this context cement aided pavement mix is good against this type of distress.

Indirect Tensile Strength and TSR

Indirect Tensile Strength (ITS) denotes the moisture stripping resistance. From the Fig-(e), the ITS value of 1 % cement content dry sample reaches the maximum ITS value of 108.58 kN. In case of wet sample 2% cement content reaches the maximum ITS value of 91.68 kN. The loss of ITS value decreases with the increase of cement percentage. This indicates that the implementation of cement resists the moisture damage compared to the untreated sample results.

In Fig-(f), the TSR value increases with the rise of cement percentage and reaches the maximum value of 88.269% after 24hrs conditioning with 2% cement content. 80% TSR value is considered as minimum for general cases of heavy vehicle loading (>106 ESALs). This causes serious moisture damage to the pavement with 0% and 1 % cement content which fails to reach this minimum criteria. On the other hand, the introduction of 2% OPC with the normal crushed stone dust resist the moisture susceptibility by increasing TSR value.

Introduction of OPC with normal crushed stone dust has potential of a great significance to the highway road network in heavy rainfall countries like Bangladesh. It makes the pavement moisture resistant and reduces the maintenance cost over the years caused by the stripping, pothole generation and cracks. Every year the countries spends a huge budget in maintenance than the new road construction. The road condition of these countries become very critical after one or two seasons of rainfall which leads bad impact to the nation transportation system. This has a bad impact to the nation economy also.

However this condition can be improved by improving the moisture resistivity of the road pavement. To meet this target the introduction of OPC at 1%-2% with the normal crushed stone improves the moisture resistivity maintaining the minimum criteria of the air void, Marshall Stability, Flow and most importantly TSR value increases up to 88 %. The comparison between OPC added and normal mix is provided in Table-3.

Table-3: Comparison of the effect of using OPC by Air void, Marshall Stability, ITS & TSR value.

% of OPC	Air Void		Marshall Stability (For Heavy Loading, >106 ESALs)		Indirect Tensile Strength (Psi)			TSR	
	Study Results (%)	Standards (%)	Study Results (kN)	Standards (kN)	Study Results (DRY) (Psi)	Study results (WET) (Psi)	Standards (Psi)	Study Results (%)	Standards (%)
0	2.96	3-5	16.11	6.672	103.02	77.95		68.32	80
1	3.37	3-5	12.83	6.672	108.57	84.79		78.09	80
2	2.96	3-5	17.92	6.672	103.87	91.68		88.26	80

By implementing OPC as mineral filler the physical properties like TSR, ITS, Marshall Stability are enhanced to meet the required minimum standard. If we use the result of this study in constructing the highway road network in huge scale, it will reduce the maintenance cost increasing strength in submerged condition, reducing the air void percentage, acting as anti-stripping additive. Therefore, the countries like Bangladesh that are affected by heavy rainfall and flooding on the road network should include TSR, mix design moisture susceptibility criteria, as a specification item in their asphalt concrete standard.

CONCLUSIONS

Marshall Stability, ITS and TSR tests were performed for laboratory prepared marshal samples and the rigidity and susceptibility of the road pavements along with their tensile properties were measured. The results of these tests show that incorporating as low as 1%-2% of OPC as mineral filler increases the strength and tensile properties of the pavement material. Although this is bound to increase the pavement construction cost by a nominal amount but considering the current situation of pavement damage in Bangladesh, huge maintenance cost can be reduced significantly with this minimal initial cost increase. Introducing TSR, mix design moisture susceptibility criteria, as a specification item in the asphalt concrete standard the highway authority of Bangladesh can meet the requirements using locally manufactured OPC as anti-stripping additive and reduce the damage of pavements leading to unhindered transportation system.

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A STUDY ABOUT THE CONGESTION AT MEGHNA BRIDGE ON DHAKA –CHITTAGONG HIGHWAY

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ABSTRACT
Dhaka, the capital of Bangladesh should have a good communication with the chief seaport Chittagong; as the latter deals with the major portion of exported and imported goods. The N1 or Dhaka–Chittagong Highway is the main transportation artery in between Dhaka and Chittagong which are approximately 250 kilometers (200 miles) in length. As GDP is increasing upward, the freight traffic and passenger transport are increasing simultaneously. The traffic capacity on the main roads connecting the major cities and metropolitan areas in Dhaka cannot keep up with the year-after-year increase of traffic volume and eliminating bottlenecks of distribution routes has become a pressing issue. In this context, this study investigates the present condition of the Meghna Bridge on Dhaka-Chittagong highway and shows fundamental relations of traffic flow along with the probable causes of traffic congestion. We have taken readings at the four-lane highway and near the two-lane bridge. Video camera was used to count traffic manually on the Highway at peak hours and off-peak hours separately. From these readings, we found that the velocity is decreased by 48.76% and volume decreased by 51.78% approximately for an off-peak hour on Sunday from Chittagong to Dhaka highway. From the result it is found that the flow, density, velocity is decreased numerously at obstructed flow than the free flow. The result indicates that traffic volume is satisfactory with highway capacity but congestions are created due to bottlenecks near the two-lane bridge.

Keywords: N1; bottlenecks; free flow; obstructed flow; density; velocity

INTRODUCTION

The National Highway N1 or Dhaka–Chittagong Highway is not only the main transportation artery but also a vital route of regional connectivity in between Dhaka and Chittagong. The Kanchpur, Meghna and Gumti bridges (KMG) project on the Dhaka-Chittagong highway created a short-cut route from Dhaka to Comilla and subsequently to Chittagong. This Bridge was built with the financial help from the Government of Japan and was opened to public on the 1990s. At first its official name was Bangladesh Japan Friendship Bridge 1 but latterly it gained popularity as Meghna Bridge. But the movement of the vital road is hampered due to traffic congestion at bottlenecks. Traffic congestion is one of the worldwide urban problems, which can lengthen journey time, increase energy consumption, aggravate environmental pollution and result in traffic accident. If we take no measure to govern it, not only individual journey cost will be enhanced, but also the entire municipal transportation systems will paralysis and urban sustainable development will be restricted (Yun, 2012). Therefore how to solve traffic congestion becomes the hot issue for each big city.

There are many reasons of traffic congestion at Meghna Bridge such as narrow roads, illegal loading, unloading, 2 lane bridge for 4 lane highway, no electronic toll collection system, no additional lay by for heavy traffic, heterogeneous traffic, increasing economic development, improper supply and demand ratio etc.

There was no extreme requirement for 4-lane bridges at that time. The economic development of Bangladesh upholds the GDP growth and it expanded 7.65% in 2017-18 from the previous year. (Byron, 2018)

The National Highway (N1) contributes approximately one third of this national GDP. Such trend in economic development of Bangladesh directly impacts on the strong growth in both the number of passengers and freight traffic. At that time the bridge was built as 2 lane bridge. But, with the passage of time, the bridges felt the need for that extra capacity in order to capacitate that extra amount of increasing vehicles.

The National Highway No.1 (NH-1) is the busiest road in the country and a top development priority. Besides, except truck and bus (12.68%), the remaining vehicular class consist of small vehicles, which marks NH-1 very accident prone and congested highway. Though individual year varies significantly, the average growth factor of Truck and Bus is found 6.68% and 4.07% per annum respectively. (Ullah et al., 2017)

A traffic stream having vehicles of varying range of speed creates great hazard that may lead to heavy traffic congestion. The slow-moving vehicle will block the way of the fast moving vehicles, thereby creating traffic congestion. (Manzur, 1986)

Toll plazas usually appear to be a bottleneck for highway traffic flow. They cause traffic congestion in the highways which in turn causes loss of time and money. It is evident that toll plazas are usually the bottlenecks for highway traffic flows. But due to delay in collection system, the users of this road normally have to face long queue. All the parties concerned are being negatively impacted by this delay. According to a traffic survey in 2005, about 3584314 vehicles were recorded to cross Meghna Ghat toll plaza (Sultana, 2010). With the passage of time, more vehicles would be passing through the bridge and the problem of long queue would be increased. There has no additional lane for toll collection system. Besides there was no additional lay be for heavy traffic.

In this sstudy traffic volume is counted at peak hour along with off peak hour for Dhaka to Chittagong and Chittagong to Dhaka both directions. We measured the data for free flow and obstructed flow.

METHODOLOGY

The bridge is located along the Dhaka–Chittagong Highway. The geographic coordinate of the Meghna Bridge is 23°36.162′N 90°36.991′E.

Fig. 1*: Location of Meghna Bridge*

Prior to the actual work, preliminary investigation was carried out along the case study road to determine the best approach to be used in dealing with the research. (Rahim et al., 2015)] The whole road was surveyed by three men and it was observed that noticeable congestions were within the exits

point of the bridge near the toll collection system. Observers were positioned at near two lane bridge where they get a clear view of traffic. Each observer should be positioned away from the edge of the roadway. Layout of the study area are given below,

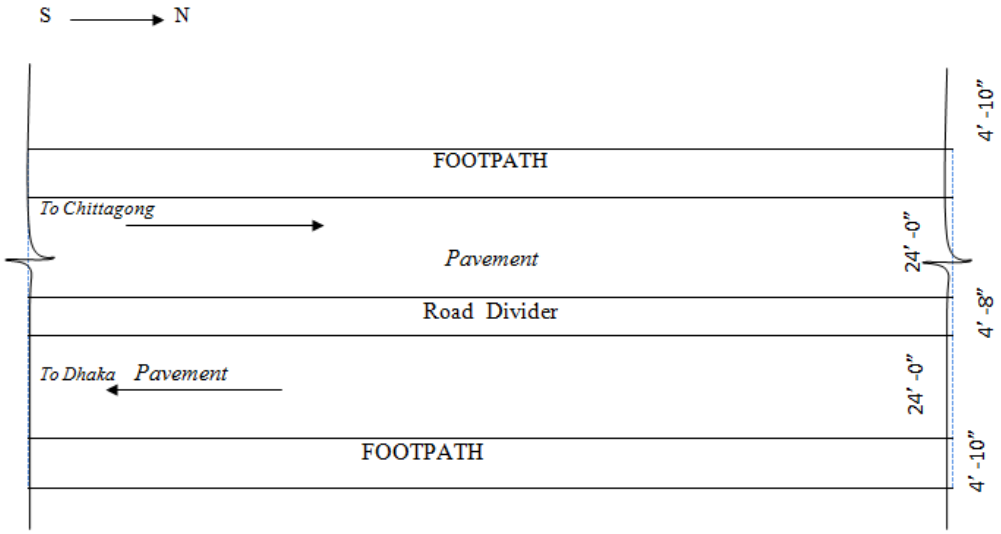

Fig. 2: *Layout of the study area*

For this study Traffic volumes was counted by viewing videotapes recorded with a camera at a collection site and, imperial data were collected for the study by sample survey method. Video is captured for one hour and data is collected later by rewinding (Botswanq Guideline 9, 2004). PCU factors are adopted from the manual book of Geometric Design Standards for Roads & Highways Department (RHD Manual Book, 2000). The following PCU values are used.

Table 1: Passenger Car Unit (PCU) for different vehicles

Type of Vehicle	P C U
Private car	1
Micro	1.5
Bus	3
Truck	3
Pickup	1.5
Motorcycle	0.5
Cover van	3
Lorry	3

For the study purpose we divided the heterogeneous vehicle into eight categories such as motorized two wheelers, motorized three wheelers, car, light commercial vehicles (LCV), Bus, truck, lorry and non motorized vehicle (NMV).

The following data were generated:

Traffic density: This is the number of vehicles in a given length of road at an instantaneous time. It is measured in vehicles per kilometres.

Traffic flow: This is the quantity of vehicles in space measured in an interval of time. It is measured in vehicle per hour.

Speed: This is the distance travelled by vehicle during a unit time. i.e. rate of movement of traffic. It is measured in kilometre per hour or mile per hour (Rahim et al., 2015). Speed was determined by sampling a set of vehicles, noting their travel time (with the use of stop watch) on a predetermined length of road along the case road. The space mean speed can be determined by,

$$v_i = \frac{\sum_{i=1}^{n} q_i}{\sum_{i=1}^{n} \frac{q_i}{v_i}}$$

Where q_i vehicle will have, v_i speed and n_i is the number of such observations.
The fundamental equation of traffic flow is

$$q = k \times v$$

Where q indicates the traffic flow, k indicates traffic density and v is space mean speed.

RESULTS AND DISCUSSIONS

The results show a very obvious change in the velocity and flow of the traffic at free flow and obstructed flow condition. As we see in figure 1a, the value of total PCU is greater for free flow for each kind of vehicles than that of the obstructed flow during peak flow. However, it is noteworthy that, the number of bus and pickup is more than that of the other vehicles. This indicates that, the number of heavy vehicles is more than that of the light vehicles like private cars or micro bus at the highway. As we look into figure 1c, we see that, the value of total PCU is changed to some extent at off peak hour than that of the peak flow. Interestingly, the change is not uniform for all the vehicles. While some private vehicles are seen more than peak hour, the number of heavy vehicles has been decreased to some extent at off peak hour.

As we see in figure 1b, we also observe a change in velocity. Here also, the vehicles are operated at more velocity during free flow than that of the obstructed one. The values show that, most of the velocities have almost been cut into halves as the vehicles enter the obstructed flow. Thus, a significant amount of clogging is created at the vicinity of the bridges. It is also observed that, the velocity at off peak hour increases to some extent at the off peak hour (comparing figure 1d with figure 1b). The decrease of the contribution of heavy vehicles on the road might play an impact in this case.

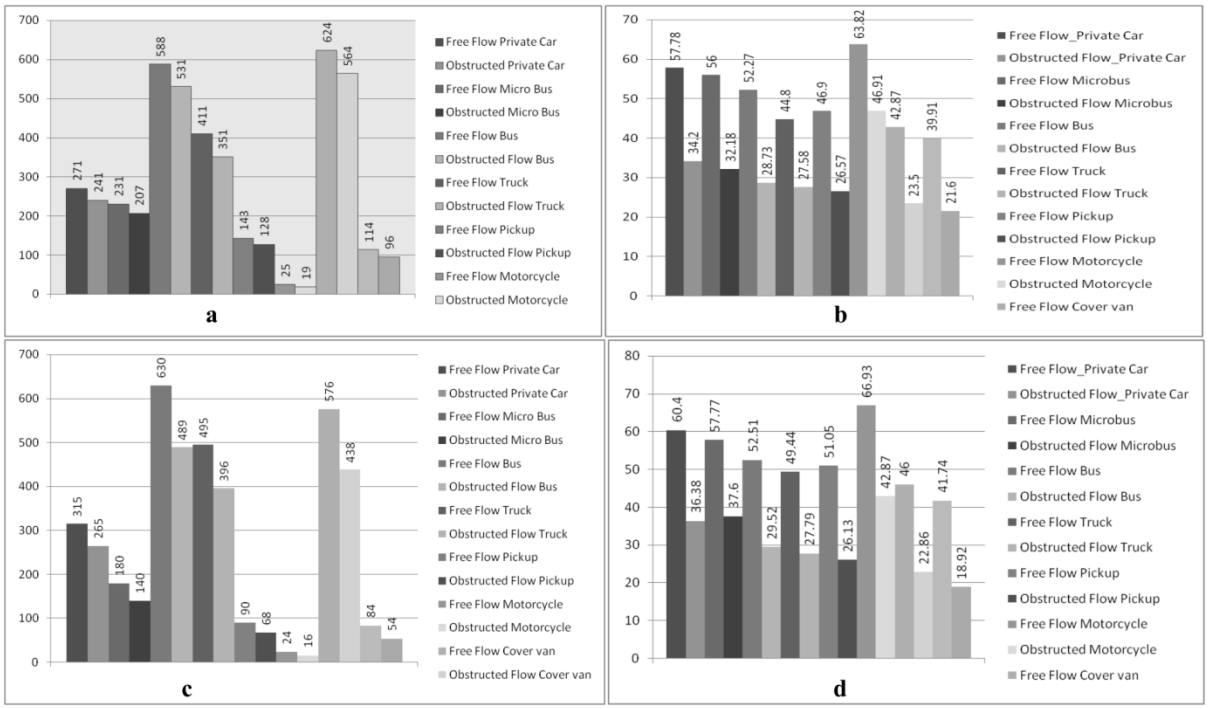

Fig. 3: Variation of free and obstructed flow for a) Total PCU on Friday at Peak hour b) Velocity on Tuesday at Peak hour c) Total PCU on Friday at Off Peak hour d) Velocity on Tuesday at Off Peak hour

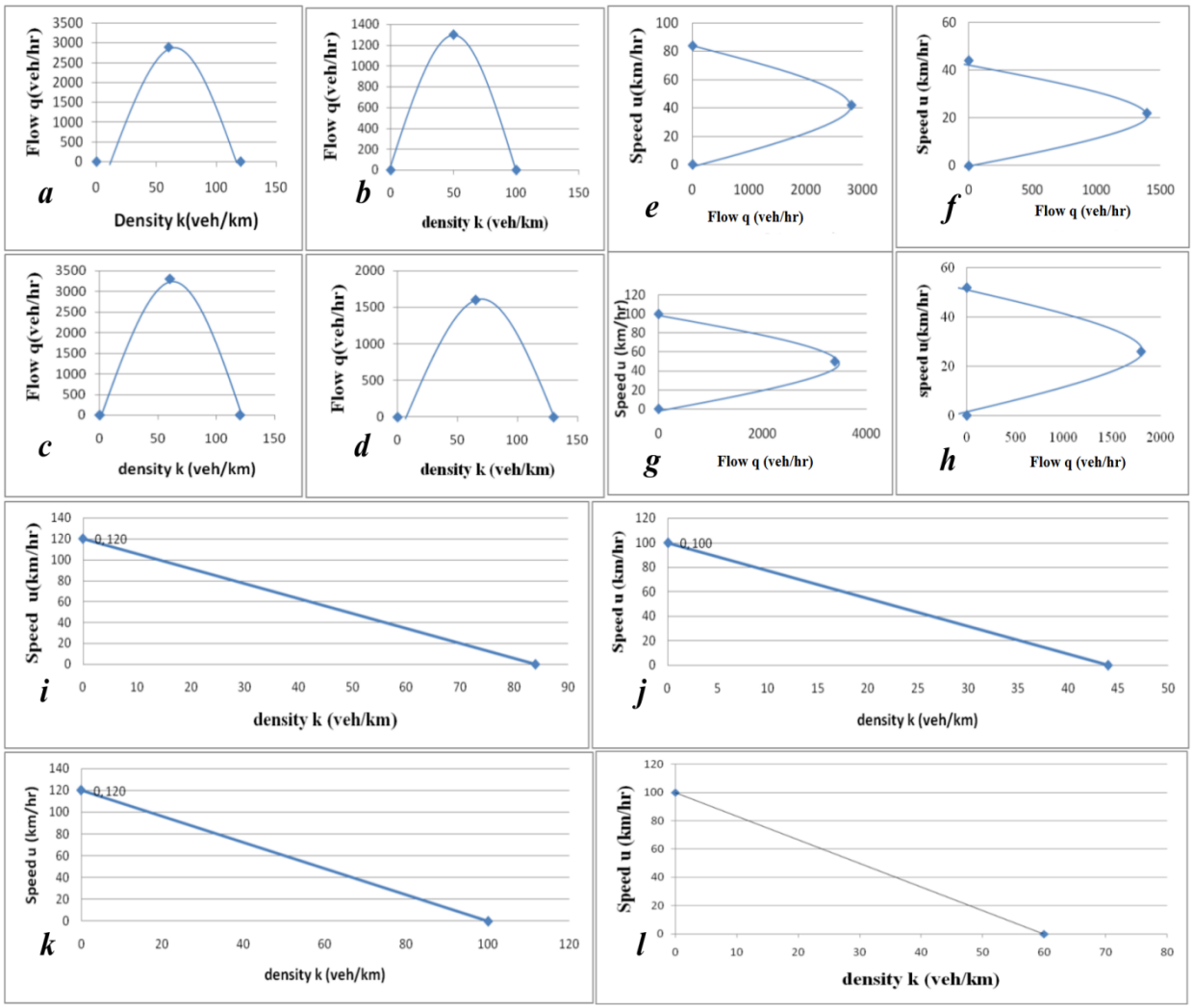

Fig. 4: Variation of q, k and v at a, e**, i**) Chittagong to Dhaka free flow b, f**, j**) Chittagong to Dhaka obstructed flow c, g, **k**) Dhaka to Chittagong free flow d, h, **l**) Dhaka to Chittagong obstructed flow.

Comparing figure, a, b, c and d it can be state that at obstructed condition flow is decreased about 51.78% than the free flow for Chittagong to Dhaka highway and about 52.94% for Dhaka to Chittagong Highway.

Figure e, f, g, and h shows velocity is changed abruptly for free flow to obstructed flow in both directions. It decreased about 48.76% for Chittagong to Dhaka highway and 47.47% for Dhaka to Chittagong highway.

In figure i, j, k and l shows that at obstructed flow velocity only decrease 16.67% for Chittagong to Dhaka highway any 16.67% for Dhaka to Chittagong highway.

CONCLUSIONS

Traffic congestion has become a major problem for all urban cities recently. In this paper, we mainly studied about the fundamental relationship of traffic at peak hour and off peak hour along with the reasons for creating the traffic congestion at Meghna Bridge. From the results it is found that the flow, density, velocity is decreased numerously at obstructed flow than the free flow. The density of car is greater on Sunday and Tuesday than Friday. Besides, travel from Dhaka to Chittagong is more convenient than Chittagong to Dhaka travel. The result indicates that traffic volume is satisfactory with highway capacity but congestions are created due to bottlenecks near the two-lane bridge. , illegal loading, unloading, 2 lane bridge for 4 lane highway, no additional lane for toll plaza, no additional lay by for heavy traffic, heterogeneous traffic are the main reason for this traffic congestion. We can solve this problem by increasing number of lane at bridge, create additional lane for toll collection system, different lay bay for heavy traffic, clearing road side shops and hawkers etc. Most importantly strict

rules and regulation should be imposed for motorized and non motorized vehicles. Only after that we can minimize the traffic congestion at Meghna Bridge. Although the 2nd bridge is under construction, a full functioning traffic flow can be obtained if the 4-lane highway and 2-lane bridge unveiled simultaneously.

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SAFETY CONCERNS FOR MOTORCYCLISTS: PERSPECTIVE OF BANGLADESH

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ABSTRACT
The everlasting traffic congestion and lack of public transport have abnormally pushed up the numbers of motorcycle in Bangladesh increasing the recurrence of fatal accidents and chaos on roads. According to Bangladesh road transport authority (BRTA) statistics from 2013 to 2016 the number of registered motorcycles increased by 287%. BRTA statistics shows that the number of registered motorcycles increases to 17.24 lakhs in 2016. In urban areas people use motorcycle to get pass the unbearable traffic jam and ensure mobility. Beside the lack of quality of public transport and also inadequacy of it results towards the increase of motorcycle. Besides certain ride sharing apps such as pathao, uber moto etc. Also encourage largely to increase the number of motorcycles. On the other hand, in rural areas people use motorcycles for mobility and also because the road communication is mostly bad. This out bursting in number of motorcycles leads to the increasing number of accidents in urban and rural areas. The key factors contributing to the accidents are - not wearing of helmet, getting on footpath due to stagnant road, hazardous road conditions, inexperienced and young riders showing stunts and reckless riding. In this paper the authors will discuss about present scenario and major concerns associated with motorcycle accidents and scope of improvement of the present condition.

Keywords: Safety, Mobility, Public transport, Hazardous road, Reckless riding.

INTRODUCTION

Road traffic accidents result from failures in the interaction of human, vehicle and the road environment - the three elements which produce the road traffic system. Worldwide, the number of people killed in road traffic crashes is estimated to be 1.3 million, with another 50 million injured each year according to WHO. The number of accidents has increased by 43% between 1982 and 2000, while the number of fatalities has increased by around 400% within the same period (Maniruzzaman and Mitra 2005). Road traffic injury (RTI) is the leading cause of death by injury(Mohan et al., 2006) and it is estimated to be the ninth leading cause of death across all age groups globally and is predicted to become the seventh leading cause of death by 2030 ("WHO | Number of road traffic deaths," 2016). Bangladesh has a very high fatality rate in road accidents – more than eighty five deaths per ten thousand registered motor vehicles per year (Ahmed, 2015). The heterogeneity of traffic, playing of modes with varying speed and maneuvering time makes the roads and intersections of cities of Bangladesh even more complex (Ahmed, 2015). Due to the easy accessibility to reach any destination and ability to escape from traffic jam motorcycles have become a popular transport mode in Bangladesh like other Asian countries. Now a days, the number of motorcycles has been increased at an alarming rate due to ride sharing services and a large portion of these motorcycles are not registered

which leads to a massive increase in motorcycle accidents. According to the Insurance Information Institute, motorcyclists are five times more likely than car passengers to be injured in an accident and 29 times more likely to sustain fatal injuries. Motorcyclists are at high risk in traffic crashes, particularly for head injury (Masur et al., 2017). Report prepared by National Committee to Protect Shipping, Roads and Railways dictates that almost 6000 were injured in 2353 road accidents in between January to June 2017 and among those 548 were motorcyclists. Statistical analysis shows that 637 motorcycle accidents occurred in 2017 out of 2917 road crashes whereas in 2014, 241 motorcycle crashes occurred out of 2585 road crashes. The present scenario reminds us the urgency of taking adequate measures to control the severity of this alarming trends of motorcycle accident. This paper reviews safety concern for motorcyclists in Bangladesh and the future challenges and opportunities of improving safety of this vulnerable road user group.

METHODOLOGY

The data of road accidents and casualties was collected from the Bangladesh road Transport Authority (BRTA) and Accident Research Institute (ARI). BRTA prepares the Annual Report of Road Traffic Accidents on the basis of reported data on road traffic accidents from Bangladesh Police. The Road Traffic Accident database is being maintained and updated by BRTA on the basis of police MAAP (Micro-Computer Accident Analysis Package) information. The shortcoming of the database is that it is prepared on the basis of reported accidents only. It's a fact that there exist some accidents in the country side which are not reported to the police, making the database virtually incomplete. However, it will invariably serve the purpose as it covers most and major parts of the accidents of the country. From the collected data different graphs, pie charts and bar charts were drawn from which the growing trends of the number of motorcycle and also the accidents associated with it are analysed. And then, contributing factors of motorcycle accidents are determined to find out the preventive measures that should be implemented to counteract this growing trend of motorcycle accident.

RESULTS AND DISCUSSIONS

With the incredible rise of the number of motorcycles in recent years, the number of accidents associated with it is also rising high in competition. From 2011 to 2014 the rate of motorcycle registration in the whole country was quite sluggish but after that it shows an incredible boost. In 2014 total 1151954 motorcycles were registered which becomes almost double in 2017 incredibly. However, road safety experts suspect the actual number to be much higher, with many vehicles being smuggled in from neighbouring India and remaining unregistered. Vying with the numbers of motorcycles, motorcycle accidents have become almost triple in between these four years (2011-2014).

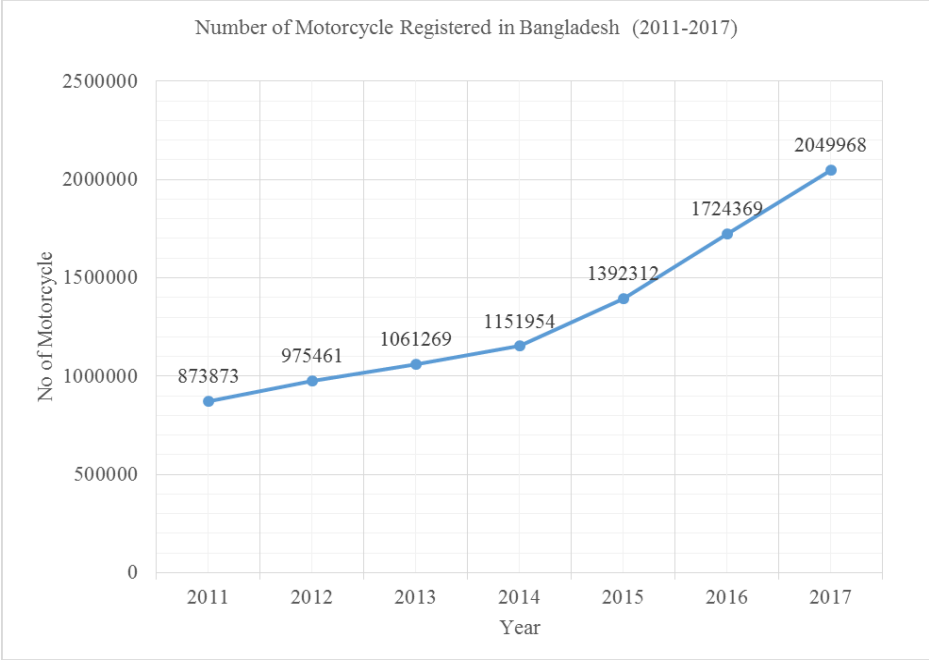

Fig. 1 Number of Motorcycle registered in Dhaka (2011-2017).

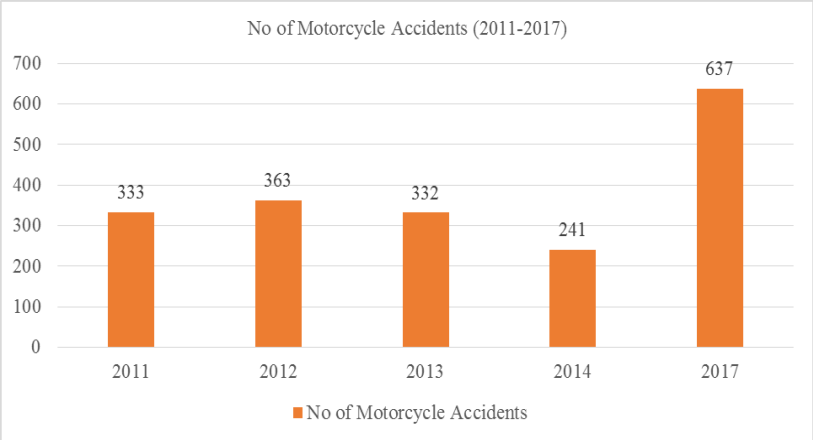

Fig. 2 No of Motorcycle Accidents (2011-2017)

Table 1: No of Accidents occurred by different type of vehicles (1998-2013)

Year	Cycle	Rickshaw	Motor Cycle	Baby Taxi	Micro bus	Mini bus	Bus
1998	125	285	181	382	224	538	912
1999	163	279	222	257	266	480	1164
2000	185	264	246	218	271	512	1162
2001	144	179	203	114	156	373	873
2002	163	245	249	140	249	595	1229
2003	146	265	273	148	242	642	1347
2004	117	209	236	122	203	488	1268
2005	96	142	240	146	172	436	1079
2006	149	203	327	128	160	403	1279
2007	167	214	343	164	190	397	1379
2008	163	188	441	164	211	354	1293
2009	107	124	382	114	154	267	866
2010	95	103	362	149	138	250	725

2011	85	100	333	110	96	190	556
2012	76	62	363	121	91	138	569
2013	41	70	332	105	50	112	466
Total	**2022**	**2932**	**4733**	**2582**	**2873**	**6175**	**16167**
%	**2.96**	**4.29**	**6.93**	**3.78**	**4.21**	**9.04**	**23.68**

According to the ARI, BUET data 241 motorcycle accidents occurred in 2014 in the country which rose up to 637 in 2017. Obviously, these are only the recorded data but many of the motorcycle accidents are unreported as they are considered as individual cases. And it is quite evident that these raising rate is not going to be sloth as the number of motorcycles is increasing added to the fact that the ride sharing services are becoming increasingly popular for which many people availing it as their main occupation. After the launching of ride sharing apps like Uber and Pathao in 2016, the number of motorcycle license issued in Dhaka city has seen a significant boost (Fig. 4). Besides BRTA has given the chance of registering unregistered motorcycles without fine which is also assisting the numbers to be raised. This implies that the numbers of illegal motorcycles are not negligible. The nagging traffic jam and the never-ending quest for speed also encourages people to rely on motorcycles specially the young generation. It is reported that among the total registered vehicles in 2015, 2016 and 2017 motorcycles consist approximately 75%, 80% and 78% respectively (ARI, BUET).

Table 2: No of Accidents occurred by different type of vehicles (1998-2013)

Year	Car	Jeep	Pick Up	Truck	Heavy Veh	Other
1998	349	86	87	67	1159	768
1999	305	125	145	102	1390	649
2000	262	129	121	172	1326	597
2001	181	83	99	106	1035	345
2002	321	100	143	144	1266	424
2003	351	109	200	147	1302	414
2004	293	85	147	148	1072	370
2005	232	95	146	153	970	327
2006	192	89	155	185	980	400
2007	214	79	167	167	996	466
2008	254	50	134	161	920	454
2009	186	70	119	139	751	312
2010	159	39	114	130	573	308
2011	123	31	97	89	473	277
2012	92	31	116	108	490	278
2013	83	44	97	109	417	225
Total	**359**	**1245**	**2087**	**2127**	**15120**	**6614**
%	**5.27**	**1.82**	**3.06**	**3.12**	**22.15**	**9.69**

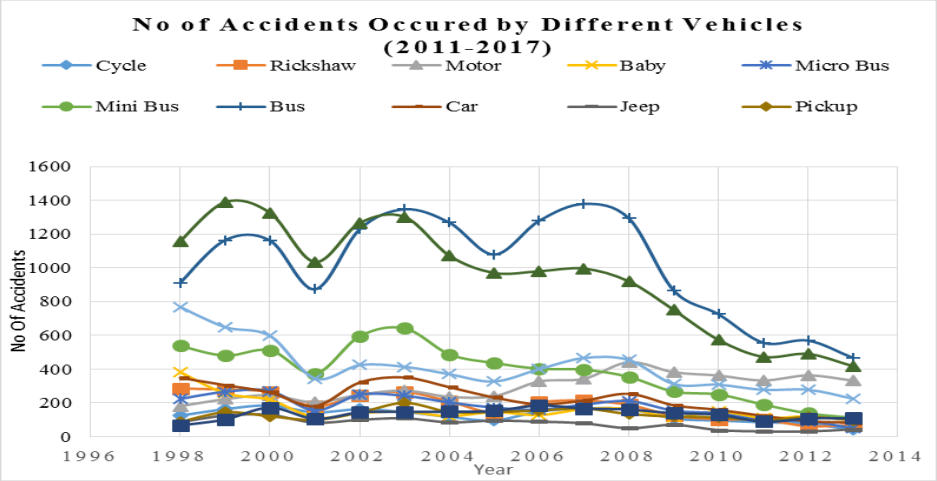

Fig. 3: Number of Accident Occurred by Different Vehicles.

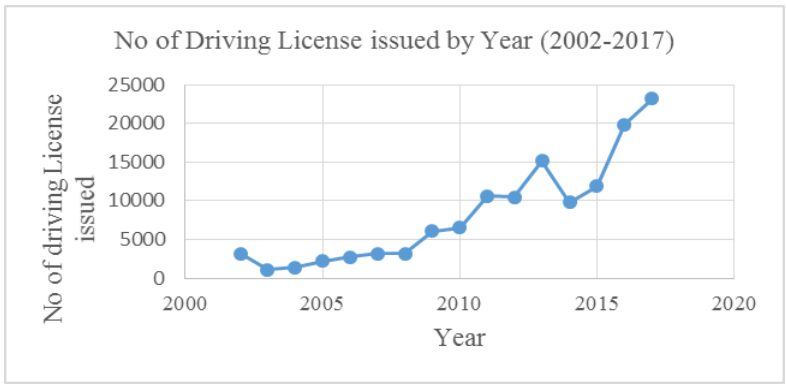

Fig.4 No of Motorcycle Driving License Issued in Dhaka (2002-2017).

Table 3 No of Vehicles Registered in Bangladesh (2011-2017).

Type of Vehicles	Year						
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Ambulance	3012	3193	3436	3774	4254	4632	5126
Auto Rickshaw	147186	170731	186428	206325	226325	237498	246708
Auto Tempo	14441	15067	15462	15962	17057	18379	19971
Bus	29539	30978	32085	33573	35964	39797	43558
Cargo Van	4011	4293	4980	5588	5987	7004	8413
Covered Van	8012	9433	11704	14573	16927	20267	25432
Delivery Van	18067	18841	19735	20911	22630	24811	27214
Human Hauler	7672	8387	8772	8997	10139	13626	17030
Jeep (Hard/Soft)	34420	35989	37303	39173	42774	47666	53083
Microbus	70430	73474	76011	80324	85548	91352	96927
Minibus	25920	26169	26317	26573	26896	27368	27858
Motor Cycle	**873873**	**975461**	**1061269**	**1151954**	**1392312**	**1724369**	**2049968**
Pick Up	42700	50325	56878	66432	76689	88060	101557
Private Passenger Car	232780	242004	252476	267175	288237	308541	330488
Special Purpose Vehicle	6767	6993	7220	7392	7688	8308	9297
Tanker	3023	3218	3444	3806	4130	4524	4842
Taxicab	44455	44627	44678	45052	45140	45184	45199
Tractor	25800	29294	31179	32701	34400	36976	39753
Truck	90198	94533	99662	107798	114128	121403	132729
Others	1324	1325	2405	4000	6073	9943	14941
Total	1683630	1844335	1981444	2142083	2463298	2879708	3300094

A combination of increasing volume of vehicles on the road, complexity of heterogeneous mix of vehicles, poor road infrastructure, unsafe vehicles, risk taking behaviour of general public, poor enforcement of traffic laws and lack of proper regulation and dedicated facilities for the vulnerable road users has led to increasing road traffic crashes and casualties in Bangladesh (Hoque, Chowdhury, & Rashedi, 2015). Due to the smaller size and faster speed motorcycles can run through narrow spaces on the road. Motorcyclists tend to take more risky overtaking than any other vehicles and due to their size and speed it sometimes very difficult for the drivers track them by the looking of heavy vehicles like buses and trucks. Availability of motorcycle to the young people is also an important factor for increasing accident as they hardly follow rules and maintain safe speed. Besides, motorcyclist often move in zigzag way and abruptly change lane which create conflicts with other vehicles. Due to the unwillingness of wearing of helmets both biker and rider often becomes victim of fatal injuries. According to research deaths can be reduced almost 40% and severe injuries can be reduced 25%-75% if safety helmets are used by the riders.

However, BRTA should be more professional and perform adequate background research before providing driving licenses. Traffic police must play their significant role to ensure the implementation of traffic rules to the violators.

CONCLUSIONS

The aim of this paper was to represent the present condition of road safety corresponding to motorcycles and to identify the factors to address the possible countermeasures for ensuring safer road for the increasing motorcyclists. If the increasing rate of motorcycle accidents are not properly handled, the situation will become worse day by day. This study has indicated the sectors where priority should be given such as unwillingness of following traffic rules, not using safety helmet for both bikers and riders, immature motorcyclist, not maintaining safe speed and most importantly unlicensed bikes that make the road more unsafe. Low enforcing authority has to play the major rule for ensuring the safety features of the motorcyclists on the road while BRTA should be strict and more professional while providing Licenses.

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A STUDY ON THE EFFECT OF NON-LANE BEHAVIOR ON HCM 2000 DELAY FORMULA

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ABSTRACT
Signalized road Intersection is one of the major sources of delay that occurs to traffic stream. Many mathematical formulas have already been developed to analyze, measure and predict this delay. HCM 2000 delay formula is one of the existing delay formulas. Similar to other delay formulas, HCM 2000 delay formula is suitable for lane based disciplined traffic. But, some previous studies suggest that this formula does not provide accurate results for non-lane based traffic condition similar to Dhaka city where frequent disturbances to traffic stream such as road side friction, interruption from pedestrians, bus stops, presence of non-motorized vehicles etc. are commonly observed. But, the impact of each disturbance factor on the delay formula have yet not been analyzed. Therefore, this study has performed a check to discover the effect of non-lane behavior on the HCM 2000 delay formula. Focus have been given simply to analyze the impact of a single factor that is the non-lane behavior. For this purpose, data collection is performed on three approaches of a single intersection where traffic flow is homogeneous in nature and frequent interruptions are least or negligible. Data is collected by video method and some special considerations during data transcription are taken to minimize the impacts of any other disturbances to traffic flow. Now, field delays are measured following HCM procedure. From the delay comparison analysis between field observed delay and HCM delay, it is observed that the effect of non-lane behavior on the HCM 2000 delay formula is statistically insignificant. The results from the t-statistic test shows that the obtained t-value falls into the acceptance region. Therefore, it can be concluded that HCM 2000 delay formula remains valid to measure delay of homogeneous traffic where lane following behavior is absent provided that the traffic flow experiences negligible amount of external disturbances.

Keywords: Signalized road Intersection, HCM 2000 delay formula, non-lane behavior, homogeneous traffic

INTRODUCTION
Traffic delays can occur due to various geometric and operational reasons. One of the most common sources of delay is signalized road intersection. In western countries, different attempts have already been taken to measure as well as formulate the delay incurred in a signalized intersection (Webster, 1958; Reilly et al.,1977; Robertson,1979; Akcelik 1980). Among various other formulas, HCM 2000 delay formula is much developed one that can predict delay for both oversaturation and under saturation conditions. However, all of the formulas including HCM 2000 formula are well suited for the western traffic which is homogeneous in nature and lane disciplined.
Now, the traffic movement in Bangladesh is completely different from the western traffic. The composition of traffic can be homogeneous as well as heterogeneous in nature. Moreover, no lane following behavior is observed in Dhaka city's traffic. Due to lack of education as well as law enforcement, activities such as frequent pedestrian crossing, illegal roadside parking and roadside

vendors are commonly observed. These activities are found to hamper the traffic operation. Because of the mentioned differences of traffic composition, traffic operation and roadway environment, formulas of western countries do not fit into the traffic condition of Bangladesh. An attempt to modify HCM 2000 delay formula to fit into the non-lane based traffic condition had been performed previously (Hadiuzzaman, 2008). The modified formula is developed based on traffic that include heavy roadside friction, heavy internal friction, frequent interruption from pedestrian crossings etc. These disturbances vary from site to site. Thus, effect of each of these factors on the formula is still unknown. Therefore, the research is focused on delays of relatively simple non-lane based homogeneous traffic with minimum external interruptions. To check the applicability of the formula considering the effect of non-lane behavior is the principle objective of the study.

METHODOLOGY

HCM 2000 delay formula predicts average control delay of vehicles of a lane or lane group by the following delay formula:

$$d_{HCM\,2000} = d_1 * P.F. + d_2 + d_3 \quad (1)$$

Where, $d_1 = \frac{\frac{C}{2}\left(1 - \frac{g}{C}\right)^2}{[1 - \min(1, x)\frac{g}{C}]}$ = Uniform delay component (sec/veh)

$d_2 = 900T\left[(x-1) + \sqrt{(x-1)^2 + \frac{8KIX}{cT}}\right]$ = Overflow delay component (sec/veh)

d3 = Delay due to pre-existing queue (sec/ veh)

P.F. = Progression Adjustment Factor

C = Cycle time (seconds) g = Effective green time (seconds);

v = Arrival Flow rate (veh/hour) c = Approach capacity (veh/hour)

x = Degree of saturation (v/c) T = Analysis period (hours)

I = Upstream metering factor k = Incremental delay factor

Now, in order to observe the effect of non-lane behavior on the delay formula (Equation 1), delay measured on the field and delay provided by the formula are compared. Field delay is obtained from traffic stream that experience least amount of external disturbances.

Field Delay Measurement: Estimation of field observed delay is performed by HCM procedure. This delay is the average time in queue delay per vehicle plus the acceleration-deceleration delay per vehicle. Chart provided by HCM 2000 to measure control delay is used. Various parameters are required for the HCM 2000 delay formula as shown in the equation 1 and these parameters are determined from traffic data collected from the field.

Site Selection Criteria: The research study has some special considerations for site selection. The intersection must have the following attributes to be selected for the study:

- The traffic stream should be homogenous in nature.
- Pedestrian interference should be as minimum as possible. Well-disciplined pedestrian behavior is expected.
- No nearby bus stop should be present.
- Road side friction should be minimum.
- Presence of accessible vantage point that can provide video recording of full queue.

Data Collection Considerations: To ensure proper comparison of field delay and formula delay, site with minimal external interferences is needed. Also, any other traffic rule violation is needed to be considered and eliminated carefully. This is why data collection require video method and also the data counting for various parameters and vehicles in queue counting need special considerations.

Table 1 is showing special considerations that are adopted so that field delay can be compared to formula delay.

Table 1: Special Considerations needed for Valid Comparison of Formula Delay and Field Delay

Lane based traffic condition	Field Condition	Considerations required during video data transcription
Vehicles on different lanes are separated and queued separately. Thus formula predicts delay of a particular lane with no influence of other lanes.	Vehicles of different direction are mixed and queued as a whole.	Delay is carefully measured for vehicles of particular direction only. Vehicles that travel in other direction during queue discharge are excluded from delay measurement.
Exclusive left turn vehicles experience no delay. Therefore, it is never a consideration of the formula.	Queued through traffic or right turning traffic is often found to block the exclusive left turn. Thus, left turning vehicles experience delay.	Delay experienced by left turning vehicles are carefully excluded from delay measurement.

First column of Table 1 is showing few characteristics of the predicted delay by the delay formula in case of lane based traffic. On the other hand, the second column of Table 1 is showing the present condition of traffic. The third column provides the necessary precautions taken to validate the comparison of the field observed delay and the formula delay.

Statistical Comparison Analysis: A statistical t-test is used as an applicability check to judge the validity of the formula for non-lane behavior condition. Formula predicted delay and field observed delay is compared. Differences of formula delays and observed delays are determined. and sample mean of the differences and sample standard deviation of differences are determined. Then, a t test is performed and the validity of the HCM 2000 formula is checked.

SITE SELECTION AND DATA COLLECTION

For the study, Hotel Sheraton intersection (3 legged) is selected. Each approach of the intersection is used for data collection. Fig. 01 is showing the intersection where data collection is performed.

Fig. 1: Hotel Sheraton Intersection

Now, Data collection needs two video cameras performing simultaneously to cover the full queue. One camera focuses on the intersection while other focuses on the tail of queue. An overlapping portion exists between the two videos so that the two videos can be combined together during data transcription. Details of data collection can be found in Farabi(2017). Data is transcripted from the videos to determine various traffic parameters and observed delays.

FIELD OBSERVED DELAY ANALYSIS

Field delays of each approach of the intersection is measured. Delays are measured for fifteen minutes mostly as suggested by HCM. The Table 2 provides a complete summery of different traffic parameters and field delay.

Table 2: Summery of different parameters and field observed delay

Approach Name of Sheraton Intersection	*Obs. No.*	*Analysis Period, T (sec)*	*Saturation Flow, S (PCU/hr)*	*Arrival Flow rate, v (PCU/hr)*	*Total Cycle Time, C (sec)*	*Total Effective green, g (sec)*	*Approach Capacity, c=(g/C)*S (PCU/hr)*	*Degree of Saturation, (X =v/c)*	*Field Delay (sec/veh)*
East	1	682	5314	1434	806	223	1471	0.97	52.91
	2	900		1207	896	320	1898	0.64	17.72
	3	840		1181	964	332	1831	0.65	28.31
	4	660		1466	837	302	1918	0.76	23.66
	5	703		1442	703	209	1580	0.91	58.53
	6	900		1614	1080	418	2057	0.78	113.63
	7	900		1860	1099	456	2205	0.84	47.12
South	1	900	2814	370	878	198	635	0.58	54.07
	2	900		465	1107	269	684	0.68	59.08
	3	900		482	872	191	617	0.78	24.94
	4	900		365	886	145	461	0.79	35.82
	5	900		520	947	228	678	0.77	39.46
North	1	900	5436	1488	993	355	2087	0.71	32.89

Table 2 is showing values of different traffic stream parameters and observed delay for corresponding delay analysis period. For each analysis period, various parameters are determined. All flow rates are described in terms of PCUs. Now, PCE values and other parameter estimations are described below:

Field Observed Delay: The analysis period is divided into constant intervals and number of queued vehicles are counted for each interval as mentioned in HCM. Queue counting continues throughout the survey period. Time in queue delay is calculated using HCM provided formula. Delay due to acceleration-deceleration is estimated using HCM provided chart as it is very difficult to determine without sophisticated instrument.

Passenger Car Equivalent: PCE values are taken directly from the Hadiuzzaman et al. (2008) which were derived from synchronous regression analysis. Table 3 shows the derived PCE values:

Table 3: Regressed PCE Values derived by Hadiuzzaman et al. (2008)

Vehicle Type	Intersection	Approach Name	Pickup	Car	Bike	CNG	Bus	Truck
PCE	Sheraton	East	1.211	1	0.108	0.69	4.513	4.513
PCE	Bangla Motor	North	1.313	1	0.453	0.338	2.252	2.252

For the east approach and south approach of the intersection, regressed PCE derived for East approach by Hadiuzzaman. et al. (2008) is used directly. But, for the north approach of Sheraton, PCE derived for the Bangla Motor north approach is used. This is because of the fact that north approach of Bangla Motor is just upstream of Sheraton north approach. Therefore, vehicle composition of North approach is mostly same as North approach of Bangla Motor. Also, approach width of Bangla Motor is 10.6 meter which is pretty close to North approach (Width is 10.23 meter) of Sheraton. Therefore, it can be considered a reasonable approximation for PCE values.

Saturation Flow: Saturation flow is measured by Road Note 34 method. As the cycle times vary greatly in the survey periods, Road Note 34 method is not possible to be applied directly. Therefore, the method is applied to each cycle to calculate saturation flow. Average of saturation flows has been used as

Saturation flow for that approach.

Arrival Flow Rate: Arrival flow rate is determined by the method mentioned by McShane and Roess (1990). This method is such that the number of vehicles that discharges during green time is counted. Also, if there are any queued vehicles at the end of green time, these vehicles are also counted. Summation of discharged vehicle and the queued vehicles are arrival vehicles in that particular cycle. Total number of arrival vehicles are divided by cycle time to get the arrival flow rate.

Other Traffic Parameters: Vehicles arrival in green, stopped vehicles are counted. Cycle time, green time, amber time are measured directly. Initial lost time and final lost time are calculated from Road Note 34 method. Effective green time (g) is determined by deducting lost times from the Green (G) plus Amber time(A). Using the effective green time (g), approach capacity (c) is determined. The formula is shown in Table 2. Degree of saturation is determined by dividing the arrival flow rate (v) by approach capacity (c).

COMPARISON ANALYSIS OF FORMULA DELAYS AND OBSERVED DELAYS

Based on the values of different parameters provided in Table 2 and other factors determined by following HCM as mentioned above, a comparison between HCM 2000 formula delays with field observed delays is provided below in Table 4.

Table 4: Delay Comparison Table

Approach Location		Field Delay (sec)	HCM 2000 Delay				Difference between theoretical delay & field delay	% of Error
			Uniform delay component, d1(sec/veh)	Overflow delay component, d2(sec/veh)	Delay due to pre-existing queue, d3 (sec/veh)	Total control delay d=d1*P.F.+d2+d3		
East	1	52.91	28.94	16.33	0	43.94	-8.97	-16.95
	2	17.72	21.92	1.64	0	25.00	7.28	41.09
	3	28.31	21.00	1.77	0	24.31	-4.00	-14.12
	4	23.66	26.51	2.93	0	23.02	-0.64	-2.72
	5	58.53	59.63	9.17	0	69.62	11.09	18.95
	6	113.6	90.65	3.09	0	93.74	-19.89	-17.50
	7	47.12	36.34	4.16	0	41.93	-5.19	-11.01
South	1	54.07	25.21	3.88	0	29.03	-25.04	-46.32
	2	59.08	55.26	5.39	0	60.12	1.04	1.76
	3	24.94	35.69	9.50	0	34.13	9.19	36.85
	4	35.82	35.60	13.03	0	42.40	6.58	18.38
	5	39.46	33.48	8.11	0	44.13	4.67	11.84
North	1	32.89	39.34	2.11	0	40.68	7.79	23.68

Table 4 shows the field observed delay and corresponding control delay value for each period. As, no period of analysis started with initial queue, this value is zero. Progression adjustment factor (P.F.) is calculated directly using formula provided in HCM 2000 manual. For incremental delay factor, the value used for each analysis period is 0.5. As most of the delay periods have high degrees of saturation, the value 0.5 is much closer to the value provided in the HCM chart. and this can be considered a very reasonable approximation. In case of upstream metering adjustment factor, value of unity is used.

Again, Table 4 compares field delay with theoretical delay and provide percentages of errors. It is observed that difference of delay from the formula ranges from -25 seconds / vehicle to +11 seconds/ vehicle. The percentage of error is below 20% for most of the points.

MODIFICATION JUSTIFICATION OF HCM 2000 FORMULA

As the Table 4 shows there exist differences between theoretical formula delays and field values, it is needed to justify whether the effect of non-lane behavior is significant or not. Now, according to HCM formula, the mean of differences of delay should be zero. So, the population mean should be zero.

Table 5: Hypothesis Testing

Sample mean of differences	Sample standard deviation	Population mean	Number of Observations	|t-statistic|	|Critical t|	Comment
-1.23728	11.23253	0	13	|-0.397| = 0.397	2.28	Non-Significant

From Table 5, it can be concluded that, null hypothesis is accepted at 5% level of significance. So, the difference between field delay and theoretical delay is in the accepted portion implying the fact that the difference is statistically found to be zero.

CONCLUSIONS AND RECOMMENDATIONS

The study asserts that the effect of non-lane behaviour on the HCM 2000 delay formula is not significant. The absence of lane following behaviour in traffic flow is not a factor that causes significant deviation of delay provided by HCM 2000 delay formula. It can also be concluded that the HCM 2000 delay formula is applicable to non-lane based homogeneous traffic where vehicular flow is not hampered by external disturbances. If external disturbances are present to a great amount, the formula may not provide actual field delay value and thus modification may be needed. Although the study provides valuable finding, there is still much scope of future development. More field data should be used to delay comparison analysis. Also, the validity of the formula should be checked with data that have degrees of saturation greater than unity.

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PERFORMANCE EVALUATION OF KHILGAON FLYOVER IN DHAKA CITY

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ABSTRACT
This paper evaluates the functional effectiveness of Khilgaon flyover in terms of road usage and travel speed. Evaluation criteria used include congestion degree and speed characteristics, measured over four time-periods, namely, weekend day, weekend night, weekday day and weekday night. On average, around 45% vehicles use at-grade facilities, leading to conflicts and congestion. Average speed was 28.11 km/hr over flyover, but merely 9.35 km/hr at at-grade level, which is only slightly faster than the average walking speed. It indicates insignificant improvement in mobility and contributes to enormous economic losses. In addition, performance measures have been compared with a previous study on the same flyover considering temporal variation. Compared to 2015 weekday day period, flow has increased 1106% at above-grade and 58% at at-grade respectively, indicating increased conflict potential. Non-motorized vehicles (NMVs) have been given special attention since geometric configuration does not allow them to use above grade facilities and nearly all NMVs use at grade facilities. This implies that there will be perennial vehicle-vehicle and vehicle-rail conflicts at grade level. The study concludes by providing suitable recommendations to address this problem, especially underscoring the need to implement demand driven policies, such as mass rapid transit.

Keywords: Rail-Road Traffic Conflict, Flyover; Performance Evaluation; Level Crossing; Dhaka City.

INTRODUCTION

With a population of 19.58 million in 2018 growing at a rate of 3.62%, Dhaka, the capital of Bangladesh, is considered to be one of the most densely-populated and traffic-congested cities in the world (Hasnat et al., 2018). Non-lane based heterogeneous traffic with weak road infrastructure makes the situation worse and eventually, results in enormous economic and financial losses along with severe environmental impacts (Hasnat et al., 2016; Hasnat et al., 2018a; Islam et al., 2018; Islam & Haque, 2016). People spend on an average 2.35 hours in traffic activities daily, of which more than a half of that (1.30 hours) is eaten up by to traffic congestion. Resulting financial loss from traffic congestion in Dhaka city is well over $18.5 million per day (Rahman et al., 2018). The media, both print and electronic, have been constantly highlighting the sufferings of the commuters in Dhaka city caused by incessant traffic problems. However, no solution to the problem has been foreseeable in the short and medium terms, despite undertaking many programmes with the assistance from a multilateral lender to improve the traffic situation of the capital city in recent years (Islam et al., 2018a, 2018b). As most of Dhaka city is built-up area, there is little provision for at-grade expansion of existing roadway (Anwari

et al., 2018a, 2018b). Hence a presumptive reliance based local knowledge has been shifted to flyovers to mitigate traffic congestion. Consequently, several flyovers have been built in Dhaka City to improve safety and mobility of at-grade traffic city (Anwari et al., 2016a, 2016b). Detailed observations have shown that of the 8 flyovers constructed in Dhaka city, 6 are partially grade separated from rail traffic and are at abject at-grade traffic conditions. This paper focuses on the partially grade-separated Khilgaon Flyover, where the prevalence of rail-road traffic conflict has drastically reduced travel comfort and mobility. This study was carried out to assess how far the objectives have been met through constructing this flyover, with respect to degree of grade separation and mobility.

LITERATURE REVIEW

Given the prevalence of flyovers in Dhaka city, surprisingly few studies have approached this subject methodically.

Taleb and Majumder conducted a research on two flyover projects at Mohakhali and Khilgaon intersections in Dhaka and investigated how people in adjacent land of newly constructed flyovers are affected. They conclude that some businessmen and land-owners have experienced reduced incomes after construction of flyovers. They argue that, the flyover construction deteriorated the visual impact and the benefits diverted to the local people are extremely negligible because they neither can use the flyover nor release from the traffic jam of the linked intersection (Taleb & Majumder, 2012). However, the questionnaire surveys were conducted on an inadequate sample number, which may not give accurate picture of people's opinions and represent the real scenario. Besides, the paper did not use any income analysis.

Uddin made important discoveries regarding seismic loading on Khilgaon flyover. He performed static and dynamic linear analyses. He urged to design such kind of structure considering a probable earthquake and investigated the behavior of the Khilgaon flyover under seismic forces. However, the study neither evaluated the performance of Khilgaon flyover nor the other flyovers from mobility and accessibility point of view (Uddin, 2006).

Kadir, Hasan, Sen and Mitra (2016) estimated vehicle operating cost and environmental cost for delay at major railroad intersections of Dhaka city corporation area. They studied nine major intersections with rail-road traffic conflict including Saidabad Level Crossing, Khilgaon Level Crossing, Maghbazar-Mouchak Level Crossing, Mohakhali Level Crossing and Banani Level Crossing. The study showed that total daily loss of time, annual cost of required additional fuel and cost of air pollution are 751.3 minutes, 103.59 million BDT and 8813.50 million BDT respectively for the studied nine intersections (Kadir et al., 2016). Although, the study dealt with rail-road traffic conflict in terms of vehicle operating cost and environmental cost, it did not incorporate any analysis regarding the flyover or traffic flow and mobility.

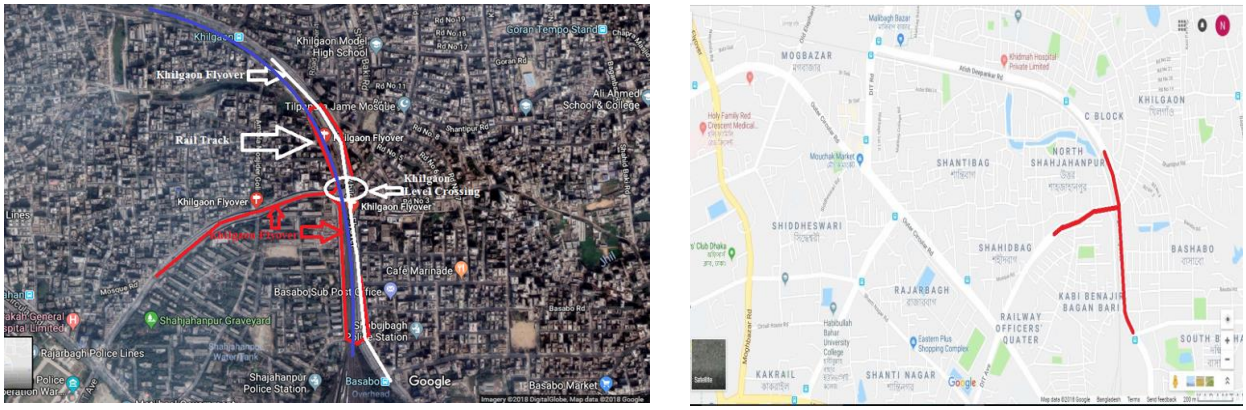
Anwari, Hoque and Islam (2016) focused on operational effectiveness of the partially grade-separated flyovers built on level crossings in Dhaka city till February 2016. They considered six partially grade-separated flyovers in Dhaka including Jatrabari-Gulistan Flyover. The evaluation criteria used include assessment of vehicular as well as pedestrian safety at level crossings under those flyovers, degree of congestion and speed characteristics. However, the study didn't incorporate the variation of flow during different times of the day (Anwari et al., 2016a).

Anwari, Hoque and Islam (2016) further explored the reasons for poor traffic operation and rail-road conflict at Shaheed Ahsanullah Master Flyover. The study was conducted to identify and evaluate the at-grade traffic movement at Tongi Level Crossing under the flyover. This paper shed light on the traffic problems prevailing at Tongi Railway Crossing. However, it is a fraction of the entire city and it didn't cover the other flyovers in Dhaka city as a sum and assess the overall impact on mobility and accessibility in Dhaka city (Anwari et al., 2016b)

Negligible systematic analysis has been performed to evaluate the performance and effectiveness of Khilgaon Flyover constructed over rail-road level crossing in Dhaka city. The aforementioned literatures neither dealt comprehensively with the performance evaluation of Khilgaon Flyover nor did they quantify the identified problems. In addition to that, performance evaluation of this flyover incorporating temporal variation of traffic flow and volume along with pedestrian consideration are completely missing. In this backdrop, this research is an attempt to investigate how the partially grade separated Khilgaon Flyover constructed at the level crossings have facilitated city-dwellers in terms of mobility and accessibility.

STUDY AREA

As a part of the total initiatives to improve the traffic situation in Dhaka, the then government approved the Khilgaon Flyover project in the ECNEC meeting held in 2000. It is the second flyover in Bangladesh and was commissioned on March 22, 2005. The latitude and longitude of the flyover is 23° 44' 36.9888" N and 90° 25' 35.9472" E. The construction process of the flyover began in September, 2001. The 1.9 km flyover was completely made by local experts. The Local Government Engineering Department (LGED) implemented the project at a cost of about BDT 81.75 crore. The two-lane flyover, which is 14 meters wide, has a 780-meters main bridge and three ramps. The ramp towards Saidabad is 220 meters, Malibagh 202 meters and Rajarbagh 222 meters (Taleb and Majumder, 2012). However, the implementation was not done as per original plan or design because the subsequent government (2001-2006) dropped one of the important loops (Saidabad side) from the project. This has seriously constrained the objectives and expected benefits of the flyover as originally planned. Till now the large volume of traffic coming from Progoti Sarani and eastern part of the city (Mothertek, Kadamtali, Basabo, Shepaibag, Meradia, Goran) cannot use the existing flyover and they do not have any other uninterrupted access toward Motijheel commercial area and Rajarbag (LGED, 2017).



(a)

(b)

Fig. 1: Khilgaon Flyover. (a) Layout of the Flyover (Google Earth and Google Map View); (b) Khilgaon Level Crossing.

The red lines and white lines shown in Fig. 1(a) (Google Earth View) show the alignment of the flyover while the indigo lines show the rail track passing through the flyover. Field study reveals Khilgaon Level Crossing acts as a rail-road conflicting point beneath this flyover, as depicted in Fig. 1(b). The latitude and longitude of the Khilgaon Level Crossing are 23° 44' 39.4008" N and 90° 25' 34.9752" E respectively.

METHODOLOGY

A reconnaissance survey was first conducted to assess level crossing adjacent land use and surrounding conditions. Video based 15 minute classified traffic counts were made by Cordon count method identified from analysis of hourly traffic count over a period of 24 hours for the following four periods: weekend-day, weekend-night, weekday-day and weekday-night. Vehicles were then counted after analyzing video. Travel speeds at each segment was calculated using travel time measured via floating car method during peak hour conditions. The field survey works were undertaken between 6th October 2017 and 11th October 2017.

ANALYSIS OF OBSERVED TRAFFIC CONDITIONS

Week-end, day data was collected at 5.15 pm - 5.30 pm on 06.10.2017 (Friday); Week-end, night data was collected at 8.30 pm -8.45 pm on 06.10.2017 (Saturday). Weekday, day data was collected at 5.15 pm -5.30 pm on 11.10.2017 (Wednesday). Weekday, night data was collected at 8.30 pm- 8.45 pm on 11.10.2017 (Wednesday). The time period for collecting data in weekday, day; weekday, night; weekend, day and weekend, night have been identified from analysis of hourly traffic count over a period of 24 hours in this corridor. After gathering data both manually and using video, comprehensive analyses of the collected data have been made and the findings are presented in the following sections.

Assessment of Traffic Flow

Classified traffic count was performed to assess the relative level of usage of road space under and over the flyover. Since vehicles of various sizes and weights pass through the study area, it was requisite that their impact be judged using a common unit. Hence, the vehicle counts were converted to passenger car units, using the following passenger car equivalent (PCE) factors prescribed by the Ministry of Communication (2000): Rickshaw/Van: 2.00, Motorcycle: 0.75: Bicycle: 0.50, Car: 1.00, CNG: 0.75,Tempo: 0.75, Bus: 3.00, Utility: 1.00, Truck: 3.00, Bullock Carts: 4.00 (Ministry of Communication, 2000). Accordingly traffic flow in terms of PCUs were obtained multiplying vehicle count data by their corresponding PCE factors.

The total flow across different times of the day are compared in Figure 3. Figure 3s reveal an interesting information regarding Khilgaon Flyover. Comparatively a higher portion of vehicles are travelling through above-grade or using the flyover in weekend night, weekday day and weekday night, reducing the relative probability of rail-road traffic conflict in Khilgaon Level Crossing. However, a completely reversed scenario has been observed at week-end day. The greatest disparity in flows between different grades is at week-day, night, with 36.92 % vehicles travelling at grade and 63.08 % vehicles travelling above grade. The reverse is case is observed in week-end, day, where 56.31 % vehicles travelling at grade and 43.69 % vehicles travelling above grade. The rationale for this may be justified by the fact that the number of induced vehicles in this flyover corridor is drastically decreased since Khilgaon Flyover is very close to central business district, Motijheel. Another reason is that there is a large whole-seller market and kacha-bazar (Good quality vegetables, fish and meat selling point with small price). This induces customers from surrounding area and they prefer to use at-grade road to go this market.

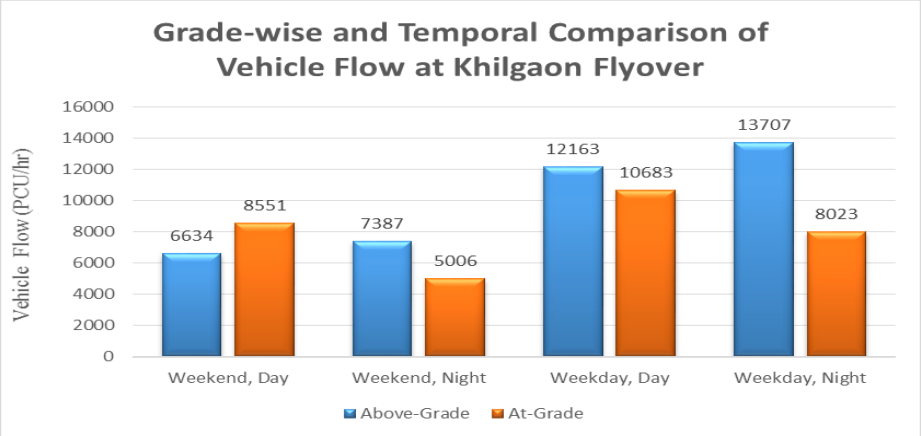


Fig. 3: Grade-wise and Temporal Comparison of Vehicle Flow at Khilgaon Flyover.

Overall, the ratio of above-grade to at-grade flow is only 1.24:1. From Fig. 3, it is observed that the highest flow at above-grade (13707.08 PCU/hr) at weekday, night and at at-grade (10683.04 PCU/hr) occurring at weekday, day. This implies that maximum flow both at-grade and above grade-occurs at weekday period. The rationale for higher flow in weekday compared to weekend day time period may be explained by the fact that people from surrounding districts and areas come to Motijheel for work purpose. As house rent and life-expense is extremely high in Dhaka, People who work in Motijheel area with less salary prefer to live outside the main city to save their cost and they usually don't come to main capital during weekend days. Hence, Weekday flow in this flyover corridor is generally higher than weekend flow.

In addition to that, maximum flow at-grade occurs at day whereas maximum flow above-grade occurs at night. Further, weekend time period, night flow is 41.46% less than that of day flow at-grade level and 11.34% higher at above-grade. Whereas, in weekday time period, night flow is 24.90 % less than that of day flow at-grade level and 12.70% higher at above-grade. It indicates that flow increases at-above grade and decreases at at-grade during night time and hence, it implies that road users are more likely to use flyover at night time. It may be due to the fact that Khilgaon is just beside the central business district. Many districts connecting vehicles take their passengers from the central area, i.e., Motijheel, Malibagh, Arambagh, Basabo and they pass through Saidabad-Jatrabari bus stand using this flyover. Hence, to save their time and make the journey faster along with avoiding the small-lane width road underneath the flyover, they prefer to use flyover at-night time.

A comparison has been drawn between the weekday, day data of Anwari, Hoque and Islam (2016) collected in 2015 with the present data set of this study to visualize the yearly variation of flow and also to observe whether the flyover is performing well than previous or not.

Fig. 4 shows that the vehicle flow has increased at both grades (from 1008 PCU/hr to 12163 PCU/hr above grade, and from 6755 PCU/hr to 10683 PCU/hr at grade. Compared to 2015 weekday day period, flow has increased 1106% at above-grade and 58% at at-grade respectively. This implies that the yearly increase rate in above-grade traffic is much higher than that of at-grade, which is definitely a positive indication regarding the performance of this flyover. In addition to that statistics, the above grade to at grade flow ratio has increased from 0.149:1 to 1.138: 1, indicating a prodigious increasing trend for vehicles to move from at grade to above grade. So, flyover has been successful in diverting greater portion of traffic at above-grade, although a larger proportion of vehicles are forced to use at-grade road because of the flyover configuration.

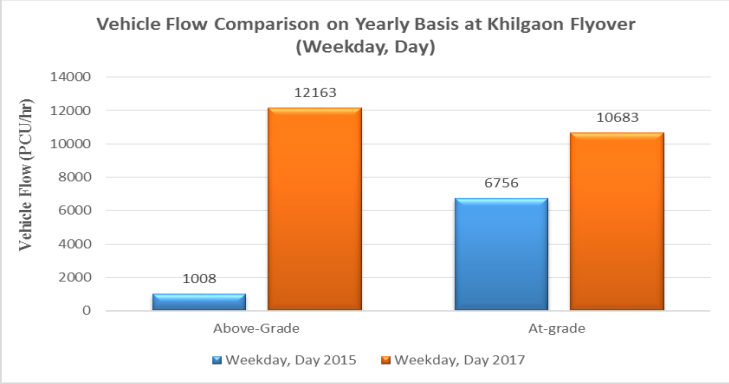


Figure. 4: Comparison of Vehicle Flow on Yearly Basis of Khilgaon Flyover (weekday day).

A comparison of modal share of observed flow has been highlighted in Fig. 5.

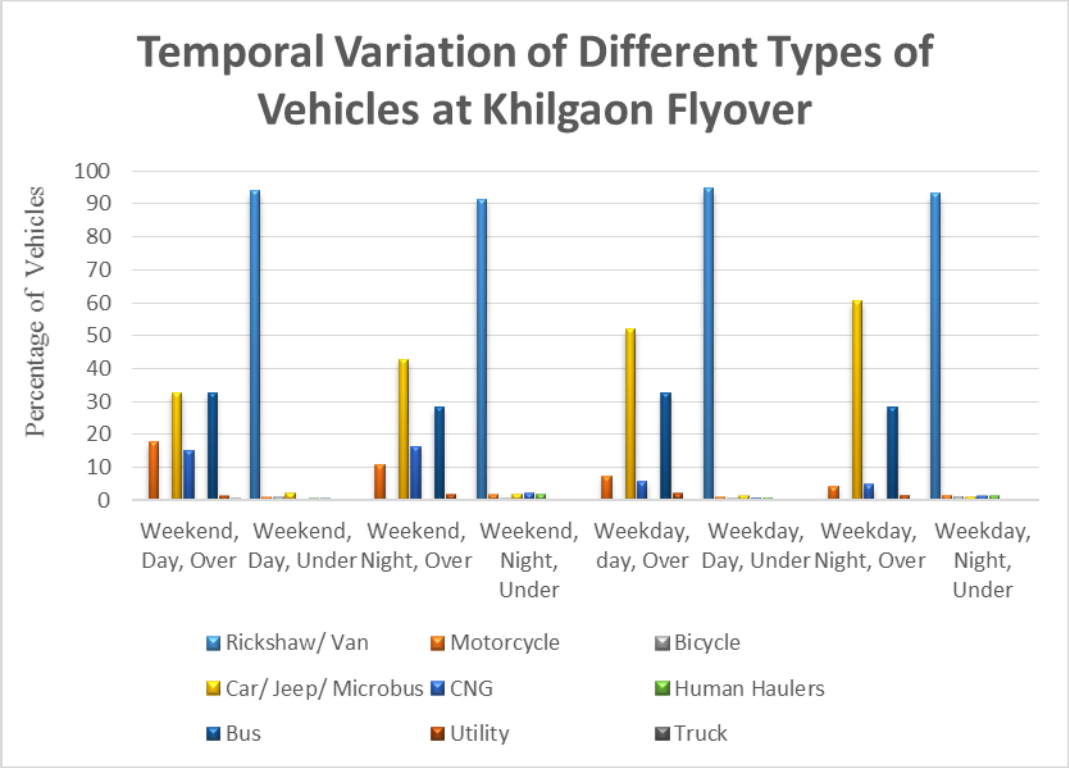


Figure 4: Temporal Variation of Different Types of Vehicles in Khilgaon Flyover

Fig. 5 reveals that Car/Jeep/Microbus is the main beneficiary of this flyover. In the considered four time periods, Car is the dominating vehicle at above-grade, and Rickshaw/Van is dominating vehicle at at-grade. In weekend, day time period, Car (32.67%), Bus (32.62%) and CNG (15.23%) are dominating vehicles at above-grade. At-grade scenario is completely different. Here, Rickshaw/Van is dominating (93.90%) exclusively. All the others vehicle's percentage is negligible in this time framework. Almost same scenario has been observed in the weekend, night period data analyses. In weekend night time period, Car (42.7%), Bus (28.4%) and CNG (16.37%) are major shareholders at above-grade. At-grade, Rickshaw/Van is dominating (91.45%) exclusively. All the others vehicle's percentage is negligible in this time framework.

Car has also been found to be used by the highest number of road users at above-grade (52.01%) in weekday, day period. Bus (32.5%) is next to car at above-grade. Rickshaw/Van is dominating (94.8%) exclusively at at-grade in this time period. Again, Car has again been found to be the most dominating above-grade (60.49%) in weekday, night period and Bus (28.43 %) is found next to car. Rickshaw/ Van (93.11%) is also dominating at at-grade of this flyover corridor. All the other types of vehicles i.e., Motorcycle, Bicycle, Utility Vehicles and Trucks are present in negligible percentage.

From Fig. 5, it is also found that Rickshaw is the overwhelming major transport used at grade (94% of total flow at-grade) while Car/Microbus/Jeep is the most numerous above grade mode (50% of total flow above-grade).

A negligible presence of NMVs (only 1.92% bicycles of total NMVs at weekend, day) travelling above grade can be attributed to the dimensions that the grades of the approach ramps of flyovers make it difficult for NMVs to get on the flyover. This means that a significant portion of traffic will always be forced to travel at-grade and come in conflict with rail, implying that there will always be conflict with rail at level crossings whether or not flyovers are present. Consequently, it can be concluded that it is never completely possible to eliminate conflicts at level crossings by continuing the design approaches adopted for flyover design in Bangladesh. Anwari, Hoque and Islam (2016) observed that nearly half of at-grade flow of all flyovers is attributed to NMVs. This implies that nearly 50% of existing vehicles will continue to come in conflict with rail. The present study reveals that 42.26 % of total traffic are NMVs and only 0.01% of total NMVs are using this flyover whereas, 99.99 % NMVs of total NMVs are forced to use at-grade road. Hence, it is clearly evident that NMVs are not the beneficiary of constructing this flyover.

However from the light of above discussion, it is clear Khilgaon Flyover is partially successful in fulfilling the objectives of segregating rail and road traffic and thereby successful in eliminating congestion as well as to improve safety issues. However, it has completely failed to provide any facility to the NMVs and pedestrian. In addition to that, the flow interruption and level of congestion will worsen with the ever growing size of motorized and non-motorized vehicle fleet along with high degree of pedestrian movement. Therefore, it is evident that it would not be able to make conflict free movements for both rail and road traffic in the studied flyover, which is the prerequisite of controlling congestion and improving safety.

Assessment of Speed

Travel speed of each type of vehicle was measured at Khilgaon Flyover to assess the mobility conditions of vehicles both at-grade and above grade. Travel speed has been calculated by dividing the segment length of the studied road segment by the sum of total time in motion, segment delay and through vehicle delay. These speeds were measured incorporating temporal variation in weekday, Night; Weekday, Day; Weekend, Night and Weekend, Day and presented in Fig. 5.

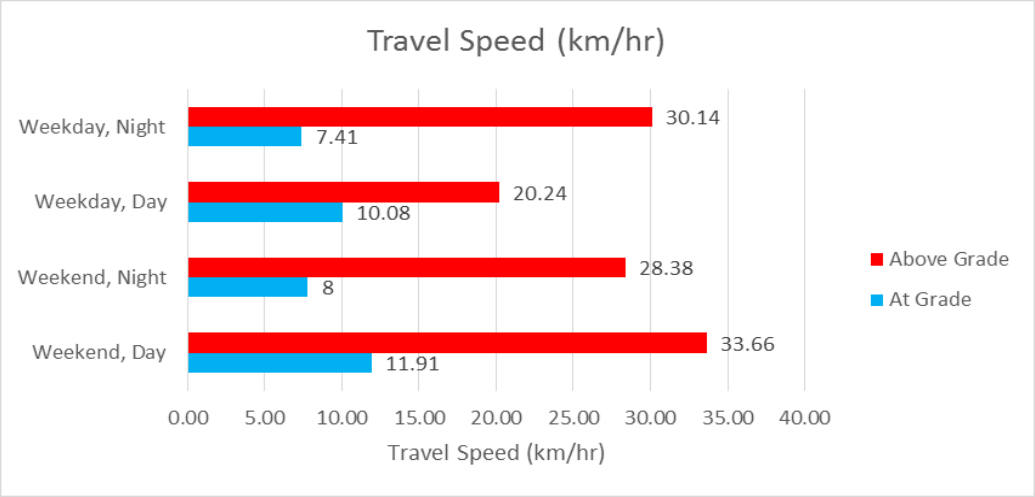


Fig. 5: Vehicle Travel Speed at Khilgaon Flyover

It is observed that the fastest travel speed above grade was in weekend, day (33.66 km/hr) while the slowest was in weekday, day (10.08 km/hr). The fastest travel speed at grade was in weekend, day (11.91 km/hr) while the slowest was in weekend, night (8.00 km/hr). The combined average speed of Jatrabari-Gulistan Flyover was 28.10 km/hr above grade and 9.28 km/hr at grade, implying a vehicle on average is 3 times slower in at-grade traffic. Comparing with 2015 data on Anwari, Hoque and Islam (2016), the discrepancy between above grade and at grade average speed has decreased (4.83 times in 2015 as compared to 3 times in 2017). The combined average speed at day was 26.95 km/hr above grade and 11.00 km/hr at grade. The combined average speed at night was 29.26 km/hr above grade and 7.71 km/hr at grade. So there is little variation in speed between day and night, meaning traffic speed is similar at both times. The combined average speed at weekday was 25.19 km/hr above grade and 8.75 km/hr at grade. The combined average speed at weekend was 31.02 km/hr above grade and 9.96 km/hr at grade. In this regard a weak relationship was observed between vehicle flow and average speed. Increase in vehicle flow reduced average speed and vice-versa.

CONCLUSIONS AND RECOMMENDATIONS

This paper has highlighted and compared the present state of flow at grade and above grade on Khilgaon Flyover. The highest flow has been observed at weekday, day while the lowest has been observed at weekday night at grade. On the other hand, the weekday, night and weekend, day revealed highest flow above grade. Even though majority of the vehicles travel above grade, a significant portion (44.64%) of vehicles continue to use at grade facilities. In addition, the average at-grade travel speed was measured to be only 9.35 km/hr, with traffic travelling as slow as 7.41 km/hr at weekday, night. This is only slightly higher than the average walking speed of 5 km/hr (Bohannon, 1997). The reason

behind such dismal performance of flyovers is the surrounding land use pattern, which attracts people and encourages access-friendly activities. It means that vehicle conflicts will be perennial, and comparison with Anwari, Hoque and Islam (2016) reveals that such conflicts will increase in future. Supply-side policies such as flyovers are not enough to meet people's demand. Developed countries have shown that demand driven policies provide long lasting solutions. For sustainable and durable solution, organized public transport system along with Bus Rapid Transit (BRT) and Mass Rapid Transit (MRT) needs to be introduced to address and focus people's demand, which is expected to reduce the volume of private cars as well as smaller sized vehicles on road.

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CLIMATIC VULNERABILITY OF RURAL INFRASTRUCTURES

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ABSTRACT
Transportation in Bangladesh remains sensitive to a number of weather-related hazards because of its geographic location, low deltaic floodplain, and hydro-meteorological influence of erratic monsoon rainfall and other extreme climate events. This study has assessed the effect of predicted water levels from BWDB stations on the RHD transportation network in the district Khulna of Bangladesh. The output of the study is the vulnerability evaluation of RHD road network of Khulna where it had been shown which portion and what percentage of the road are at a risk of inundation and future damage and need urgent measurement to fight against overtopping or getting submerged.

Keywords: RHD; BWDB; Vulnerability; Inundation; Overtopping.

INTRODUCTION

Being susceptible to natural hazards, road infrastructures are on a major threat for being especially vulnerable due to the natural terrain and shortage of fund to build sustainable infrastructure. The study aims to identify the points on RHD roads of Khulna region those are at the risk of inundation for the rise of water level of the adjacent rivers during storm surges. An inventory of the roads was made to identify which one is extremely susceptible to climatic impacts. Sustainability of recently approved Road Master Plan for Bangladesh was also analyzed. The ultimate objective of this study is to recommend adaptation measures for coping with existing and possible vulnerability and climate change impacts on transport infrastructure of the country.

METHODOLOGY

The objective of this study is to find out the vulnerable transport networks i.e. roads, highways, culverts and bridges with respect to Climate Change related impacts especially due to sea level rise, flood and inundations along the coastal areas of Bangladesh.

Theory for Remote Sensing and GIS

Remote sensing provides synoptic view of the terrestrial landscape and is used for inventorying, monitoring, and change detection analysis of environmental and natural resources (Narumalani et al. 1997). The recently developed remote sensing and GIS technologies and availability of better resolution data have revolutionized the mapping of wastelands and other natural resources. Hydrological models and remote sensing techniques are advanced tools that are better suited to estimate the evaporation, the related hydrological and the hydro-morphological processes at the regional scale (Beven et al., 1988). Remote Sensing technology has been recognized as a useful means of supplying up to date information on activities within the urban environment (Treitz et al, 1992)

Theory for IDW interpolation method

Inverse distance weighted (IDW) interpolation determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. This method assumes that the variable being mapped decreases in influence with distance from its sampled location. IDW relies mainly on the inverse of the distance raised to a mathematical power. The Power parameter controls the significance of known points on the interpolated values based on their distance from the output point. It is a positive, real number, and its default value is 2.By defining a higher power value, more emphasis can be put on the nearest points.

Collection of Base Data of the study area

For conducting the analysis, water level data of 41 BWDB stations in the south-western region of Bangladesh was collected for the years 2009, 2010, 2011, 2012, 2013, 2014, 2015 and 2016. These water level data were analyzed and maximum water level for each year was enlisted. Collected water level data were enlisted with respect to PWD (Public Works Datum). So for the sake of the analysis of the data with elevation data from DEM, the units are converted from PWD to MSL which is with respect to Mean Sea Level. MSL = (mPWD – 0.46) demonstrates the method of converting PWD to MSL. Also the RHD road network of Khulna was collected from RHD [Fig 1]. Digital elevation model (DEM) was collected for the south-western region [Fig 2] (Source: USGS Earth Explorer).Finally all the data sets were superimposed as layers on ArcGIS according to their individual coordinate system for further analysis [Fig 3].

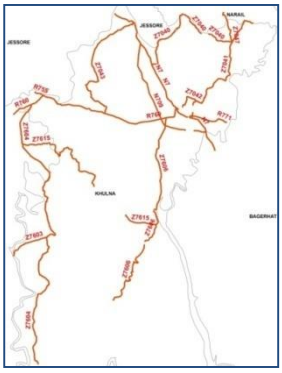

Fig 1: RHD road of Khulna

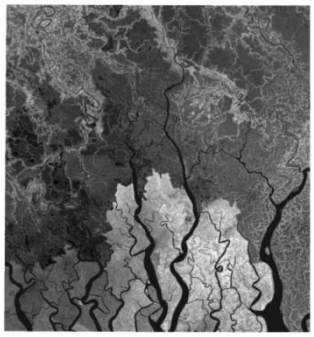

Fig 2: Digital Elevation Model of Khulna

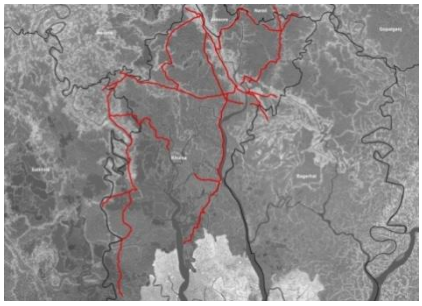

FIG 3: RHD Road network with DEM

Extraction of the elevation of road crest level from DEM

A 90m resolution DEM gives a single elevation data for every 90m distance. By superimposing RHD road network over DEM in ArcGIS, points were created at every 90m over the crest level. For each of these points, elevation data were extracted from DEM those are in the unit of MSL (Mean Sea Level) by simulation in ArcGIS. Accuracy of the model was further checked by cross matching the average elevation data of each road with original surveyed average elevation by RHD.

Interpolation of Water level over pavement surface by IDW method

Stations of BWDB that had been used for water level data analysis was found to be over the river surface that was a bit far away from the road network system. [Fig. 4] clearly demonstrates the relative positions of water level and road network. So direct comparison between the elevation of the Road crest level and water level data would predict erroneous result. For the sake of the accuracy of the analysis, a spatial analyst tool, Inverse Distance Weighted interpolation (IDW) was used in ArcGIS to predict the effect of maximum water level over the pavement surface for every single year. This simulation results in a raster data set and a surface of water over the entire road network [Fig 5, Fig 6, Fig 7, Fig 8, Fig 9, Fig 10, Fig 11, Fig 12, Fig 13]. From this model, elevation of the water level was extracted exactly of those points whose elevation was extracted from DEM.

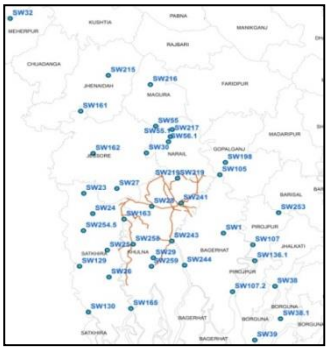

Fig 4: BWDB Stations in south-western region

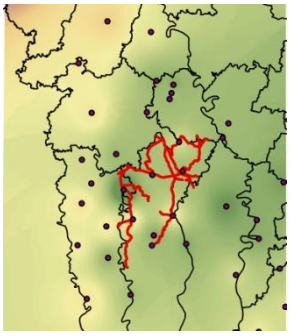

Fig 5: IDW for 2009

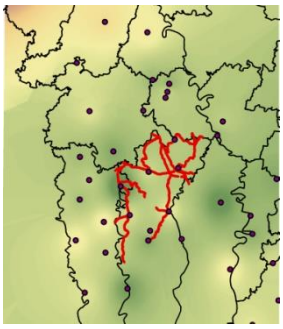

Fig 6: IDW for 2010

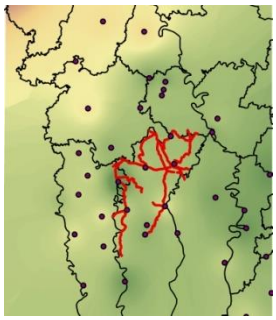

Fig 7: IDW for 2011

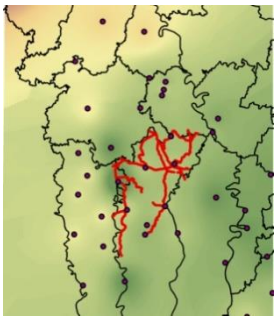

Fig 8: IDW for 2012

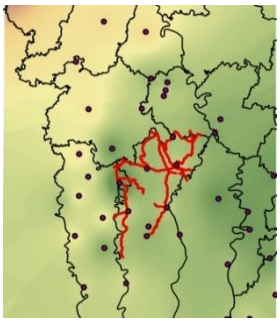

Fig 9: IDW for 2013

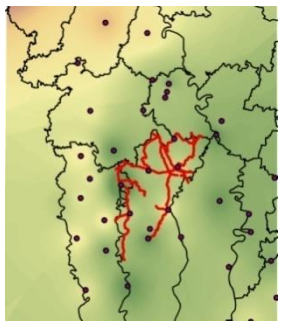

Fig 10: IDW for 2014

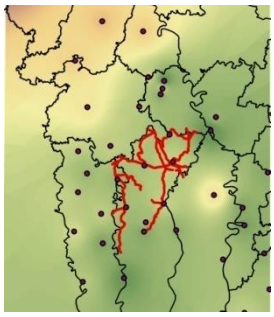

Fig 11: IDW for 2015

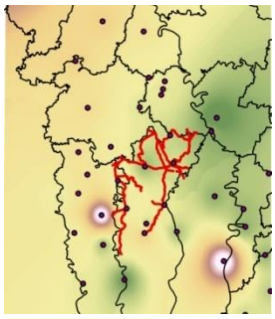

Fig 12: IDW for 2016

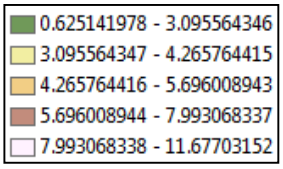

Fig 13: Legend

Identification of Vulnerability

From BWDB the water level station location that had been simulated in ArcGIS and IDW interpolation model had been produced, those layers of GIS based data are overlaid with the RHD Road GIS layer for comparison [Fig 3]. As in the pavement design of RHD roads, a depth of one meter freeboard is generally kept for drainage and bad climate scenarios. Therefore in the comparison of inundation data and elevation data on every single point at 90m interval, elevation difference found within 1.5 meter were taken as vulnerable point : Water level ~ Elevation from DEM ≥ 1.5 ; point is vulnerable. On each road- National Highway, Regional Highway and Zilla Road, this research study analysis was conducted to find vulnerability of roads and highways in combating climatic extreme impacts.

Road maintenance data analysis

Roads and Highway Department website contains data for maintenance of RHD road networks for last few years. From the website, data had been collected regarding maintenance of RHD road network of Khulna region for further analysis.

RESULTS AND DISCUSSIONS

The main objective of the study was to examine the vulnerability of road network with respect to inundation and to determine the possible adaptation measures. To achieve this goal, water level interpolation was done from the IDW model simulated and elevation data of road crest level was extracted from DEM in ArcGIS. The test results were tabulated and figures from Model's output were collected from the software for further analysis.

Road Wise Vulnerability Analysis

The comparison between the simulated water levels with the elevation of road crest level data found major vulnerability risk of almost every single road in the entire network. To designate vulnerability of the network, % vulnerability was evaluated by: (Vulnerable points / Total Points) x 100 = % percent Vulnerability. Among all the roads in Khulna RHD road networks, N710, a national highway found to be the safest of all for the risk of inundation having 0% of the % vulnerability. But N709 which is also a national highway, was found to be extremely vulnerable with % vulnerability of 89.14% in 2016 [Fig 14]. Last but not the least total network was analyzed to evaluated ultimate vulnerability trend for the entire network which had been demonstrated in [Table 1 and Fig 15]. Final result regarding the vulnerability of the entire result showed that from 2009 to 2016 the vulnerability increased from 55.71% to 73.37% which indicates a rapid growth of the risk of inundation in the study network.

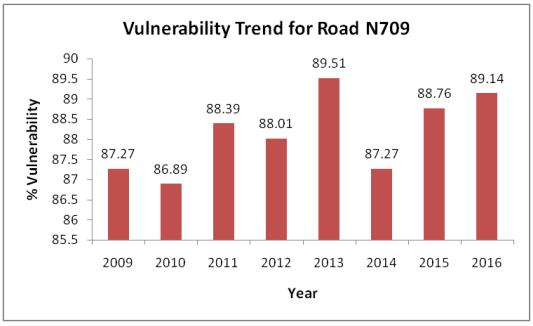

Fig 14: % Vulnerability of N709

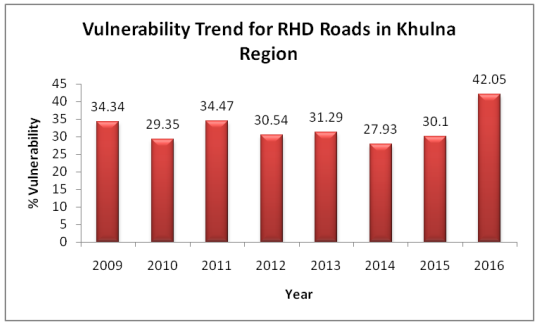

Fig 15:%Vulnerability of total road network of Khulna

Table 1: % Vulnerability evaluation of the entire road network of Khulna Region

Vulnerability Check for RHD Roads in Khulna			
Year	**Total Number of Points taken**	**Vulnerable Points**	**% Vulnerability**
2009	3867	1328	34.34
2010	3867	1135	29.35
2011	3867	1333	34.47
2012	3867	1181	30.54
2013	3867	1210	31.29
2014	3867	1080	27.93
2015	3867	1164	30.1
2016	3867	1626	42.05

Road Wise Maintenance Data Analysis

RHD online database regarding maintenance of roads in Khulna network was analyzed for last few years that were available [Fig 16] It was found that among all the maintenance work, Pavement reconstructed was found to be more frequently done than any other maintenance work. Pavement Reconstruction owns 45% of the total maintenance work done over these years in the study area. Also 26% of the entire maintenance work was found to be Carpeting which is the second most recurrent maintenance performance. This result clearly reflects the pavement condition of the road network of Khulna region that validates the vulnerability model to some extent.

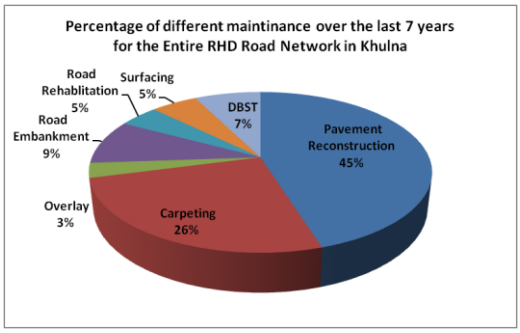

Fig 16: Road Maintenance data analysis of Khulna Region

CONCLUSIONS

Adaptation to climate change risk will put additional strain on development efforts of a country like Bangladesh. This study was conducted as an attempt to understand the risk of vulnerability due to existing extreme climatic condition and to predict future risks as well. The observations, evaluations and results were critically examined and the following conclusions were drawn:

1. In the road transport sector of Bangladesh, research and analysis of road infrastructure vulnerability to climate change impacts is hardly done and conducted.
2. Road N709 was found to be most vulnerable to inundation risk having vulnerability of about 89.14%. Rise of existing embankment and retrofitting of structures is urgently needed on those.
3. Key documents for the planning and development of methodologies and implementation plan in transport sector to combat against climate change- like Roads & Highways Department (RHD) Master Plan, National Adaptation program of actions (NAPA) and Bangladesh Climate Change Strategy and Action Plan (BCCSAP) 2009 has to be revisited.
4. All national and regional roads in Bangladesh has to be designed to build above the highest flood level with a return period of 70 years, and feeder roads need to be designed above highest flood levels.

Following recommendations can be extracted from this project work:

1. In this study road crest level data were taken from the Google Earth software which may differ from the actual level of road. So, from Government as well as institutional level study with proper arrangement to determine crest level by spot level and survey has to be carried out.
2. Culverts and bridges are also important transport infrastructure where a lot of impacts can be impacted by the factors of climate change. So further studies must include all transport infrastructure including roads, roadway embankment, bridges, culverts, bus bay-stations, ferries etc.
3. Storms and Cyclones- this dynamic factor of climate change, Surface Runoff, Precipitation etc was not considered in this study which must have to be considered in the further study along with inundation modeling.
4. In the research study, crest level of the roads of Roads and Highways Department (RHD) were taken into consideration. Same of Local Government Engineering Department (LGED), City Corporations or Municipalities were not included in the study which is recommended to include in further research.

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The author expresses gratitude to Mr. Md. Mahbubur Rahman, Executive Engineer, Roads and Highways Department (RHD) and Mr. Mohiuddin Ahmed, AC, Bangladesh Water Development Board (BWDB) for their help and permission to collect valuable maps, inundation data, report and different facilities regarding the research.

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TRIP GENERATION ANALYSIS OF SHUGHONDA RESIDENTIAL AREA IN CHITTAGONG CITY, BANGLADESH: USERS PERSPECTIVE

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ABSTRACT
As a developing country the transportation system of Bangladesh is facing several problems such as extreme traffic congestion especially in Dhaka and Chittagong. Because of increasing population in Chittagong, the efficiency of the transportation system is becoming more complicated like Dhaka city. Trip generation analysis plays an important role in transportation planning as it is the process of determining the number of a trip that will begin or end in each traffic zone. Depending on the analysis, a smooth transport network can be designed. The study is undertaken to evaluate the total trip generated in different areas of Chittagong city and identify the factors which influencing trips. Shugondha residential area is selected as the study area which is an attractive place for accommodation with all services & facilities and some employment opportunity. Through random sampling, 175 households were taken under a questionnaire survey. The multiple linear regression method is used to predict the trip generation. From the analysis it is found that the variables that mostly affect the trip generation model are trip fare, family size, total time and reliability. The study will be helpful for developing the existing transportation facilities and amenities which conditions are inferior and have a negative impact on total trips.

Keywords: Trip Generation; Travel Analysis Zone; Multiple Linear Regression.

INTRODUCTION

Trip generation defines the frequency of origins or destinations of trips in each zone by trip purpose, as a function of land uses and household demographics, and other socio-economic factors. It aims at predicting the total number of trips generated by (Oi) and attracted to (Dj) each zone of the study area (Ben-Akiva, 2006). It usually answers the question: How many trips originate at each zone? A trip generation has two requirements: trip production and trip attraction. Trip is either produced from traffic zone or attracted to the traffic zone (Zenina & Borisov, 2013). Direction and production define the origin and destination of a trip and land use of traffic zone defines the attraction of the trip (kadiyali, 2009). Trips are generally projected by the trip purposes like trip to work, school, shopping, medical center etc. among which work trips can be regular, often during peak hours. Common socio-economic factors considered for trip generation analysis include population, educational qualification, income and auto ownership rates (Zenina & Borisov, 2013) (Arabani & Amani, 2007) (kadiyali, 2009). For the estimation of trip generation, developed countries have their own trips rates or models as well as trip rates from ITE's Trip Generation Manual in absence of their own trip rates. But those trip rates and models are not applicable in our country because of distinctions in land-use pattern, socio-economic characteristics and road network facilities and physical features may have a significant influence on trip attractions (Mamun *et al*., 2017). Trip generation models are divided into three levels: strategic, tactical

and operational ones. Regression is a statistical technique to determine the relationship between different variables. The variables are classified as dependent variables and independent variables. Cross-classification models or category analysis are used for trip generation calculations at the strategic and tactical levels (Zenina & Borisov, 2013). Linear regression models and Rate methods with linear regression equations or with average rates are used to calculate transport generated trips (Lenzini et al., 2008). The regression equations are developed using the data collected from the field. It is not unique as the coefficient of independent variables varies from a different set of data collecting from the field. Trip rate analysis model is based on the determination of the average trip production or trip attraction rates associated with the important trip generators within the region. Different criteria are used for the selection of explanatory variables in regression analysis (Zenina & Borisov, 2013). Cross-classification model may be used as an extension of simple trip rate models (Ortúzar & Willumsen, 2011). In a study of evolution of parameter affecting the trip generation, the stepwise linear regression method was used which suggest the use of a decision making algorithm consisting of a set of income, family-size, trip time and car-ownership parameters to estimate the number of daily trips produced by a household (Arabani & Amani, 2007) and also another study for for the projection of transport demand for New Delhi adopted operational models for the purpose of transport analyses and developed trip-generation models based on the least-square regression analysis method as this method is easier to interpret (Sarna *et al*., 1992).

According to the perspective of Bangladesh trip production and attraction is usually related to the three variables which considered a number of factors that are density of land use affecting production and attraction (i.e. number of dwellings, employees etc. per unit of land and higher density), social and economic characters of users influencing production, such as average family income, education and car ownership, and location like traffic congestion and environmental conditions (Rahman, 2011) (Mousavi, 2016). The location and intensity of land use are important variables to understand the relationship between land use and the volume of urban travel (Hurst, 1970). In a study of trip generation model development in the perspective of a developing country's city, Dhaka, Bangladesh, variables considered to influence trip making are–household income, region, household size, the number of employed persons and the number of students in the household region type has the least effects for all the trip purposes (Hasan & Hoque, 2015) and also another research use income, family-size and car-ownership parameters to estimate the number of daily trips production (Arabani & Amani, 2007). The aim of the study is to determine of the trip generation model of *Shugondha* residential area of Chittagong city. As people who live in the study area belong to different income groups, i.e. higher, middle- and lower-income groups. The travel behaviour of inhabitants of the study area depends on trip maker's socio-economic characteristics and the purposes of traveling within or outside of the study area. The total number of trips generated from the area has a significant impact on the overall transport system of the city.

METHODOLOGY

Sugondha residential area is selected as the study area which is situated at the western part of Chittagong City Corporation. This area is very near to Panchlaish police station and Chittagong medical college which is considered as one of the finest and well functioned residential units in Chittagong. Though it's a residential area, there is also some other land use like commercial, mixed, education etc. for convenience of the inhabitants. To conduct this study a consecutive methodology has been adopted. For primary field data collection random sampling process has been adopted and total 175 samples of household have been taken from the field through home interview process about frequency (origin and destination) of trips, total household's trip etc. Some socio-economic, accessibility data are collected from the field through questionnaire survey for the trip generation analysis. After completing the field work and data collection, SPSS software has been used to analyse the data through multiple linear regression method. Regression equation is established for the trip generation model on the basis of different dependent and independent variables (Arabani & Amani, 2007). Applying the linear regression model is a common form of using a correlation model as follows**:**

$$Y = a + b_1x_1 + b_2x_2 + \ldots + b_n x_n \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

From the equation (1), Transport generated trips are expressed as the number of trips per unit x, where x the factor that describes the independent variables and Y- the dependent variable (trips/household), x_1, x_2…...independent variables , b_1, b_2…….b_n – regression coefficients that show to what extent Y

changes, if x_n variable increases (Zenina & Borisov, 2013). For regression analysis different explanatory independent variable are taken such as accessibility status access time, egress time, access mode, egress mode etc. also analysed and represented through graph, chart etc. The current paper considers various information systems for trip generation calculation based on regression equations. After data analysis the output is interpreted and on the basis of it final conclusion of the analysis is reached.

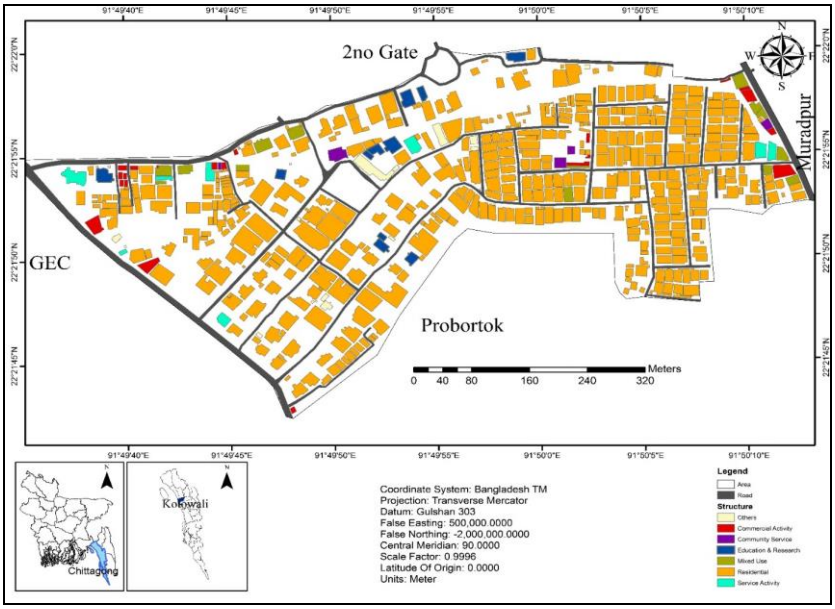

Fig.1: Location and Land-use Map of Sughondha R/A

RESULTS AND DISCUSSIONS

Regression

The results of these investigations are accomplished by statistical software through the regression method. Several independent variables are selected for determining the regression equations of the trip generation model.

Table 1: Coefficient Table of Explanatory Variables

Coefficients[a]							
Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**95.0% Confidence Interval for B**	
	B	**Std. Error**	**Beta**			**Lower Bound**	**Upper Bound**
(Constant)	4.27	.979		4.364	.000	2.333	6.208
Family size	.374	.074	.387	5.065	.000	.228	.520
Total trip time	.031	.004	.763	7.889	.000	.023	.038
Ownership of mode	-.012	.098	-.008	-.127	.055	-.207	.182
Comfort	-.060	.109	-.040	-.544	.087	-.276	.157
Fare	.012	.083	.014	.142	..022	-.153	.177
Reliability	.019	.106	.016	.183	.855	-.191	.230
a. Dependent Variable: Total number of trips							

The variables are mode ownership, family size, reliability, total trip time, comfort and fare. It is known that explanatory variables should be highly correlated to the dependent variables but they should not be highly correlated among them. Table 1 and 2 representing the coefficient correlation value of the explanatory variables. From the correlation table 2 showing the Pearson correlation and significance (2-tailed) among the four variables which are main mode, comfort, fare and reliability and the mode choice of the residents are highly correlated with the fare and reliability. Here people tend to choose the

mode of travel where comfort and reliability correspond to the fare, they actually have to pay to commence the travel.

As shown in table 1, the number of trips produced by a household is highly dependent on family size and household structure. The number of the trip increases with the extended family size. Another factor affecting the number of household trips is its trip time. As the coefficient of total time .031 increases with higher number of trip generation, household with higher number of people spent more time in trip purpose. Whether different household members use a private car or public mode of service, the availability of alternative modes of transport and average income level also reflects the number of trips originated in that community. So, the number of trips made by each mode of transport is under the influence of comfort, fare and level of services of that mode to the community. The coefficient of comfort is -0.060, which indicates that with the increase in the average number of household trips, the comfort of the people decreases. Since, the coefficient of trip fare is 0.012, which means with the low fair rate in trips the average number of household trip will be increased. The reliability depends on the level of service of transportation modes and with the increase rate of reliability .019, the number of trip also increases.

The final estimated total number of trip equation is

$Y= 4.27+.374X_1+.031X_2-0.012X_3-.060X_4+.012X_5+.019X_6$

Here X_1, X_2, X_3, X_4, X_5, X_6 are explanatory variables which represents the value of family size, total trip time, comfort, fare and reliability respectively.

Table 2: Correlation Table of Explanatory Variables

Correlations					
		Main mode	**Comfort**	**Fare**	**Reliability**
Main mode	Pearson Correlation	1	.162*	.221**	.139
	Sig. (2-tailed)		.042	.005	.082
Comfort	Pearson Correlation	.162*	1	.498**	.657**
	Sig. (2-tailed)	.042		.000	.000
Fare	Pearson Correlation	.221**	.498**	1	.644**
	Sig. (2-tailed)	.005	.000		.000
Reliability	Pearson Correlation	.139	.657**	.644**	1
	Sig. (2-tailed)	.082	.000	.000	

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3: Model Summary

Model	**R**	**R Square.**	**Adjusted R Square**	**Std. Error of the Estimate**
1	.774[a]	.599	.572	1.01291

a. Predictors: (Constant), Reliability, Educational qualification, Family size, Ownership of mode, Comfort, Total trip time, Fare

The table 3 represents the total model summary of the multiple regression analysis of trip generation model. From the table it has been seen that the value of R is 0.774 and the value of R^2 is 0.599 indicating that the explanatory variables (dependent variable) entered into the model explain 59.9% of the variation of the trip generation model where the significance level is less than .05.

Table 4: ANOVA for regression

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	183.782	8	22.973	22.391	.00[a]
	Residual	123.118	120	1.026		
	Total	306.899	128			

b. Dependent Variable: Total number of trips

The results obtained from the ANOVA table 4 shows the analysis of total variance (regression and residual) in the dependent variables. The degree of freedom found for the regression is 8 and for residual is 120.

Socio-economic analysis:

The relation between occupation and income is shown in Figure 2. Among the high-income class people, most of them are mainly associated with job or service occupation. Another profession found in the residential area is business class people working in different parts of Chittagong city. The middle-income class people are dominated by government or private jobs than business which is very common among the higher income class people. In middle-income class dominating profession is job than business. The lower income class people correspond to almost the same number of professions like job, business or others.

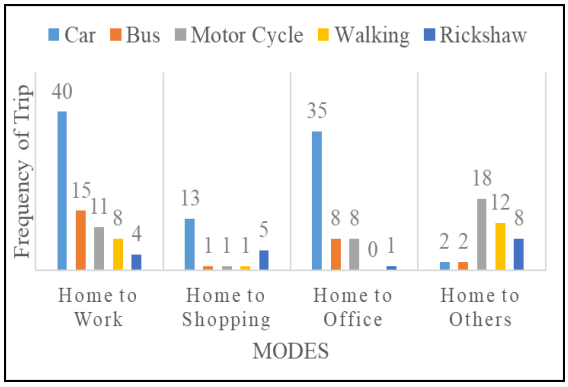

Fig.2: Relation between Occupation and Income

Fig.3: Frequency of Trip with different Modes

The scenario of different types of trip frequency with mode of transport is described in figure 3. Car trip frequency is high for home to work, home to office and home to shopping trips. Some people also use other modes of transport for their trip. Mostly the high-class groups use the car to reach their destination and this is maximum. The lowest usage of car is in the home to others as the middle and lower classes are major here. The variation of the required time to reach the destinations by different modes of transportation is explained in figure 4. The required time of the high-class groups is the lowest. It's because of the rich use car or motorcycle or other motorized private vehicles and faster than the other non-motorized vehicles like the rickshaw. So, they can get to their destination at the shortest period of time. On the contrary, the middle- and lower-class group's required time for making a trip is higher, especially highest for the lower class groups.

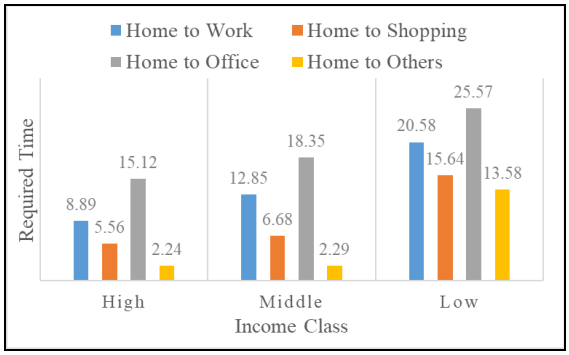

Fig.4: Relation between Time with Income class

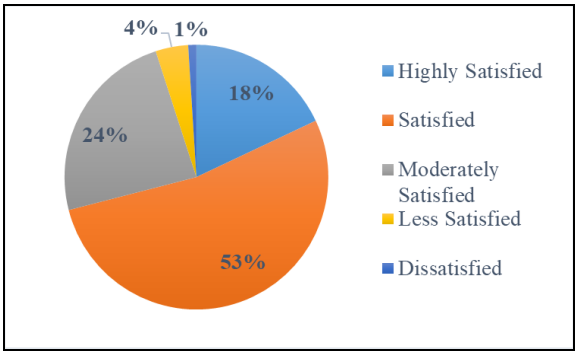

Fig.5: Satisfaction with Comfort of Trip Mode

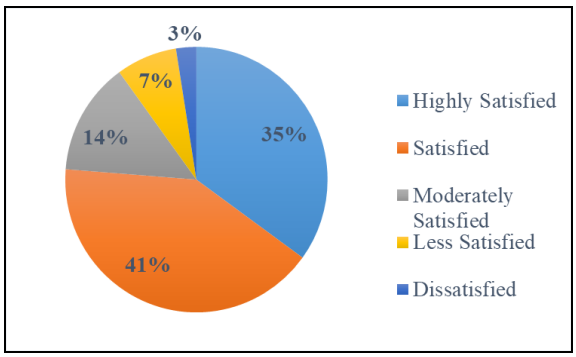

Fig.6: Satisfaction with Reliability of Trip Mode

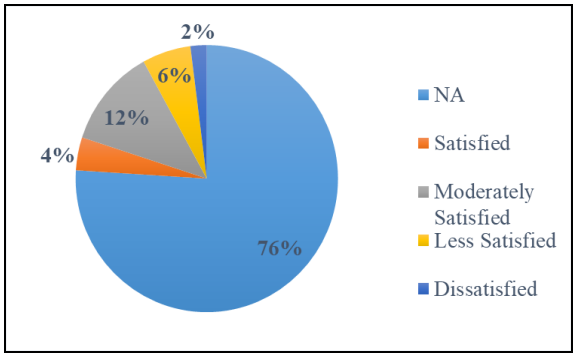

Fig.7: Satisfaction with Fare of Trip Mode

The graph 6 shows, the satisfaction level of the residents on the reliability of the transport mode they use for their daily purpose. Among the total respondents 33% people are satisfied and 28% people are highly satisfied with the reliability of transportation mode as most of them have their own vehicle ownership more specifically car ownership as a transport mode. It is found from the analysis that 31% of the total respondents are moderately satisfied with the reliability of the transport mode as for reliability even the car owners cannot rely completely on it as the traffic jam severe someday. The satisfaction level of the residents of the residential area on the fare of the transport mode is shown in figure 7. Among the total respondents, 76% people didn't respond their comments on this as most of them have their own vehicle ownership they don't need to pay the fare of transport mode. The percentage of moderate and less satisfied respondents are respectively 12% and 6% with the fair of the transport mode. Only 4% people are satisfied with fair and 2% people are completely dissatisfied as shown in Fig 7.

SUMMARY AND FINDINGS

Trip generation model is the first step of four stages Travel Demand Model. It determines the total number of trips generated from a parcel to the others parcel of the city. Transportation trip generation models were evaluated taking into account the socio-economic character, accessibility status, and land use and transport infrastructure availability in the research area. Derived findings from the research work are given below

- The results obtained from this research are variables mostly affect the trip generation model are Family size, total trip time comfort, fare and reliability respectively and among them some are positively and rests are negatively related.
- It is found that among the high-income class people, most of them are mainly associated with job or service occupation and rest of them are found to be businessman.
- In this research, it was observed that in middle-income class people are dominated by the profession of Government or private job.
- In transport mode and work purpose relationship, it is seen that car trip frequency is high for home to work, home to office and home to shopping trips.
- Also found that the required time of the high-class groups to reach the destination is the lowest as the rich use car or motorcycle or other motorized private vehicles and they are faster than the other non-motorized vehicles like rickshaw.
- On the contrary, the middle- and lower-class groups required time is higher, as they depend on the non-motorized vehicle or public buses.
- It was also observed that among all the total respondents most of the people are satisfied with the comfort and reliability of transportation mode as most of them have their own vehicle ownership.

CONCLUSIONS

Traffic generation analysis plays an important role in transportation planning. Shugondha residential area, because of its good transport system is an attractive place to people for accommodation with all services & facilities and some employment opportunity. The population of the study area is increasing day by day and the increasing population pressure increasing the total trip generated from the study area rapidly. In the study area, there is some potential employment opportunities for people, who live there

and as well as for people who come from outside of the study area. Depending on the analysis of trip generation, a smooth transport network can be designed for the study area. The factors which have the negative impact on the total trip generation from the study area should be taken into the consideration. Measures should be taken to fix the problems of those factors. Since the generation of trips from any particular area has a significant impact on overall transportation planning, especially to determine travel demand and modal availability for the inhabitants of the study area. The study should be done on regular basis for development, improvement and upgrading the transport facilities. The design of the street should also be made after forecasting the total number of trips to ensure accessibility of modes operating in the study area. Proper emphasis should be given for the development of road network of the study area by determining the total number of trips generated from the study area for smooth operation of traffic and as well as for proper management of the traffic system

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A STUDY ON SCHOOL COMMUTING TRIPS IN URBAN AREAS OF BANGLADESH

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ABSTRACT
Congestion is a common problem in urban areas of Bangladesh. This problem becomes even more acute during the times when school students make their trip to the school or return trip to home. An initiative is thus taken to find out various facts associated with those school commuting trips. Three schools of Dhaka and Chattogram city are taken as study area. Face-to-Face questionnaire survey method is used to collect data directly from students. School bus and school van related secondary data is also collected from School authorities' in-charge. To study problems in the roads adjacent to school, video survey is done. A big portion of students of both Dhaka (23%) and Chattogram (25%) use their private automobiles to reach schools which create congestion problem throughout the urban road networks as the distance of these trips extend even greater than 10 kilometres in Dhaka (4%) and greater than 7 kilometres in Chattogram (20%). Safety problems are also alarming as 55% of the student cross roads unsafely. Speed reduction rate is significant (up to 46% for private cars) adjacent to the school areas for various road side activities adjacent to school. This study will help the policy makers to take decisions on admission policy of schools about admitting more students from catchment areas to reduce heterogeneous trips to schools as well as the policy for establishing new schools in urban built up areas.

Keywords: Travel Mode; Travel Time; Travel Distance; Safety; Congestion.

INTRODUCTION

School commuting trips or the trips made by students and/or guardians to reach school and return from school contribute to urban road congestion situation to a large extent. There is a large amount of research works around the world regarding this topic but the situation in Bangladesh is still unknown as there is few literatures in the context of Dhaka and Chattogram city. School commuting trips are important not only for the understanding the impact on congestion but also the safety of school students making those trips.

The objective this study is to find out various facts regarding school commuting trips such as mode choice, travel distance, travel time, relation between distance and travel time, relation between distance and mode choice, safety issues such as road crossing behaviour of students, effect on existing road traffic such as speed reduction etc.

METHODOLOGY

The study area and methods used to collect and analyzing data are described in the following subsections.

Study Area

Considering all the factors and difficulties three schools were selected as final study area. They are Willes Little Flower School and College situated in Kakrail, Dhaka. Viqarunnisa Noon School and College situated in Baily Road, Dhaka and Chattogram Cantonment Public College situated in Cantonment, Chattogram. Willes Little Flower School and College is situated at heart of the town at the kakrail main road known as Bir Uttam Shamsul Alam Road. This road connects kakrail intersection with the kakrail and VIP road and as a result any congestion on this road creates queue of vehicle in the surrounding important intersections like Paltan and Shantinogor.

Viqarunnisa Noon School and College is situated on New Baily Road which is well known as for the school itself as well as various shopping malls and restaurants. Two major schools situated on both ends of New Baily Road worsens the traffic congestion at the peak hours especially when the school starts and ends.

Chattogram Cantonment Public College is not free of access for everyone as it is situated inside the cantonment. To reach the main gate of the school one must be student, guardian or school staff. The main school building is situated far away from main road thus contributing less to the congestion on the main road. One of the main reasons of choosing this school as a study area is its school bus service. It has a total of ten buses which are in service and carries a significant number of students from various parts of Chattogram city. This bus service is well organized by the school authority as they maintain a strict schedule and discipline in running those buses.

Data Collection

Data is mainly collected in two methods and they are questionnaire survey and video survey. Questionnaire survey is done to gather information directly from students and guardians about their trips. Face-to-face questionnaire, internet-based survey and distributed survey form method has been used to collect all necessary information.

A pilot survey is first carried out to find any fault in the questions of the survey form. Few corrections were done prior to the main survey operation. A total of 232 responses are found complete and 54 responses are rejected because of incomplete or unclarified answers.

A video survey has been carried out in front of Willes Little Flower School and College to find out safety and other related problems on the roadway adjacent to a school. Student's and guardian's road crossing behaviour related data is found from this survey. Also, drop-off and pick-up activity timing and related bottleneck problem is identified.

Spot speed measurement method is used to find out speed reduction problems in front of a school. To determine the speed variation between a school day and school holiday, speed measurements are done on two different days.

Data Analysis Method

The collected data from the questionnaire survey is used to find-out different aspects of school trips. Necessary graphs, pie charts, bar charts are plotted. Straight forward linear equation has been established to find out travel time based on distance.

RESULTS AND DISCUSSIONS

Travel Mode Choice

Travel mode choice for the students of Dhaka and Chattogram city has been found which are represented below:

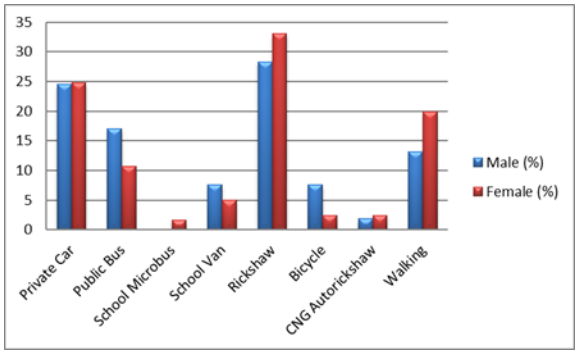

Fig. 1: Travel Mode Choice (Dhaka)

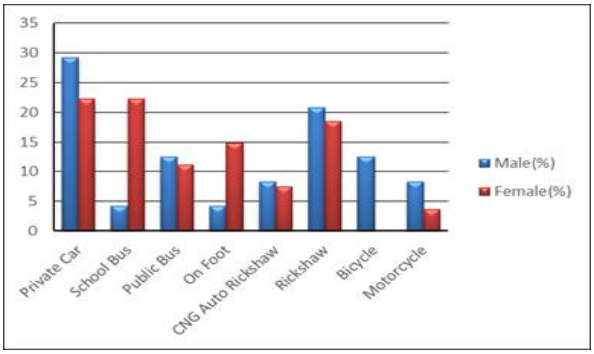

Fig. 1: Travel Mode Choice (Chattogram)

Referring to [Fig. 1] it can be seen that the trend among the students of Dhaka. Female students are more seen to use Rickshaw (33%) than male students (28%). There is also a small proportion of female students using micro bus service. Referring to [Fig. 2] In case of Chattogram city students, the trend to use private holds the major share. In case of our neighbouring country India, the situation is quite unchanged as here also the trend towards using private or individual modes have increased over time. a study in the city of Kanpur reveals that most percentage of students use their family vehicles to reach school whereas most of the respondents using private vehicle are female. Bicycling is also gender biased as 25% of the respondents were male and only 9% were female. (Singh et al., 2017). For the state of California in USA, it can be seen over time from 1969 to 2009 the trend has been shifted towards private vehicles abandoning walking or cycling. However, school bus service has been predominant throughout the time. (National Household Travel Survey-2013, California).

The trend to use private cars seems to increase also in Bangladesh as it can be seen from [Fig.1] and [Fig. 2], a both male and female students are already using private car as their daily travel mode.

Travel Distance

Travel distance is the distance travelled by individual student daily between residence and school. The questionnaire survey revealed the following situation.

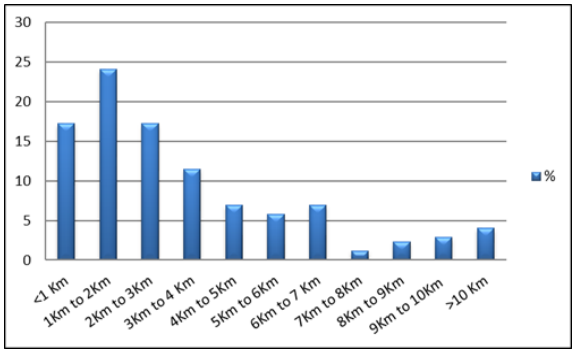

Fig. 3: Travel Distance (Dhaka)

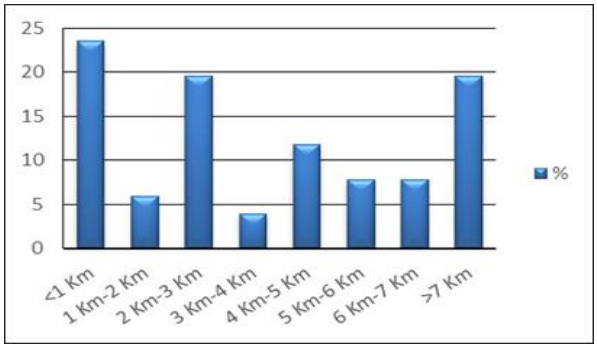

Fig. 2: Travel Distance (Chattogram)

Travel distance vary between Dhaka and Chattogram city as it can be seen in [Fig. 3] and [Fig. 4] that the maximum distance for Dhaka extends up to more than ten kilometres but in case of Chattogram this extends up to more than seven kilometres. In both cases, majority of the students lives within two kilometres. Another study shows that whereas the maximum travel distance for USA California is just above 2 miles (National Household Travel Survey-2013, California) in case of Dhaka city 18.01% of the respondents live above 5 kilometres and 52.7% students live within 2 kilometres of the school campus. (Khan et al., 2015).

The reason of this variance between Bangladesh and USA is because of lack of regulations in school's admission policy about catchment area from where students can be admitted in a particular school. One such regulation about from how far a student can travel from residence to home can be found in Urban Institute Student Transportation Working Group, 2017. Which reveals different maximum permitted travel distance for students of different grades. This reveals a maximum permitted travel distance of 3.5 miles for students of grade 9,10,11,12 in case of Denver City.

Relation between Distance and Mode Choice

There exists a relation between travel distance and mode choice. This is a very important fact in case of urban transportation as more length of school trips encourage using private vehicles which create congestion problems throughout the city. Students tend to walk up to 4 kilometres, and use other modes of transportation beyond this limit including public transit (Ermagun et al., 2017). Also motorized travel trend tends to increase if the distance from home to school exceeds a certain distance (Easton et al., 2015)

In the context of Bangladesh walking and rickshaw travelling diminishes with the increase in travel distance and a consequent increase in the trend of using public bus is seen. However private car use remains prominent through all the distances no matter how far or close the destination is.

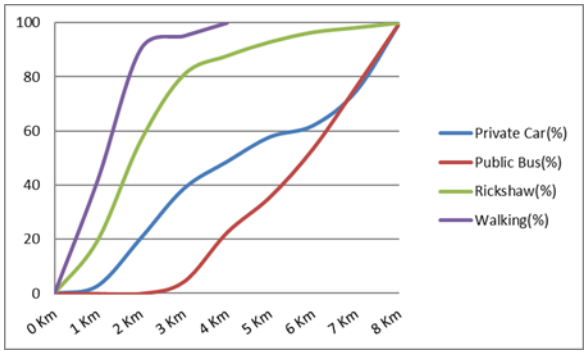

Fig. 5: Mode Choice Variation with Distance (Dhaka)

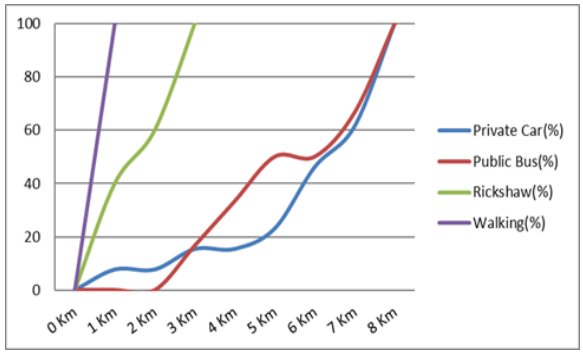

Fig. 3: Mode Choice Variation with Distance (Chattogram)

Referring to [Fig.5] and [Fig. 6] it can be seen that walking trend tends to diminish earlier (within 1 kilometre) in case of Chattogram where in case of Dhaka this extends up to 4 kilometres. Rickshaw use also diminishes earlier in Chattogram.

Relation between Distance and Travel Time

Travel time typically varies with a variety of parameters. However, the most important of them two are distance and mode choice. So, a simple straight forward analysis has been carried particularly for private cars in Dhaka and Chattogram city for both free flow condition and congested (Peak) condition.

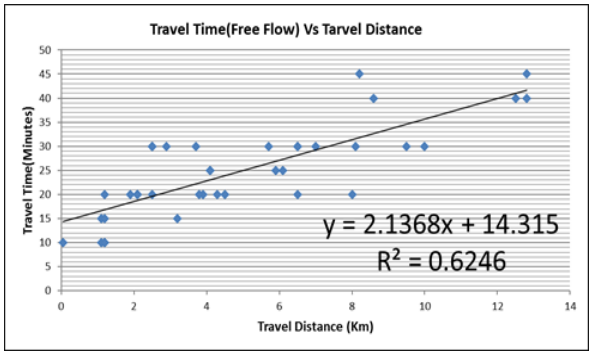

Fig. 7: Free Flow Travel Time Variation with Distance (Dhaka)

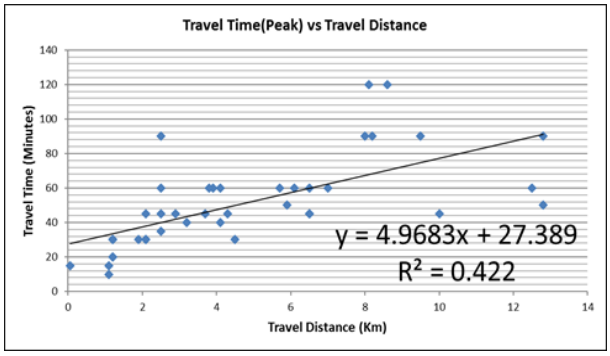

Fig.8: Peak Hour Travel Time Variation with Distance (Dhaka)

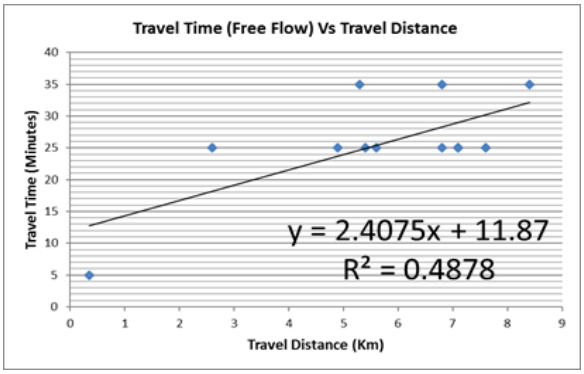

Fig.9: Free Flow Travel Time Variation with Distance (Chattogram)

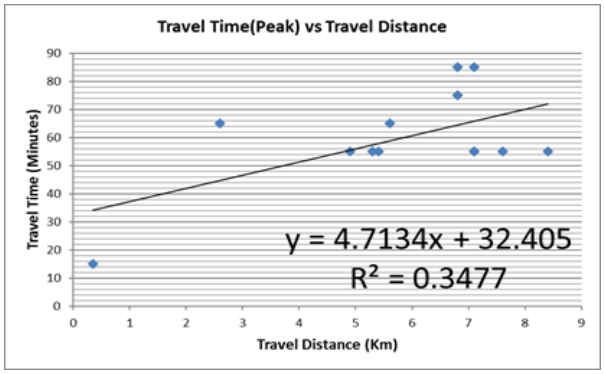

Fig. 4: Peak Hour Travel Time Variation with Distance (Chattogram)

Travel time in free flow condition is more predictable in Dhaka as can be comparing the R^2 value. Peak hour travel time is more unpredictable as can be seen from the scattered data points. However, it is only a straight-line equation and has been established not considering urban road delay factors such as number of intersections in the route, particular road section delay, intersection cycle time etc. but this can give an approximate travel time of school trips.

Problems on The Roadway Adjacent to School

Several problems arise on the roadway because of bottleneck created during peak hours especially when school begins or ends. A large amount of trip is attracted to the school in those times. These trips are made not only by the students but also their guardians who gives them company. One of the main problems is on-street parking of vehicles. This on-street parking reduces the effective driving lane of main road and reduces vehicles speed to a large extent in a specific road section. The situation of Dhaka city is illustrated in [Fig.11] and [Fig.12].

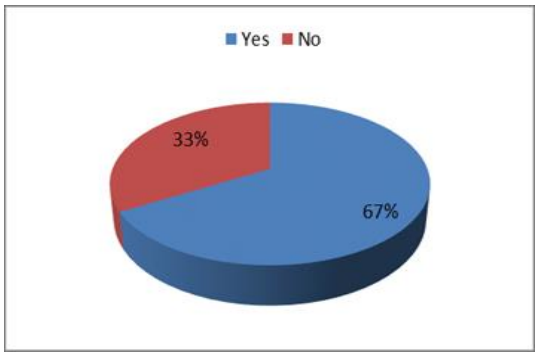

Fig. 5: On-Street Car Parking

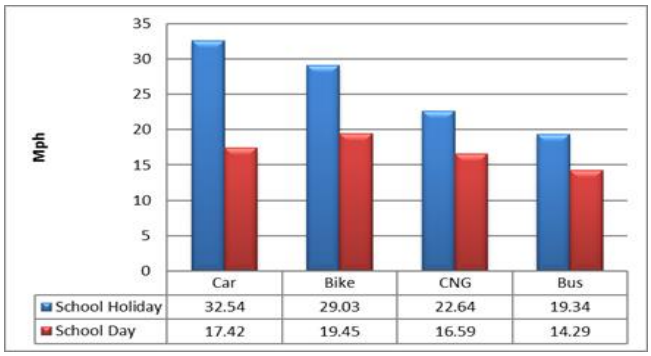

Fig. 6: Speed Variation between A School Day and School Holiday (Both Working Day)

67% of the respondents who travel to school by car, reported that their cars are being parked outside school. As there are no legal on or off-street parking facilities outside schools which were study area, it can be said that all the parked cars are being parked illegally reducing effective lane width and creating bottleneck.

The result can be seen in [Fig.12] where the speed reduces to a great extent (17.42 Mph) especially for private cars on school day. Whereas on other working days, when schools are closed the speed is quite good (32.54 Mph).

Not only the on-street parking tendency but also drop-off and pick-up activities involving both guardians and students create bottleneck. It is found that single person drop-off or pick-up operation takes on average 10.34 seconds and multiple persons operation involving multiple door opening require on average 19.38 seconds. This drop-off and pick-up operation time is very important for urban roadways as these operations in front of any school entirely takes place on main road hampering through traffic.

Safety Problems

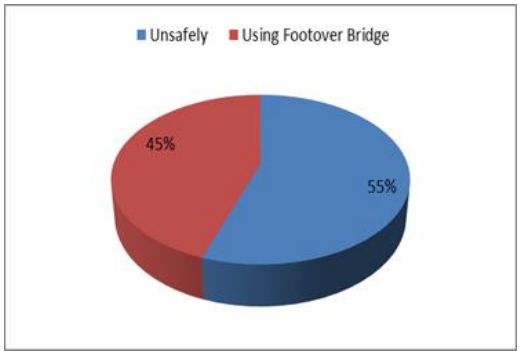

Fig.13: Road Crossing Behaviour (Video Survey Based)

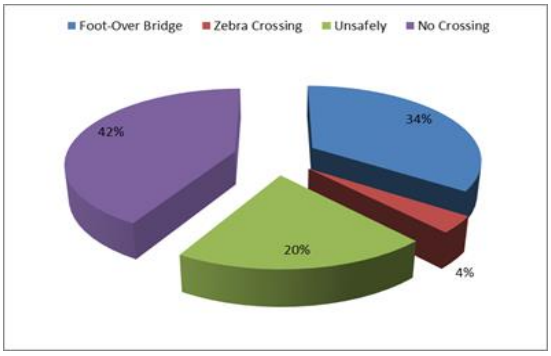

Fig. 7: Road Crossing Behaviour (Questionnaire Survey Based)

School commuting trips starts from the door of a residence and ends at the door of the school and vice versa. In urban areas it is always not possible to get-off from vehicle just on the side of the school. Many students have to cross main road every day to reach school. However, students of Dhaka and Chattogram city are found to cross road unsafely without using zebra crossing or foot-over bridge.
A video graphic survey. Different answers are found as 45% of total students crossed road unsafely but questionnaire survey revealed 20% students cross road unsafely. In a report of BBC on 30 November, 2014 it was stated that every year about 150 people die in Dhaka while crossing road. Last five years 950 people have been died in road accident in Dhaka city (Aminuzzaman, 2014). So this thing must be given importance to avoid loss of valuable lifes.

CONCLUSIONS

The current congested roadway situation of urban areas of Bangladesh can not be improved unless policy makers make some importatnt decision beased on research. In the analysis it is found that mainly long distance education trips attract a large number of private automobiles. Thereby, increases travel demand unnecessarily and contribute to congestion significantly, particularly at peak periods. It also make longer travel time which has detrimental effect on both student's health, educatiuon and urban roadway network. To reduce the impact of these school induced uncontrolled trips, there is a need to implement and adhere compliance of 'school zoning' policy in all residential landuse development plans. For sustainable solution, this policy intervention is also needed for the unplanned areas being developped with individual initiatives. The safety problem can only be reduced through public awareness and strong enforcements of existing law.

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PERFORMANCE EVALUATION OF SELECTED INTERSECTIONS IN DHAKA CITY WITH RESPECT TO CONTROL DELAY UNDER NON-LANE BASED HETEROGENOUS TRAFFIC CONDITION

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ABSTRACT
The widespread commercial, industrial, government, private and other activities have encouraged migration of people from outside resulting in abnormal growth of vehicular population in Dhaka city. The rapid growth of vehicular population is causing an enormous effect on traffic system. At present the traffic signal system in Dhaka city cannot manage this traffic. The traffic density has exceeded saturation level in most of the arterial roads. Kakrail and Shapla Chattar intersections have been used in this research study. In order to assess delay incurred at the junction as well as to make the junction operation by signal, in this study attempt has been made to determine control delay by different formulas. On the basis of average delay Level of Service of different approaches of these intersections at different peak time periods has been determined according to Highway Capacity Manual. Worst case scenario has been observed at evening peak period for both Kakrail and Shapla Chattar intersections and LOS is F and D respectively. From this research huge impact of heterogeneity as well as random lane changing behaviour on control delay has been found. Low level of service from longer delay incurred in these intersections can be improved by providing separate lane for NMV movements and lane based traffic circulation.

Keywords: Non-lane based heterogeneous traffic; Saturation level; Control delay; Level of Service

INTRODUCTION

Dhaka city which is the administrative, commercial and cultural capital of Bangladesh has been turned into 26th Mega City and 10th most populous city of the world (Habib et al., 2005). In last five years the population of the city has grown by about 50% to about 18.7 million, while for the same period the vehicle population has also grown by about 50% to more than 375,000 vehicles. Immense densification and mushrooming development of residential, commercial and other infrastructure, trim down the opportunity to construct new road infrastructure or introduce modern system for taming overall transportation system. Incomplete understanding of the inherent weakness of the city, the authority is providing piecemeal solution without a long term vision which is becoming an extra burden on the overall system of the city and the city is developing without a decent growth (Mahmud, S.M. Sohel, 2009). The road traffic system of Dhaka Metropolitan City is in the worst phase now. All major signalized intersections (presently controlled manually through responsive signal system in field condition) within this city have got severe traffic congestion producing long delay and untold sufferings of the road users. Intersections are one of the important bottlenecks, which interrupt the smooth flow of traffic which cause delay (Alam, M.S., 1997).

In this research study main focus is to evaluate the performance of the two major intersections in Dhaka based on control delay. The delay is defined as the difference in travel time when a vehicle is unaffected by the controlled intersection and when a vehicle is affected by the controlled intersection. This delay

includes lost time due to deceleration and acceleration as well as stopped delay. Thus, intersection delay estimates are directed toward estimating total delay or simply stopped delay (Kadiyali, L.R., 2016). In this study delay has been estimated using three different formulas such as Webster's formula (Webster, 1958), Miller's formula (Miller, 1968), Modified Webster's formula (M.S. Hoque et al., 2007). Modified Webster formula has been used to show the impact of heterogeneity and non-lane based traffic with variation of delay with classical delay estimation formulas. For estimation of delay some key parameters are needed such as vehicular composition, flow fluctuation, design arrival flow (counting of vehicular flow with PCU conversion factor), saturation flow, Degree of Saturation. These are also important parameters for performance evaluation of the selected intersections. Saturation flow is estimated using Road Note 34 method (Road Note 34, 1963).

Delay is an important parameter for the measurement of the level of performance of signalized intersection. In HCM 2000 level of service for signalized intersection is defined in terms of control delay, which is a measure of driver discomfort, frustration, fuel consumption, and increased travel time. The average control delay per vehicle is estimated for each lane group, and aggregated for each approach and for the intersection as a whole. Level of Service is directly related to the control delay value. According to HCM 2000 Level of Service is categorized into A, B, C, D, E, F (Highway Capacity Manual, 2000). The operational conditions of such intersections profoundly affect the well-being of the surface transportation of goods and passengers in cities; whose social, economic, recreational, and other activities depend on an efficient road system. As the operational quality of urban road systems gradually deteriorates due to increase in traffic volume and a higher level of service (LOS) is required. Based on assessment results, the authorities can isolate those strategies and plans that make both the improvement measures and the allocation of limited funds more rationally (J. Li. et al., 2004).

METHODOLOGY

Methodology of this research has been divided into three parts: a) study area selection; b) data collection, c) data extraction and analysis.

Study Area Selection

At the beginning of this research a preliminary survey was conducted within the Dhaka city. The main purpose of this preliminary survey was for the selection of suitable intersections for research. There are about ninety-eight (98) major intersections in Dhaka Metropolitan city, out of which sixty-one (61) intersections were surveyed in this preliminary survey. After having done the preliminary survey of 61 major intersections of Dhaka Metropolitan City and analysing the findings of preliminary survey, two intersections (Kakrail and Shapla Chattar) have been selected for this research study.

Data Collection

Video camera was used to collect field data because it provides permanent record of data with minimum manpower and data collection is much more superior to manual data collection. Recorded film was replayed in the laboratory and required information for saturation flow and delay estimation was retrieved. For Kakrail intersection data was collected from 8:00 am to 6:00 pm with 15 min interval on Sunday, 24 December 2017 from 3rd floor of a multi-storeyed building near the intersection. For Shapla Chattar intersection data was collected from 8:00 am to 6:00 pm on Tuesday, 26 December 2017 from 16th floor of Sena Kalyan Bhaban.

Data Extraction and Analysis

Performance of the intersections has been evaluated on the basis of control delay based Level of Service. For determining control delay following parameters have been obtained: a) Vehicle composition; b) Flow fluctuation; c) Counting of vehicular flow; d) Saturation flow; e) Degree of saturation; f) Control delay; g) Level of Service.

(a) Vehicular Composition

Vehicle composition at different approaches of both intersections have been extracted from counting of vehicles from video camera.

(b) Flow Fluctuation

Flow fluctuation at different approaches at different time period has been obtained by vehicular count at 15min interval in hour for 10 hours' data from analysing video camera recording.

(c) Counting of Vehicular Flow

After obtaining vehicular count at 15 min interval in hour PCU conversion factor has been used to convert vehicles into standard PCU value to obtain design arrival flow at peak periods.

(d) Saturation Flow

Saturation flow has been determined per Road Note 34 Method (1963), consists of taking classified counts of vehicles crossing the stop line, within the approach width, in six second intervals during the green and amber period of the cycle under saturated flow condition.

(e) Degree of Saturation

The flow ratio is expressed by the ratio of design flow and saturation flow, y = q/s where q indicates design flow and s indicates saturation flow. After calculating u and y, they are used to calculate the degree of saturation, x by the equation x = y/u.

(f) Control Delay

Miller's Formula: The Miller's formula (1968) for delay is based on an explicit use of the average overflow queue parameter, *nr*, given by Eq. (1) and Eq. (2)

$$d = \frac{1}{2} \times \frac{c \times (1-u)^2}{1-y} + \frac{nr \times (1-u)}{q \times (1-y)} \qquad (1)$$

$$nr = \frac{1}{2} \times \frac{\Phi \times e^{-1.33}}{1-x} \qquad (2)$$

Webster's Formula: The first widely used approximate delay formula was developed by Webster (1958) from a combination of theoretical and numerical simulation approaches given by Eq. (3)

$$d = \frac{1}{2} \times \frac{c \times (1-u)^2}{1-y} + \frac{x^2}{2q \times (1-x)} - 0.65 \times \left(\frac{c}{q^2} \right)^{\frac{1}{3}} \times x^{2+5 \times \left(\frac{g}{c} \right)} \qquad (3)$$

Modified Webster's Formula: Modified Webster's formula (2007) developed from classical Webster's delay formula by M.S. Hoque and M.A. Imran under Bangladesh condition given by Eq. (4)

$$d = \frac{1}{2} \times \frac{c \times (1-u)^2}{1-y} + \frac{x^2}{2q \times (1-x)} + 46.93 - 46.04 \times q - 37.32 \times x - 0.3608 \times pnmv \qquad (4)$$

Here, d = average delay per vehicle in seconds; u = green time ratio; q = average arrival rate (flow) in pcu per seconds; s = saturation flow in pcu per seconds; nr = average overflow queue in pcu; c = cycle length in sec; g = Effective green time in sec; x = Degree of saturation; pnmv = percentage of non-motorized vehicles.

(g) Level of Service (LOS)

Level of Service of the intersections have been identified in accordance with HCM 2000 with respect to average control delay per vehicle.

RESULTS AND DISCUSSIONS

Vehicular Composition

Below Fig.1 and Fig.2 it has been found that percentage of NMV in Kakrail and Shapla Chattar intersections is 20.73% and 21% respectively.

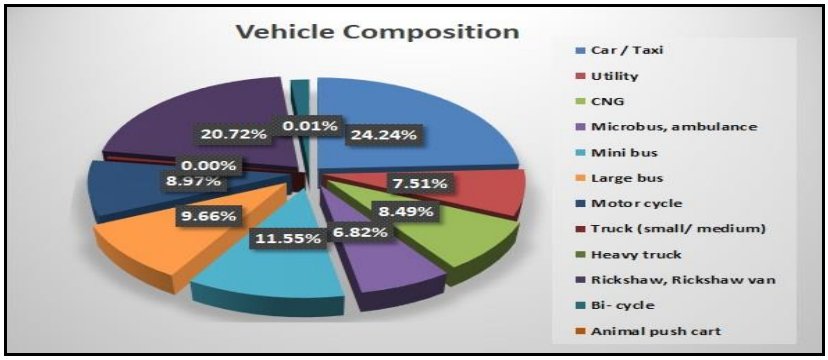

Fig.1 Vehicle Composition in Kakrail Intersection

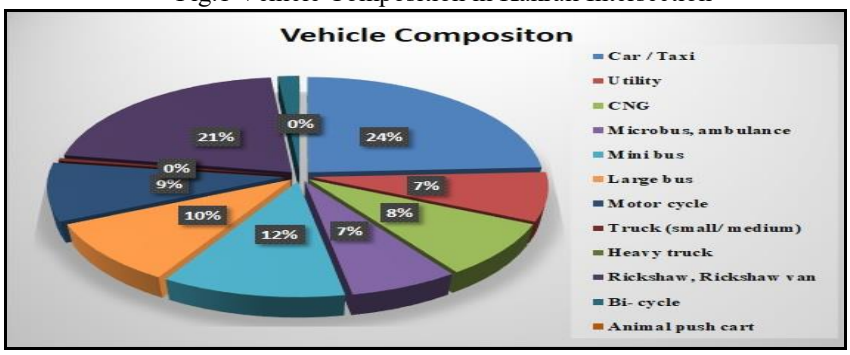

Fig.2 Vehicle Composition in Shapla Chattar Intersection

Flow Fluctuation

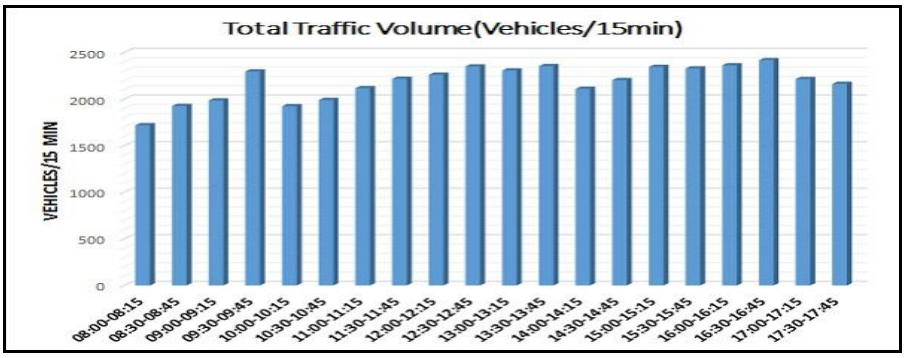

Fig.3 Flow Fluctuation at Kakrail Intersection

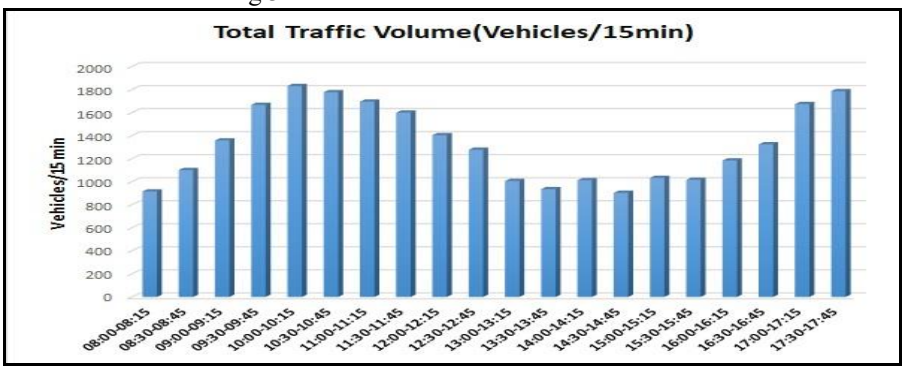

Fig.4 Flow Fluctuation at Shapla Chattar Intersection

From Fig.3 and Fig.4 it has been found that Morning peak for Kakrail and Shapla Chattar intersections starts at 9:00 am and 10:00 am respectively. Similarly Evening peak starts at 4:00 pm and 5:00 pm respectively.

Counting of Vehicular Flow

Table 1 Design Arrival Flow at Kakrail Intersection

Approach	Morning Peak (pcu/hr)	Evening Peak (pcu/hr)
Paltan	1087.88	1244.13
Shantinagar	1248.13	1259.63
Kakrail Circle	426.63	246.75
Segunbagicha	801.13	832.75

Table 2 Design Arrival Flow at Shapla Chattar Intersection

Approach	Morning Peak (pcu/hr)	Evening Peak (pcu/hr)
Fakirapul	1216.75	1029
Kamlapur	387.38	357
Tikatuli	759.63	895
Doinik Bangla	638.75	557.5

Saturation Flow

Table 3 Saturation Flow at Kakrail Intersection

Approach	Morning Peak (pcu/hr)	Evening Peak (pcu/hr)
Paltan	7811	8246
Shantinagar	4276	6785
Kakrail Circle	4643	5109
Segunbagicha	4815	8033

Table 4 Saturation Flow at Shapla Chattar Intersection

Approach	Morning Peak (pcu/hr)	Evening Peak (pcu/hr)
Fakirapul	3752	3777
Kamlapur	Unsignalized	Unsignalized
Tikatuli	4367	3381
Doinik Bangla	Unsignalized	Unsignalized

Degree of Saturation

Table 5 Degree of Saturation at Kakrail Intersection

Approach	Morning Peak (pcu/hr)	Evening Peak (pcu/hr)
Paltan	7811	8246
Shantinagar	4276	6785
Kakrail Circle	4643	5109
Segunbagicha	4815	8033

Table 6 Degree of Saturation at Shapla Chattar Intersection

Approach	Morning Peak (pcu/hr)	Evening Peak (pcu/hr)
Fakirapul	3752	3777
Kamlapur	Unsignalized	Unsignalized
Tikatuli	4367	3381
Doinik Bangla	Unsignalized	Unsignalized

It has been found that DOS is less than 1 for both intersections. So both intersections are under saturated.

Control Delay

Table 7 Control Delay by Different Formulas at Morning and Evening Peak

Intersection Name	Webster's Formula (sec/veh)	Miller's Formula (sec/veh)	Modified Webster's Formula (sec/veh)	Webster's Formula (sec/veh	Miller's Formula (sec/veh)	Modified Webster's Formula (sec/veh)
Kakrail	192.36	147.22	220.19	237.87	242.82	300.54
Shapla Chattar	51.64	50.47	75.78	50.05	48.74	72.37

From Table 7 it has been clearly observed that delay determined from Modified Webster formula at both intersections in peak period is higher than other formulas. As overall delay for Shapla Chatter Intersection is lower, it can be decided that Shapla Chattar Intersection as a controlled round about intersection performed better than Kakrail Intersection as a cross intersection.

Level of Service (LOS)

Table 8 Saturation Flow at Kakrail Intersection

Approach	Morning Peak (pcu/hr)	Evening Peak (pcu/hr)
Paltan	D	E
Shantinagar	C	E
Kakrail Circle	D	F
Segunbagicha	D	F

Table 9 Saturation Flow at Shapla Chattar Intersection

Approach	Morning Peak (pcu/hr)	Evening Peak (pcu/hr)
Fakirapul	C	D
Kamlapur	A	A
Tikatuli	D	D
Doinik Bangla	A	A

CONCLUSIONS

As huge impact of heterogeneity on delay has been identified for both intersections. So separate lane for NMV can be an option to reduce its impact to minimize delay. As non-lane based traffic condition exists random and irregular lane changing behaviour has been observed in both intersections which has an impact on delay and LOS. So for increasing performance of these intersections lane behaviour has to be strictly followed by drivers by imposing rules. Worst case scenario has been found in evening peak and for this tidal flow operation can be a good option to increase LOS at that time period.

ACKNOWLADGEMENTS

I would like to express my deepest gratitude to my supervisor, Prof. Dr. Md. Shamsul Hoque, Dept. of Civil Engineering, BUET for his guidance, valuable suggestions and inspiration for this research work.

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FEASIBILITY ANALYSIS OF PROVIDING TAKE OFF AND LANDING RAMP TO A FLYOVER AT A ROAD CIRCLE - A CASE STUDY OF AKHTARUZZAMAN FLYOVER IN CHITTAGONG

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ABSTRACT
Flyover is one of the most efficacious options which can make an existing transportation system of a city more efficient. Additional ramps are often provided to a flyover to change the direction of the movement of vehicles from the central road to their destination without any interruption. The main purpose of this research is to visualize the benefits of the flyover bridge which is under construction in Chittagong over three busy intersections, 2No Gate intersection, GEC intersection and WASA intersection to increase the capacity of traffic flow from Muradpur to Lalkhan bazaar, by providing landing (descending) and takeoff (ascending) ramp at GEC intersection. It also presents the performance of the flyover over GEC intersection and points out the remaining problems including long delays under the flyover as a result of avoiding any ramp in proposed plan at this intersection. It is found that only a few traffics will use the flyover as vehicles can neither ascend nor descend from the flyover at GEC intersection. It will be a great problem for the vehicles which will move from the southern region of Chittagong to the Dhaka-Chittagong trunk road through the GEC intersection. It is shown in the paper that, to make the flyover fully effective, it is necessary to provide the ramps at the GEC intersection.

Keywords: Feasibility; Flyover; Traffic Volume; Capacity; Cost-Benefit.

INTRODUCTION
Flyover bridge construction in two directions on one of the main highways is a popular way to minimize traffic volume at any grade intersection in a city(Yahampath, Bandara, and Perera n.d.). Though the flyover accelerates the vehicle flow towards the bridge, but it cannot properly mitigate all of the difficulties especially on the secondary road (Maitra et al., 2004). A flyover is proposed in Chittagong and is constructed from Muradpur to Lalkhan bazar via Gate no 2, GEC and WASA junction. The Proposed plan of the Flyover is shown in Fig 1.The flyover is 5200m long, 4 lane and have two ramps at 2 no gate intersection. There are four main roads coming towards the GEC intersection. Khulshi in the east, Golpahar in the west, WASA in the south, and 2No Gate in the north, it is the geographical location of GEC intersection. Among the roads, the road towards Khulshi is the connecting road of Dhaka-Chittagong highway and CDA Avenue. According to the proposed plan of the flyover, there will be no ramp at GEC intersection. As a result, different type of problems will arise. The percentage of local vehicles is above 60% of the total vehicle passing this road. So, the drivers will not try to avoid the GEC circle. For maximum passenger they will avoid the flyover. The intercity buses, heavy truck and vehicles moving through this connecting road will avoid the flyover because they can't take direct entry to the Shahid Abdul Halim road as there will not be any ramp. As a result, very poor number of traffic will use

the flyover. In addition, as the GEC intersection is a junction of four roads, providing a ramp or two ramps will be highly effective to reduce the traffic jam at that junction. The vehicles which are moving towards the GEC can't use the flyover. In the future, flyover may not be able to reducing traffic jam. This is why the feasibility is needed to be studied by providing landing and takeoff ramp at GEC intersection. It is shown in figure 2 that, to reach at point D from point A (GEC junction), a vehicle have to go through two intermediate point B and C. Point B is the junction of Mohammad ali road and CDA avenue. The vehicleshave to take a U-turn at that point and go through point C Garibullah Shah bus stop and finally at point D. The whole root is 1000 m in length and indicated by pink line. But the yellow line shows the direct direction of route from point A to point D. Its length is only 200m. The proposal of this report is about providing a landing ramp and a takeoff ramp from A to D and vice-versa.

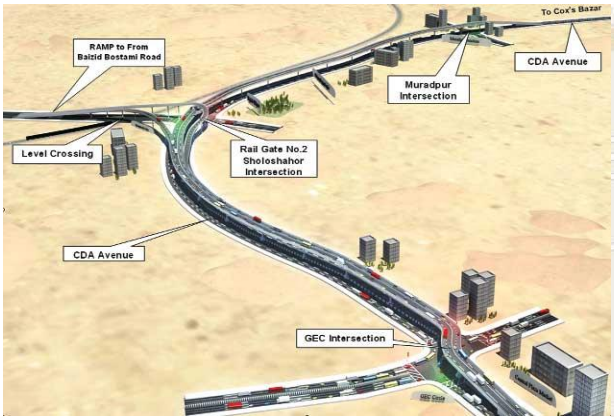


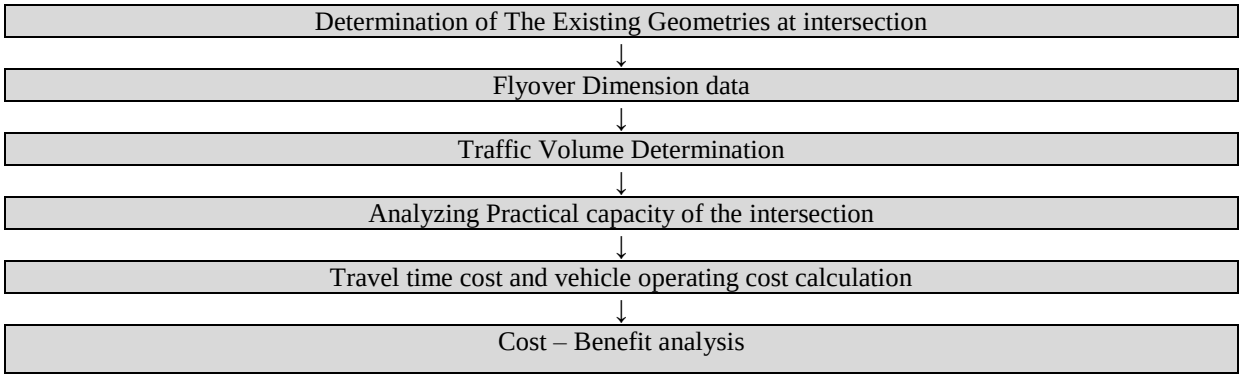
Fig. 1 Proposed Plan (Version 2018)Fig. 2 Route of Vehicle at base case % project case

As a result of above discussion, the following objectives have been emphasized for the present study-

- To determine the problems of existing road and its capacity.
- To determine the problems that will arise after opening the flyover.
- To determine the advantages of providing landing and takeoff ramp at GEC intersection
- To determine the annual saving and benefit-cost ratio after providing ramps at the junction.

METHODOLOGY (SECTIONS)

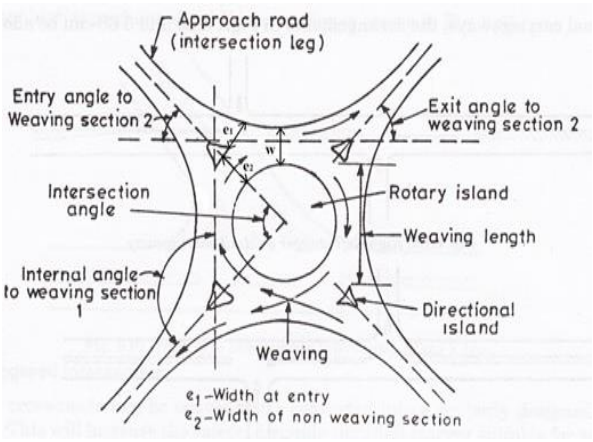
To study feasibility mainly the practical capacity and economical evaluation, the following work plan is followed.



Geometries at intersection

Any intersection consists of the following elements like weaving length, weaving width of entry, width of exit, entry angle to weaving section, internal angle to weaving section, internal to weaving section, exit angle to weaving section, directional island outer edge of rotary and the approach roads which make the

intersection complete and eligible to receive the vehicular concentration using it and weave them out. A typical figure of rotary intersection with all elements has been shown in Fig 3.
Though GEC intersection doesn't look like rotary intersection but it works like a rotary intersection. A survey is done to determine the existing dimension of the intersection is shown in Fig 4.



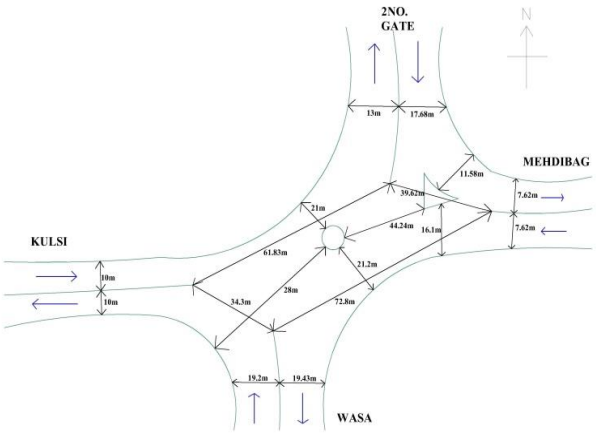


Fig. 3 Element of Rotary Intersection(Kadiyali, 2005)Fig. 4 Dimension of GEC intersection

Flyover Dimension

According to Chittagong metropolitan master plan 1995 & CDA detailed area plan 2008, there is a recommendation for construction of a flyover in different junction of Chittagong city. The main junctions are GEC junction, 2No Gate junction & Muradpur junction. The Flyover dimensions are given below is collected from Chittagong development Authority (CDA) Portal.

- Length of the flyover-3.5 km
- Width of the flyover-17.5m, 4 lanes
- Length of the loop-1.7km
- Width of the loop-7.5 m, 4lanes

Traffic Volume

A traffic survey is carried out to understand the transportation system of the area and to determine any necessary step required to capacitate existing or projected traffic volumes. Average daily traffic, Annual average daily traffic, passenger car unit are the common term to determine traffic volume.

Passenger car Unit

The basic consideration behind this practice is that different types of vehicles offer different degrees of interference to other traffic and it is necessary to bring all types to a common unit (Sarraj and Jadili, 2012). The common unit is known as passenger car unit (PCU)

TABLE 1.PCU FOR DIFFERENT VEHICLE

Types of Vehicle	PCU
Heavy truck	3.00
Bus	3.00
Micro bus	1.25
Car	1.00
Tempo	1.00
Motor cycle	0.25

Hourly Traffic Volume

Traffic Volume data are necessary to do all kinds of practical and financial analysis. Traffic survey data are collected for 18hr from 6 AM to 24 PM. Later, that data are converted into passenger car unit (PCU). Maximum of these hourly volume data are shown in Table 2.

TABLE 2.MAXIMUM HOURLY TRAFFIC VOLUME COUNT AT GEC JUNCTION(IN PCU) FOR 18 HOURS (6 AM TO 24PM)

Direction of flow	**Max PCU/hr**		
	Right	Straight	Left
Mehdibag to GEC	648	1534	714
2NO. Gate to GEC	1429	4704	482
Wasa to GEC	521	3958	1188
Kulsi to GEC	1200	442	1119

Practical capacity of the intersection

The capacity of the weaving section determines the practical capacity of the rotary. The transport and Road Research Laboratory (U.K.) which has pioneered research on this aspect, recommends the following formula, which is a modification of the well-known Wardrop formula (kadiyali, 2005).

$$Qp = \frac{280w(1+\frac{e}{w})(1-\frac{p}{3})}{1+\frac{W}{L}}$$

Where Qp is the practical capacity of the weaving section in PCU, w is the width of the weaving section in meter, e is the average entry width of the rotary in meter equal to $(e_1+ e_2)/2$, L is the length of the weaving section, p is the proportion of weaving traffic i.e. ratio of sum of crossing streams to the total traffic on the weaving section is equal to (b+c)/(a+b+c+d).

- The site of the rotary is level and approach gradient do not exceed 1 in 25.
- e/w should be between 0.40 -1.00
- w/L should be between 0.12-0.40
- P should be between 0.40 and 1.00
- L should be between 18-90m.

The following cases are taken under consideration for capacity analysis of GEC intersection

A. Before construction of flyover
B. After construction of flyover (without landing &takeoff ramp)
C. After providing landing ramp of flyover
D. After providing landing &takeoff ramp of flyover

Case B, C & D is done with following considerations.

1. 30% right vehicle over the Flyover &70% right in the intersection
2. 40% right vehicle over the Flyover &60% right in the intersection
3. 50% right vehicle over the Flyover &50% right in the intersection

Practical capacity of GEC intersection case-A before construction of flyover is solved here.

TABLE 3.PRACTICAL CAPACITY IN THE GEC INTERSECTION

Approach	**Wasa&Mehdibag**	**Mehdibag& 2NO. Gate**	**2NO.Gate &Khulshi**	**Khulshi&Wasa**
Width of entry, $e_{1\,(m)}$	16.10	17.68	10.00	19.20
Width of entry, $e_{2\,(m)}$	19.45	11.58	13.00	10.00
$e = (e_1+e_2) / 2$ (m)	17.775	14.63	11.50	14.60
Width of the weaving section, w (m)	21.2	57.92	21.00	28.00
Length of the weaving section, l (m)	72.80	39.62	61.83	34.30
Total traffic in the weaving section, a+b+c+d (PCU/hr)	10229	8778	7888	9278
Total weaving traffic, b+c (PCU/hr)	8086	7096	6248	7442
P=((b+c)/(a+b+c+d))	.8	.81	.8	.81

Practical capacityQp (PCU/hr)	6198	6024	4982	4794

From the Table 3 it is clearly visible that, for all approaches before construction of flyover in GEC intersection practical capacity is less than weaving traffic. That means traffic congestion will happen.

TABLE 4.SUMMARY OF CAPACITY ANALYSIS

GEC Circle		Capacity			
		Wasa&Mehdibag	**Mehdibag& 2NO.Gate**	**2 no Gate &Khulshi**	**Khulshi&Wasa**
Case-A		Not Satisfied	Not Satisfied	Not Satisfied	Not Satisfied
Case-B	1	Not Satisfied	Satisfied	Not Satisfied	Not Satisfied
	2	Not Satisfied	Satisfied	Not Satisfied	Not Satisfied
	3	Not Satisfied	Satisfied	Not Satisfied	Not Satisfied
Case-C	1	Not Satisfied	Satisfied	Not Satisfied	Not Satisfied
	2	Not Satisfied	Satisfied	Not Satisfied	Not Satisfied
	3	Not Satisfied	Satisfied	Not Satisfied	Not Satisfied
Case-D	1	Not Satisfied	Satisfied	Not Satisfied	Not Satisfied
	2	Not Satisfied	Satisfied	Not Satisfied	Not Satisfied
	3	Satisfied	Satisfied	Satisfied	Satisfied

Project Cost

The total construction costs of the flyover are estimated 450 crore. The financial costs are at market price. The proposed flyover is 5200 m long and it is designed as 4 lane. The length required for two single lane ramps are 200m for each ramp. The required investments to construct the ramps are following.

Total length of single lane legs = 200 + 200 = 400m
Estimated cost of the extended project = 176000000 Tk
Routine maintenance cost = 65384 Tk
Periodic maintenance cost = 2600000 Tk (Per 5 Years)
Major maintenance cost = 13000000 Tk (20 years)
Total lifetime of the project = 40 years

Travel Time cost (TTC) Saving

Travel Time Cost (TTC) also referred to as Value of Travel Time (VOT) for waiting vehicles and passengers are very important parameters for economic analysis of transport projects, particularly for Flyover construction, where reduction of journey time is the objective.

Vehicle Operating Cost (VOC) Saving

Vehicle Operating Cost (VOC) includes vehicle purchase cost, registration, tax and root permit cost, tire cost, fuel cost, maintenance cost, crew cost and lubricant cost (Naudé et al. 2015). Passenger loses valuable time and significant amount of fuel misused during the congestion. For this reason the wasted fuel cost has been considered as Vehicle Operating Cost.

TTC, VOC and Speed of Vehicles at base case and project case are taken from RHD(Roads 2001)

TABLE 5.TTC, VOC & SPEED FOR DIFFERENT MODES OF VEHICLES

Vehicle Category	Speed at Base Case (km/hr)	Speed at Project Case (km/hr)	Economic Cost [TTC per passengers](Tk/hr)	Economic Cost [VOC savings] (Tk/hr)
Truck	11.55	65	104.85	140.00
Bus	17.33	74.29	622.50	140.00
Minibus	26	74.29	164.85	100.00
Jeep	26	86.67	215.37	100.00
Car	34.67	86.67	108.77	100.00
Tempo	20.8	52	65.76	75.00
Motor Cycle	34.67	74.29	45.80	15.00

Total Cost Saving

Total annual cost saving for all types of vehicles is shown in Table 6

TABLE 6.CALCULATION OF TOTAL COST SAVING

Vehicle Category	Total annual TTC saving (tk)	Total annual VOC saving (tk)	Total annual saving (tk)
Truck	2719159.44	3630732.68	6349892.12
Bus	23577128.10	5300868.72	28877996.82
Minibus	1760217.21	1067833.78	2828050.99
Jeep	2141700.93	994428.64	3136129.57
Car	4492841.98	4130589.30	8623431.28
Tempo	4839600.94	5533080.23	10372681.17
Motor Cycle	2651815.90	868498.64	3520314.54
Total	42182464.55	21526038.73	63708503.28

Cost-Benefit Ratio

A benefit-cost ratio (BCR) is the ratio of the benefits of a project or proposal, expressed in monetary terms. It follows that the criterion for accepting an independent project on the basis of the benefit-cost ratio is whether or not the benefit-cost ratio is greater than one (B/C > 1) (Chhatbar and Shinkar 2016).

Total equivalent uniform annual Cost = 27076831Tk

Annual savings from the project = 63708503 Tk

Annual benefit = 36631672 Tk

Benefit-Cost ratio (B/C ratio) = 1.353

RESULTS AND DISCUSSIONS

Benefit-cost ratio 1.353 shows that the proposed ramps will be fully feasible at the GEC intersection.

CONCLUSIONS

From the analysis it is found that providing both of the ramps will be an effective solution to reduce the congestion at GEC intersection. The left turning ascending ramp will allow the vehicles coming from Dhaka-Chittagong highway easy transit over the flyover while the most viable right turning landing ramp will make a speedy route towards Khulshi. These steps can make the flyover more feasible and prevailing.

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IMPROVEMENT OF SKID RESISTANCE IN COASTAL HIGHWAYS USING CRUMB RUBBER

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ABSTRACT
In Bangladesh, historical evidences show that accidents occur in the coastal areas especially in the Chittagong–Cox's Bazar highway. Raw salt is often carried by truck from Cox's Bazar to different parts of the country. But most of the salt businessman don't follow the rules and regulations of salt transportation. As a result, in winter season especially during night salts deposit on the pavement while being transported and make the surface slippery. Due to the slippery condition, the vehicles had to cover a higher stopping distance while overtaking. This results in fatal accidents in the form of head on collision between two vehicles. Bangladesh generates huge amounts of non-biodegradable waste tire annually which can be used with conventional bitumen to make flexible pavement more skid proof. After conducting physical property test on both conventional and modified bitumen, we find that crumb rubber modified bitumen (CRMB) is less ductile, has low stripping value. Further skid resistance test is conveyed on both road models by PORTABLE SKID RESISTANCE TESTER and evaluate the result as a BPN value which is directly related to frictional resistance. The reduction in stopping distance in the case of CRMB after applying brake also justifies the above statement. So modification of conventional bitumen can be a solution to improve the skid resistance of road surface.

Keywords: Coastal areas; Salt transportation; Skid resistance; Accidents; Crumb rubber.

1. INTRODUCTION

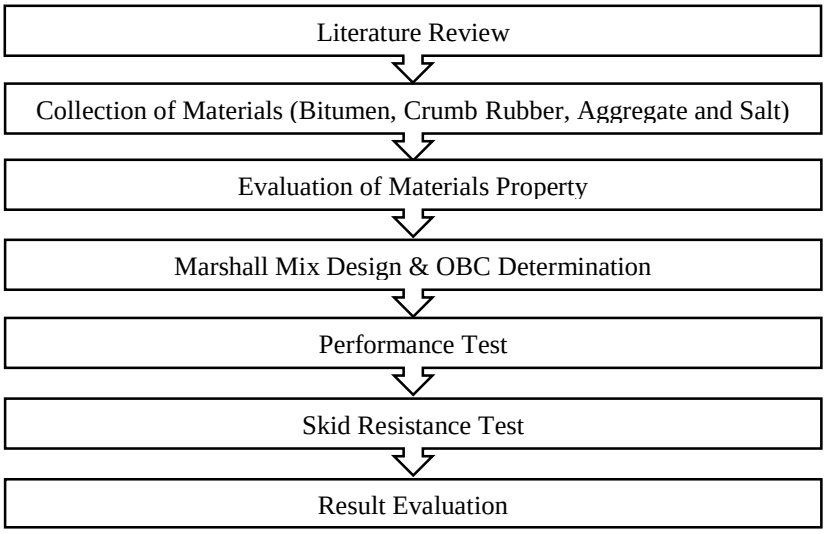
Bangladesh is a country of rivers. Coastal zone of Bangladesh covers about 710 km in length. In Bangladesh, about 98% of paved roads are flexible pavement. Raw salt is often carried by truck from coastal area to different parts of the country. During transportation of salt, salt water comes in contact with the surface of the pavement. This problem adds up more in winter due to the foggy condition at night when salt deposits on the pavement surface. This phenomena makes the pavement surface slippery. As such the braking force of the vehicles decreased and the vehicles lose their control. This results in fatal accident. In Chittagong-Cox's Bazar-Teknaf highway 253 people were killed and 1,144 injured in road accidents in the last six months. The main reason of the majority of those accident is slippery condition of the pavements.

In Bangladesh, we commonly use bitumen for road construction. But is has low stability and low skid resistance under adverse condition of environment. As a result it has been necessary to go for constant maintenance and awareness works which results in huge amounts of money loss in our country. To remove this problem, we can use modifier to improve the life time, stability and skid resistance of the bitumen. Among the different types of modifier, we can use waste tire powder as this is available and

cheap in our country. Today the availability of the tire wastes is enormous, as the automobiles have become the part and parcel of our daily life. They are thrown over land area. If they are not recycled, their present disposal may be by land filling or it may be by incineration. Both the processes have significant impacts on the environment. If they are incinerated, they pollute the air and if they are dumped into some place, they cause soil and water pollution. Under these circumstances, an alternate use for those tire wastes is required. By using this polymer with neat bitumen, environmental impact can also be removed.

2. METHODOLOGY

During our investigation we followed various steps. Our project work is shown below in a flow chart:



2.1 MATERIAL USED IN INVESTIGATION

Crumb rubber collected from a local tire retreading shop near New market, Chittagong was used to modify 60/70 penetration graded asphalt obtained from Bay Terminal & Distribution Company Limited located also in Chittagong. The crumb rubber was generated by scraping old tires of automobiles. Crumb rubber passing ASTM 30 sieve and retained on ASTM 50 sieve was used for bitumen modification. Stone chips collected from local quarry in Chittagong were used as aggregates. Due to local practice IRC, 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	2.67	2.63	2.82
Water Absorption (%)	1	-	-
Impact value (%)	5.97	-	-
Los Angles Abrasion (%)	11.84	-	-
Elongation Index	18.35	-	-
Flakiness Index	24.32	-	-

Table 2: Gradation of Aggregates Used

Sieve Size (mm)	Individual retained (gm.)	Retained percent percentage (%)	Cumulative weight by weight of total aggregate passing	Cumulative % by weight of total aggregate passing	Passing percentage (%)
26.5	0.00	0.00	0.00	0.00	100.00
19	146.00	13.27	146.00	13.27	86.73

13.2	198.00	18.00	344.00	31.27	68.73
9.5	80.00	7.27	424.00	38.55	61.45
4.75	180.00	16.36	604.00	54.91	45.09
2.36	110.00	10.00	714.00	64.91	35.09
1.18	99.00	9.00	813.00	73.91	26.09
0.6	66.00	6.00	879.00	79.91	20.09
0.3	66.00	6.00	945.00	85.91	14.09
0.15	66.00	6.00	1011.00	91.91	8.09
0.075	44.00	4.00	1055.00	95.91	4.09
Pan	45.00	4.09	1100.00	100.00	0.00

The aggregate gradation curve of used aggregate is as below:

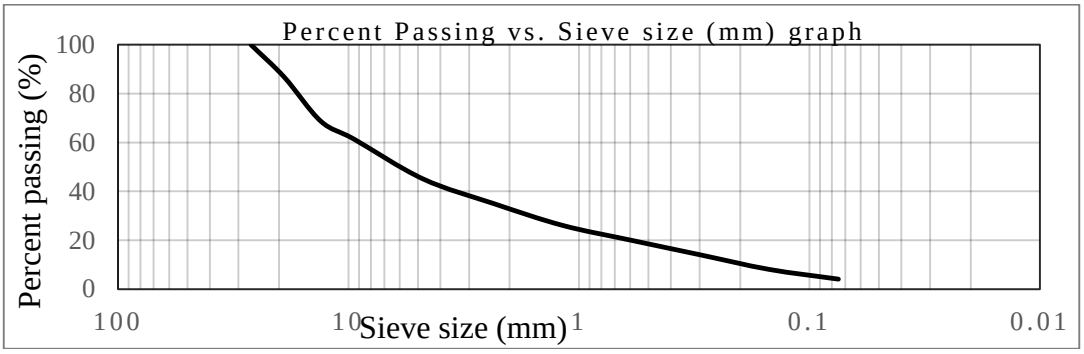


Fig. 1: Aggregate Gradation Curve

The properties of the salt are given in the Table 3.

Table 3: Properties of salt tested in the laboratory

Appearance	Chemical formula	Solubility in water (g/L)	Melting Point (℃)	Boiling Point (℃)	Density (g/cm^3)
Colorless, transparent crystals or white crystalline powder, odorless and hygroscopic.	NaCl	360	801	1413	2.16

2.2 PREPARATION OF CRUMB RUBBER MODIFIED BITUMEN

In preparing the modified binders, about 4500 g of the bitumen was heated to fluid condition in a 8 liter capacity metal container. For blending of crumb rubber with bitumen, it was heated to a temperature of 180°C and then crumb rubber was added. For each mixture sample 10% of crumb rubber by weight fine (300µm-150µm). The blend is mixed manually for about 3-4 minutes. The mixture is then heated to 160°C and the whole mass was stirred using a mechanical stirrer for about 50 minutes maintaining rotation at 1200 rpm. Care is taken to maintain the temperature between 160°C to 170°C. The contents are gradually stirred for about 55 minutes. The modified bitumen is cooled to room temperature and suitably stored for testing.

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2.3 SKID RESISTANCE TEST BY BRITISH PENDULUM TESTER

Two road models which are at the optimum asphalt content and design gradation are prepared.

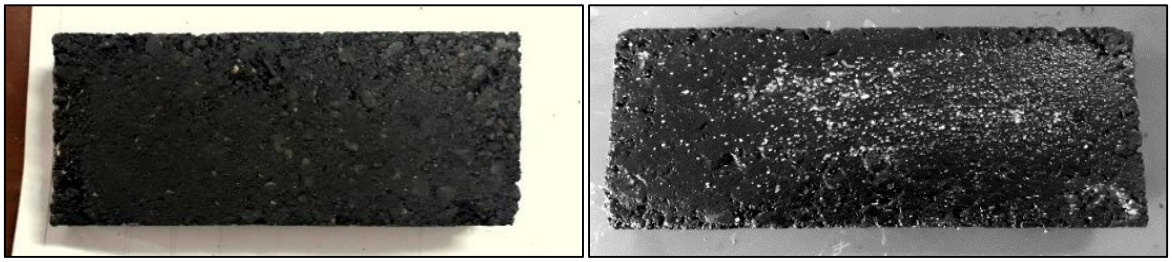

Fig 2: Road models

Apply sufficient water to cover the test area thoroughly. Execute one test swing to check whether the pendulum makes enough contact with the road model surface. Make four more swings and record the results. Report the individual values as BPN also note down the temperature and condition of test surface. The measurement obtained from the scale represents the skid resistance of the material tested such that higher values indicate greater skid resistance.

2.4 DETERMINATION OF STOPPING DISTANCE

If a driver puts on the brakes of a vehicle, the vehicle will not come to a stop immediately. The stopping distance is the distance the vehicle travels before it comes to a rest. It depends on the speed of the vehicle and the coefficient of friction (*f*) between the wheels and the road. This stopping distance formula does not include the effect of anti-lock brakes or brake pumping.

Stopping Distance at level, SD = (lag distance + braking distance)

$$= \mathbf{Vt} + \frac{\mathbf{V^2}}{\mathbf{30f}} \quad (1)$$

Where,

v = speed of vehicle (mile/hour)
f = **coefficient of friction**
t = reaction time (sec)

3. RESULTS

The different physical properties tests of both the neat and modified bitumen were conducted according to ASTM specifications. The property test results of both neat and modified bitumen are shown below by table 4

Table 4: Physical Properties of Bitumen Used

Name of Property Test	Neat Bitumen	CRMB
Specific Gravity	1.037	1.048
Penetration ($1/10^{th}$ of mm)	68	48
Flash Point (℃)	262	239
Fire Point (℃)	280	260
Softening Point (℃)	52	58
Ductility (cm)	100	42
Loss on Heating (%)	0.1	0.4
Solubility (%)	95.3	82.69
Stripping Value (%)	0	0

The Marshall Mix design test results at OBC for both neat and modified bitumen are shown below by table 5

Table 5: Comparison of Marshall Test Result at OBC

Bitumen Type	OBC	Stability (KN)	Bulk Density ($gm./cm^3$)	Air void (%)	Flow value (in 0.25 mm)	Volume of Bitumen (%)	Void in mineral agg. (%)	Void filled with asphalt (%)
Neat	5.28 %	13.33	2.34	5.38	1.32	11.83	16.83	68.38
CRMB	5.00 %	16.68	2.337	5.56	1.57	11.37	16.92	67.17

The measured value, or British Pendulum Number (BPN) is approximately 100 times the coefficient of friction (Williams, 2008). So it is possible to find out the coefficient of friction from the tested value. The coefficient of friction values are listed in the table 6.

Table 6: Coefficient of friction values of different conditions and temperatures for both Conventional Bitumen and CRMB model roads

Temperature	Coefficient of Friction Values					
	Conventional Bitumen			Crumb Rubber Modified Bitumen		
	Dry Condition	Wet Condition	Salt affected Surface	Dry Condition	Wet Condition	Salt affected Surface
25℃	0.60	0.55	0.39	0.65	0.63	0.48
12℃	0.48	0.45	0.34	0.55	0.53	0.40
8℃	0.41	0.39	0.31	0.46	0.43	0.37

So, the stopping distance can be computed for the above coefficient of friction values at level by assuming vehicle speed of 50 km/hr. and reaction time of 2.5 sec using equation (1).

Table 7: Stopping distance of different conditions and temperatures for both Conventional Bitumen and CRMB at level for vehicle speed of 50km/hr.

Temperature	Stopping Distance (ft.)					
	Conventional Bitumen			Crumb Rubber Modified Bitumen		
	Dry Condition	Wet Condition	Salt affected Surface	Dry Condition	Wet Condition	Salt affected Surface
25℃	167.65	172.54	196.63	163.52	165.09	181.10
12℃	181.10	185.59	208.76	172.54	174.77	194.55
8℃	192.59	196.62	217.95	184.02	188.91	201.08

By using Crumb Rubber Modified Bitumen stopping distance can be reduced. The Reduction of stopping distance of different conditions and temperatures for using CRMB at level for heavy vehicles are listed in the Table - 8

Table 8: Reduction of stopping distance of different conditions and temperatures for using CRMB at level for vehicle speed of 50 km/hr.

Temperature	Reduction of stopping distance (ft.)		
	Dry Condition	Wet Condition	Salt affected Surface
25℃	4.13	7.45	15.51
12℃	8.56	10.83	14.21
8℃	8.56	7.71	16.86

The Reduction of stopping distance for crumb rubber modified bituminous on road models in various temperatures and conditions are represented graphically as below:

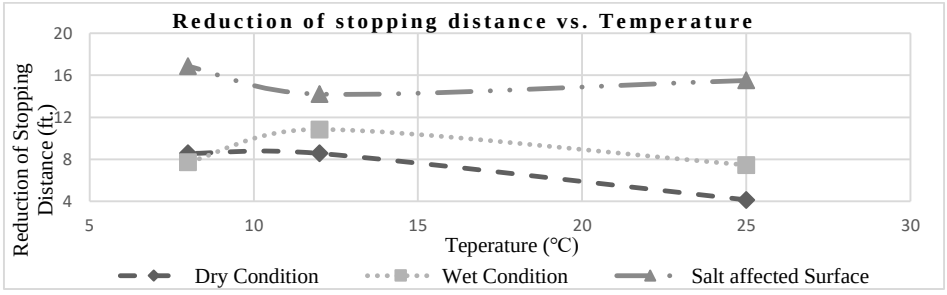

Fig 3: Reduction of stopping distance for using CRMB Analysis Graph for at level for vehicle speed of 50 km/hr.

4. CONCLUSION

The experimental results and related information presented in this research leads to the following conclusions:

CRMB increases the strength and lifetime of pavements. It also helps the pavement to withstand with heavy traffic as well as reducing the maintenance and repairing cost. From the physical perspective, CRMB shows 6℃ more softening point than the conventional 60/70 penetration graded bitumen and possess zero percent stripping value. After performing the skid resistance test on both CRMB and conventional bituminous road model, we can say that BPN value which is a Skid resistance parameter of pavement related to braking force is 22.30%, 17.04% and 16.80% more for CRMB sample than the CB sample conducted respectively in 25℃, 12℃ and 8℃ temperature for salt affected surface. For the vehicle speed of 50 km/hr. stopping distance in winter season reduced by 16.86 ft. in coastal highway by using CRMB.

So, it can be suggested that Crumb Rubber Modified (CRM) Asphaltic road can carry heavier traffic than the conventional bituminous road. Besides CRMB roads possesses higher skid resistance than the conventional bituminous roads in the case of salt affected surface. As a result, the probability of occurring accidents get reduced especially in winter season. Such incident happens because of the reduction of the stopping distance covered by the heavy vehicle in the salt affected CRMB roads after applying brake.

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PASSENGERS' PERCEIVED SERVICE QUALITY OF PUBLIC TRANSPORT IN DHAKA CITY, BANGLADESH

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ABSTRACT
Public Transport (PT) is an inevitable mean to establish a sustainable transportation system for carrying significant number of people in developing cities where rapid urbanization and economic growth has resulted increased travel demand. The main aim of this paper is to assess the bus service quality (SQ) in Dhaka city, based on public perception. A questionnaire survey was conducted at 15 major bus stops in Dhaka to 956 regular bus users in March 2017. Important service aspects that are stated as poor by the respondents are convenience, ease of entry and exit facilities, fitness, frequency, cleanliness, noise level, comfort level, punctuality, movement flexibility on road, seat conditions, availability of information, ticketing system, condition of bus stop, courtesy of helpers/contractors, drivers skills and travel time during office days. Conversely the respondents are satisfied with the speed of bus, transport cost, lighting facility, accessibility of bus, reliability and travel time during holidays. The result shows that passengers in Dhaka city rated overall bus service quality as poor or very poor although some are satisfied with the service. By improving the service features highlighted in this research, the overall condition of bus can be improved.

Keywords: Users' satisfaction; Public Transport; service quality; service features.

INTRODUCTION
Public Transport (PT) is an inevitable mean to establish a sustainable transportation system for carrying significant number of people in developing cities where rapid urbanization and economic growth has resulted increased travel demand. To establish balanced urban transportation system, reduction in private transport use and enhancement of public transport (PT) service quality (SQ) are two imperative but challenging tasks. Hence, the SQ becomes a matter of great concern since an improvement in the quality of service leads to a higher satisfaction of the passengers, which in turn leads to increased use of that system. De Oña et al., (2013) suggested that the number of passengers a public transport system can attract and retain is the measure of success of that system. Service quality depends on a series of features relating to the PT service. According to Berry et al. (1990), customers are the sole judges of service quality. Hence evaluations of users' perceptions about the service on a regular basis are vital to establish efficient transportation strategies. Customer satisfaction survey by asking them to rate the attributes based on their importance is mostly used to know their perceptions. However, for determining these measures, they need not only to know the perceptions about the attributes of quality, but also to identify which attributes have the highest influence on the global assessment of the service (de Oña et al, 2013).
Dhaka is one of the most populated cities in the world, with a density of 45,700 people per square kilometer (Demographia, 2017). In 2024, it is estimated that the population of greater Dhaka will be 36

million with around 70 million person trips a day (STP, 2005). In an ideal city, 25% of the surface area should be used for constructing roads and lanes, (Hossain, 2006) but Dhaka has only 8% of that (DCC, 2002). The existing bus service is not sufficient to keep pace with the growing demand of passengers. Buses and minibuses are the cheapest modes of transport and average cost of transport ranges from 8% of household income for high income groups to 17% for low income groups' (DITS, 1993). A substantial majority of the city dwellers have very poor access to transport service.

Dhaka city needs significant improvement of service quality of Public transport system, which can be accomplished by a clear understanding of its users' needs and expectations. Thus the objective of this research is to evaluate overall customer satisfaction and to investigate the associated service quality attributes that influence mostly to the quality of service. Addressing these attributes will help service providers' gain competitive advantages by executing specific strategies to increase their service quality offer.

Service quality can be outlined as a comparison between customer expectation and perception of service (Parasuraman et al. 1988; Gronroos 1984). 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; Lai and Chen, 2011). Service quality is an abstract concept that is hard to be defined, and in practice, often used interchangeably with satisfaction (Lagrosen et al. 2004; Lai and Chen, 2011; Sumaedi et al. 2011). However, the differences between both variables have been clarified in the literature.

Oliver et al. (1997) explains that service quality is more specific and related to perceptive judgments while satisfaction is more holistic and associated with affective judgments. Furthermore 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. According to Oliver et al. (1997), satisfaction is the customer's contentment. It is a judgment that a product or service feature, or the product or service itself, provided (or is providing) a pleasurable level of consumption-related fulfilment, including levels of under- or over-fulfilment. Need accomplishment is a comparative processes giving rise to the satisfaction responses. Any gaps lead to disconfirmation; i.e., positive disconfirmations increases or maintain satisfaction and negative disconfirmation create dissatisfaction. Perceived quality is defined as how well the service level delivered matches customer expectations. If perceived performance ratings are lower than expectations, it indicates a sign of poor quality, and the reverse implies good quality (Cheng Lim & Tang, 2000). In the services marketing literature, perceptions are defined as consumers' beliefs concerning the service received (Parasuraman et al., 1985) or experienced service (Brown and Swartz, 1989). Parasuraman et al. (1988) defined expectations as desires or needs of consumers, i.e., what they feel a service provider should offer rather than would offer.

Lai and Chen (2011) have confirmed a direct positive relationship between service quality and behavioural intention in the public transport context. In addition, other researchers found that service quality influence behavioural intention indirectly through satisfaction and perceived value (Wen et al. 2005; Joewono and Kubota, 2007).

Very few studies have been conducted regarding the service quality of PT in developing countries. Specifically for Dhaka, comprehensive studies on bus SQ with reliable and large data sets are absent. Das (2001) measured the LOS (Level of Service) provided by two service providers operating in a single route of Dhaka. Using five performance measures namely travel time, waiting time, load factor, regularity of service, and comfort; this study determined aggregate level of service scores for each bus services. Andaleeb et al. (2007) used factor analysis and multiple regressions, to find out significant factors affecting the passenger's satisfaction on bus service quality based on 248 samples. Eight factors namely comfort levels, staff behaviour; number of buses changed to reach destination, supervision and waiting facilities were found to have significant effect on passenger satisfaction.

Rahman et al. (2017) explored the contributory factors for the unsatisfactory bus services in Dhaka city as 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). 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.

METHODOLOGY

A comprehensive questionnaire survey was carried out face to face at 15 locations of major bus stands in Dhaka city. The survey was conducted in March 2017 at fifteen locations in Dhaka 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 attributes on a five point likert scale ranging from 1 to 5 (1 is for 'excellent' and 5 is for 'very poor'). Total 956 samples were interviewed by ten enumerators. Table 1 shows general information of respondents.

Table 1 General information of Respondents

Characteristics	Statistics
Gender	Male (67%), female (33%)
Age	10~19 years old (7%), 20~29 years old (50%), 30~39 years old (29%), 40~49 years old (10%), 50~60 years old (3%), >60 years old (1%)
Occupation	Student (34%), Private Service (34%), Public Service (11%), House Wife (8%), Labour (2%), Businessman (11%)
Monthly income	<10000 Tk. (32%), 10000~30000 Tk. (46%), 30000~50000 Tk. (17%), 50000~70000 Tk. (3%), >100000 Tk. (2%)
Cars ownership	Did not any car (75%), A unit (19%), Two units (5%), Three units or more (1%)
Motorcycles ownership	Do not have (60%), A unit (31%), Two units (8%), Three units or more (1%)
Main mode of travel	Bus (87%), Rickshaw (3%), Para transit (1%), Motorcycle (4%), Car (5%)
Monthly travel expenditure	1%-10%Travel cost (48%), 11%-20% Travel cost (40%), 21%-30% Travel cost (9%), >30 Travel cost (3%)
Trip purpose	School/College/Polytechnic/University (31%), Office/Business (49%), Emergency/Hospital (4%), Park/Zoo/Museum (1%), Other (15%)
Reason of using bus	Low cost 31%, No own transport 31%, No other option 23%, Safety 7%, Fast travel 8%
Mode take to get bus stop	Waking 54%, Rickshaw 39%, Para transit 5%, Motorcycle/Cycle 0%, CNG 2%
User time for reach bus stop	5 min (21%), 10 min (31%), 15 min (27%), 20 min (11%), 25 min (10%)
Waiting time of the service	5-10 min (16%), 10-15 min (30%), 15-20 min (30%), 20-25 min (15%), 25-30 min (9%)

1 US $ = 83 Tk. (approximate)

Data Analysis and Results:

According to the survey report most of the respondents' (59%) answered that they travel by local bus every day while 17% answered they travel more than twice a week but not every day. Figure 1 shows users' frequency of travel by local bus. 37% of the users' agree or strongly agree that the bus is always over crowded.

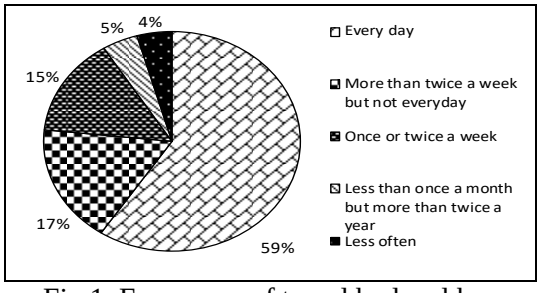


Fig 1. Frequency of travel by local bus

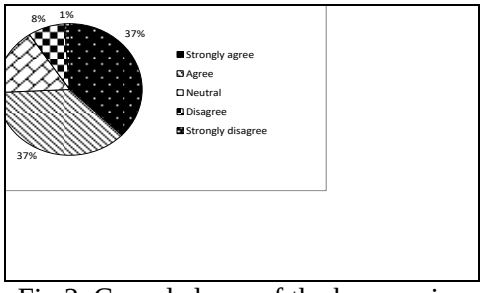


Fig 2. Crowdedness of the bus service

Figure 3 to 12 shows different service attributes of bus service as rated by the respondents. 42% respondents answered overall fitness of bus is poor while 24% and 23% replied very poor and satisfactory respectively (Fig. 3). Most of the respondents (42%) assessed the physical condition of bus as poor while 27% and 21% answered satisfactory and very poor respectively (Fig. 4). Majority (41%) of respondents replied that the cleanliness of bus is poor and 24% expressed that cleanliness of bus is

very poor (Fig. 5). 42% of the respondents said that the seat condition of bus is poor while 21% revealed it as very poor (Fig. 6). Result shows that 41% of the respondents perceive that the lighting facility is satisfactory while 34% answered poor (Fig. 7). 40% of the respondents rated the noise level of the bus as poor while 27% of them answered satisfactory (Fig. 8). Respondents' opinion about the movement flexibility inside the bus (Fig. 9) ranges from poor (37%) to very poor (26%). Most of the respondent (44%) answered poor about comfort level (Fig. 10). Half of the users' (50%) answered the condition of bus stop is poor while 22% and 18% of them replied satisfactory and very poor respectively (Fig. 11). Similarly, half of the respondents' replied that the cleanliness of bus stop is poor (Fig. 12).

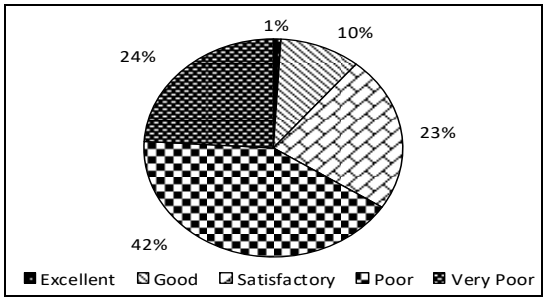


Fig 3. Fitness of bus

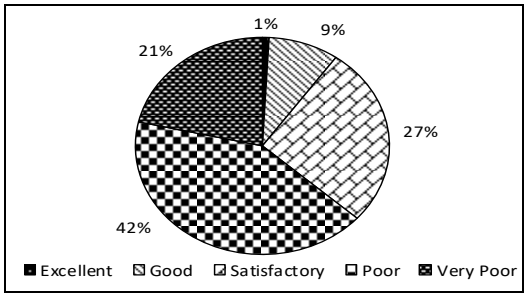


Fig 4. Physical condition

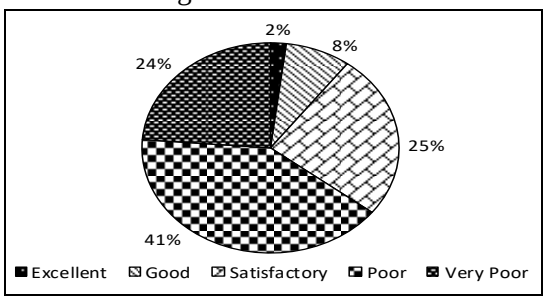


Fig 5. Cleanliness of bus

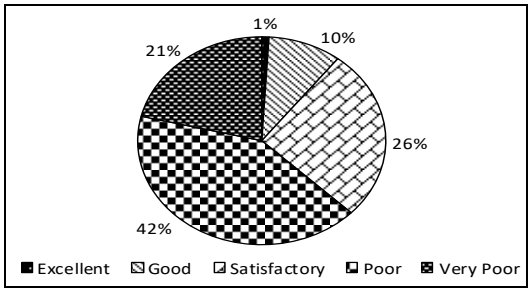


Fig 6. Seat condition

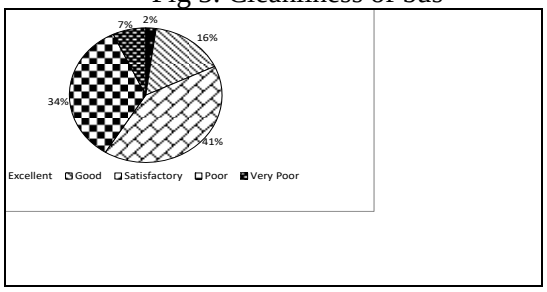


Fig 7. Lighting facility

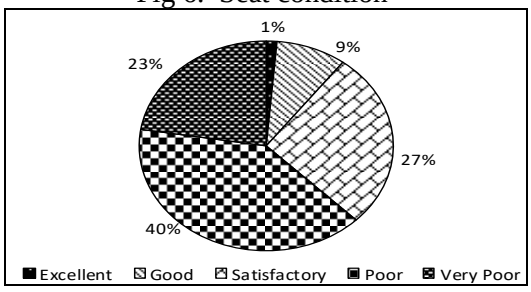


Fig 8. Noise level of the Bus

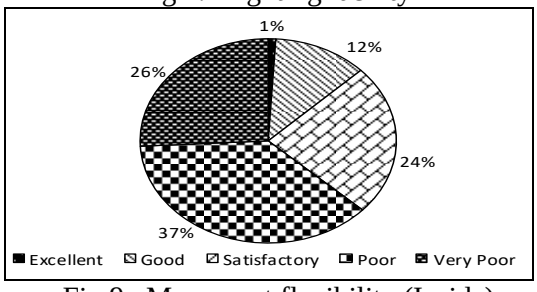


Fig 9. Movement flexibility (Inside)

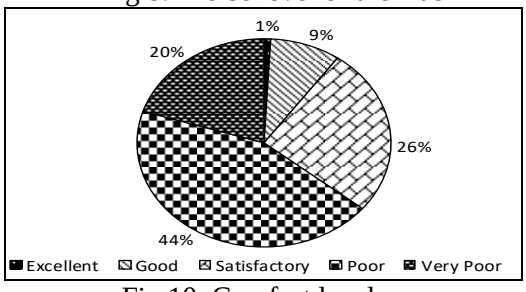
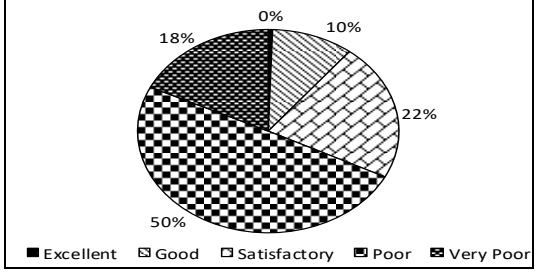


Fig 10. Comfort level



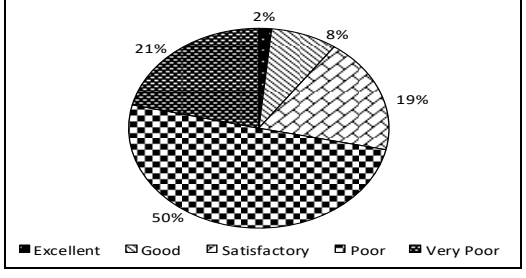


Fig 11. Condition of bus stop

Fig 12. Cleanliness of bus stop

The respondents were asked to rate the service features of bus service quality. Majority of the respondents perceive that the safety at bus stop (45%), security at bus stop (42%), level of personal security inside the bus (35%) and security of passengers in off peak period (42%) is poor as shows in table 2. Majority (38%) of the respondents rated ease of entry and exit facilities of bus as poor while 26% and 25% replied satisfactory and very poor respectively. 34% of the respondents replied that the behaviour of drivers is satisfactory while 31% and 20% replied poor and very poor respectively. About 37% of respondents mentioned that the driver skill is poor while 31% mentioned satisfactory. 34% of the users rated the reliability of bus service is poor while 32%, 18%, 14% respondents replied satisfactory, good and very poor respectively. Majority (40%) of the users' perceived that the courtesy of helpers/conductors is poor. 39% of the respondents identified that the accessibility of bus stop is poor. 41% of the respondents replied that the travel time of bus service during office days is poor while 38% rated it as satisfactory during holidays. On the other hand 33% and 7% of the users think the travel time of bus service during office day and holidays is very poor.

The convenience of service, frequency of service, punctuality of transport, movement flexibility on road, sitting arrangement, availability of information and paying fare or ticketing system are rated as poor by 39%, 36%, 42%, 45%, 40%, 42% and 40% respondents respectively. Speed of bus and transport cost are rated as satisfactory by 38% and 37% respondents respectively. About 41% of the respondents' rated the service quality as poor while 26% ranked as satisfactory. 23% of them think that the service quality is very poor.

Table 2: Quality of bus service

Sl. no	Question/Factor	Rating				
		Excellent	Good	Satisfactory	Poor	Very Poor
1.	Safety at bus stop	1%	10%	23%	45%	21%
2.	Security at bus stops (others)	1%	9%	28%	42%	19%
3.	Levels of personal safety (inside)	3%	15%	30%	35%	17%
4.	Security of passengers (off peak)	1%	10%	33%	42%	14%
5.	Entry and Exit	2%	9%	26%	38%	25%
6.	Behavior of driver	2%	13%	34%	31%	20%
7.	Driving safety (Drivers Skill)	1%	12%	31%	37%	20%
8.	Reliability of local bus service	2%	18%	32%	34%	14%
9.	Courtesy of Helpers/Contactors	0%	8%	24%	40%	28%
10.	Accessibility of bus stop	1%	11%	34%	39%	15%
11.	Accessibility of Bus	0%	10%	40%	40%	10%
12.	Travel Time (office days)	1%	7%	19%	41%	33%
13.	Travel Time (holidays)	5%	34%	38%	16%	7%
14.	Convenience of Service	2%	13%	30%	39%	16%
15.	Frequency of service	1%	19%	35%	36%	10%
16.	Punctuality of transport	0%	11%	28%	42%	19%
17.	Movement flexibility (On Road)	0%	8%	28%	45%	19%
18.	Sitting arrangement	1%	11%	27%	40%	22%
19.	Availability of information	1%	11%	24%	42%	23%
20.	Paying fare / Ticketing system	1%	11%	28%	40%	21%
21.	Speed of bus	1%	13%	38%	35%	12%
22.	Transport Cost	1%	14%	37%	31%	17%
23.	Bus services quality rating	1%	9%	26%	41%	23%

RESULTS AND DISCUSSION

This study evaluated passenger's satisfaction level of various service aspects provided by public transport in the city of Dhaka in Bangladesh. About 87% passengers use bus as a main mode of transport. Low travel cost and absence of own transports are the main reasons of using bus as mentioned by the respondents. Result indicated that most of the users' travel by local bus every day. The maximum respondents rated poor about convenience of service, frequency of bus service, punctuality of transport, movement flexibility on road, sitting arrangements, seat conditions, availability information of the bus, paying fare/ticketing system, fitness of bus, cleanliness of bus, noise level of bus, cleanliness of bus

stop, Movement flexibility inside the bus, comfort level, physical condition of bus, condition of bus stop, entry and exit, courtesy of helpers/contractors, driving skills, accessibility of bus, and travel time during office days. Moreover they have also mentioned poor about safety and security for both bus and bus stop. 37% respondents agree or strongly agree that the buses are overcrowded. On the other hand the respondents are satisfied with the speed of bus, transport cost, lighting facility, accessibility of bus, reliability of local bus service and travel time during holidays. At the end about 41% of the bus users' ranked the overall bus service quality as poor in Dhaka city.

CONCLUSION

Passengers' satisfaction level of the bus service quality in Dhaka city is explored in this study. The paper explores passengers' satisfaction on various service aspects provided by the public transports on the overall ratings of SQ perceived by the users'. The result shows that majority of the passengers in Dhaka city are not satisfied with the service provided by the public bus transport though bus is the main mode of transport in Dhaka 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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EXPLORING PARATRANSIT SERVICE QUALITY BASED ON LOW-INCOME WOMEN'S PERCEPTION: A CASE STUDY IN DHAKA CITY

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ABSTRACT
This paper assesses paratransit service quality based on low-income womens perception. Although paratransit service plays crucial role for transportation of significant number of people, especially the low-income people in emerging cities, their services are frequently insufficient to meet demand. Factors affecting passengers' perceived paratransit performance are investigated in this study by ordered probit model. A face to face interview survey with 410 low-income women in Dhaka city, Bangladesh was conducted in July 2017. The respondents were asked about 22 service attributes to rate the paratransit service quality on a five-point likert scale. The result shows that the most significant service quality variable that has impact on low-income womens satisfaction about paratransit are seat comfort level, travel cost, ticketing system, quality of driver, cleanliness and sitting arrangement. On the other hand the respondents are not satisfied with the fitness of vehicle, noise level, movement flexibility inside the paratransit, performance for long route movement, availability, security of goods and passengers, riding safety, and movement flexibility in any road. The findings provide useful information to the service providers for considering appropriate strategies to improve the paratransit service.

Keywords: Paratransit service quality, low-income women, ordered probit model.

INTRODUCTION
In developing countries, it is necessary to satisfy the mobility needs with sufficient capacity while quality is constrained by various issues. In absence of effective public transportation system, the paratransit modes have spreaded all over the city to meet the present demand. They provide flexible and frequent services to small settlements through narrow streets, where no other public transport service is available at a relatively low fare. In many cities, more than half of the total public transportation demands are carried by them (Joewono and Kubota, 2005).
Dhaka is the most densely populated mega city having more than 105 million people within an area of 1463.60 square km and about half of the dwellers are women (Bangladesh National Portal, 2016). More than 4 million people in Dhaka live in slums. Being the main commercial centre, Dhaka offers lots of income generating opportunities and is the main employment hub for working people. Many low and middle-income households in Dhaka have been moving to peripheral suburban areas because of the lack of affordable housing in the central cities. Walking serve the highest percentage of trips in slum areas where incomes are lower, trip distances are shorter and public transport is not available while longer distances are served by bus or paratransit.
As urbanization changes the face of poverty in Bangladesh, widespread insecurities within the urban environment force low-income households to deploy new strategies of labour mobilization that challenge the women to take part in family wages. According to Moon and Miah (2017), the women respondents in respect of financial support contributed 40% to 58% of their income to the family

expenses. The income thresholds low income are (defined as those with a GNI per capita): low income - $1,025 or less; lower middle income - $1,026 to $4035; upper middle income - $4036 to $12,475; and high income - $12,476 or more (World Bank, 2016). According to (BLF, 2018), low income mainly includes garments, textile, domestic worker, street vendors, agricultural workers, waste pickers, retail, logistics, jute and cotton, leather and shoe, handloom, ship breaking, security, day labour and so on. Majority of poor female workers are employed in two types of jobs in Dhaka city as domestic workers (16%) and garment workers (32%) (LFS, 2000).

The number of domestic workers in Bangladesh is about 2 million, out of which 83% are female (The daily independent, 21 March 2016). Ready Made Garment (RMG) industry of Bangladesh is the highest export earning sector of the country. It is the second largest export sector of RMG in the world after China (Ali, 2017). About 4.2 million workers (BGMEA, 2017) are employed in this sector where approximately 80% of them are women (World Bank, 2017) who came from rural areas of Bangladesh. The most predominant mode of travel for women of low-income group in Dhaka is walking. A World Bank study on Dhaka, Bangladesh revealed that 35% of female commuters relied on rickshaws as their sole mode of transport (Peters, 1999). Besides walking, non-motorized (Rikshaw) or motorized paratransit mode is the most accessible and available mode for women; which is often much more expensive than formal public transport (Rahman, 2009).

Paratransit modes are usually demand responsive and provide shared trips. Their services may differ considerably on the degree of flexibility they provide to the users. Paratransit is used extensively in almost all cities in Bangladesh. It provides personalized and flexible transport services to wide-ranging people (Roos and Alschuler, 1975). Various forms of paratransit modes exist in the cities of developing countries from simple non-motorized human or animal powered vehicles to motorized mini buses, the motorized paratransit modes are dominant in most of the cities. Rickshaw is most popular non-motorized paratransit at Dhaka city. Figure 1 shows types of paratransit modes in Dhaka city. This study considers motorized Tempo/Leguna as paratransit.

Generally, paratransit are based on three/four wheeled scooter chassis; its seat arrangement is such that it can carry 10/12 persons at back and two persons at front, beside the driver. Most of these vehicles are indigenously manufactured to fit the market needs (Phun and Yai, 2016). These vehicles usually run more or less in defined routes and stop to pick up or discharge passengers upon request. In Dhaka, there are 32 such defined paratransit routes offering mobility to the users across the whole city.

Auto Tempo CNG Rikshaw

Fig 1. Types of Paratransit modes in Dhaka city

The remaining sections of this paper are outlined as follows. Section 2 presents the previous studies on SQ evaluations and empirical models of public transportation including paratransit. Section 3 presents study location, sample size, selected SQ variables, proposed empirical model and model findings. Section 4 concludes major findings and provides recommendations for future research.

LITERATURE REVIEW

A sustainable transportation system needs to be established in the modern ever-growing megacities to achieve a balanced urban transportation system. Among different public transportation modes, paratransit has become a vital mobility option in many developing countries to fill the gaps left unserved by public transit services and providing efficient feeder connections. Moreover, majority of people in developing countries, especially the low-income people, cannot afford private transport, and hence predominantly rely on paratransit services. Paratransit offers several advantages compared to other public transport modes, such as high accessibility and mobility, more beneficial operating cost for short trips, easy and unimpeded lane movement and relatively low maintenance costs (DLLAJ, 2001).

Paratransit supply is the best in meeting the transport requirements of the low income people in terms of fares and flexibility (Kaltheier, 2002). This mode is contributing only 18% of traffic flow while being able to transport more than 50% of passenger trips. In Dhaka, it is found that around 72% households use paratrasit for their daily travel (Shimazaki and Rahman, 2002). Because of its service necessity the role of paratransit remains inevitable in urban mobility context.

Service quality (SQ) depends on a series of features relating to the PT service. SQ can be defined as the extent of discrepancy between customers' expectations or desires and their perceptions as stated Zeithaml et al. (1990). Berry et al. (1990) explored that customers are the sole judges of SQ. SQ is measured from the customer's perspective since transit quality depends on the passengers' perceptions regarding each attribute characterizing the service. Asking customers to rate each attribute on an importance scale is the method mostly used by the operating companies.

A number of researches have been carried out to investigate various study fields of paratransit system including physical and operational characteristics, cost and benefit and its sustainability (Shimazaki and Rahman, 1995; Regidor et al. 2009). Joewono and Kubota (2007) evaluated the SQ of Indonesian paratransit using nine variables: availability, accessibility, reliability, information, user service, comfort, safety, fare and environmental impact. Rahman et al. (2016) applied SEM to develop relationships between user satisfaction and paratransit SQ. The analysis revealed that the latent variables 'Service Features' and 'Physical Appearance' are related to the constructs 'Speed of paratransit', 'Punctuality and reliability', 'Riding safety', 'Travel cost', and 'Fitness of vehicle'. De Oña et al. (2013) revealed that 'Service' was linked to observed variables like 'Frequency', 'Punctuality', 'Speed', 'Proximity', 'Fare' and 'Information' having the greatest influence on the overall bus transit SQ of Granada, Spain.

From the literature review, it can be found that in most cases, the exploration about user perception on the public transportation SQ employed data from developed countries; however, it is a fact that there are so many things differentiating the characteristics, behaviors, expectations, needs, and perceptions between developed and developing countries. As far authors concernvery limited number of studies explored public transit data from developing countries by OPM.

METHODOLOGY

Data collection

A comprehensive questionnaire survey was carried out face to face to the low-income working women in Dhaka city, Bangladesh. The survey was conducted from 16th to 19thJuly 2017. The survey was conducted during working days and holidays, when Paratransit users (women) either start for their work or return after work. Targeted respondents were from slum areas of Jhauchor and Kamrangichor slum areas where no bus service is available. The respondents rated 22 service attributes regarding their overall satisfaction on prevailing paratransit service. Total 410 samples were interviewed by seven surveyors. After checking the completeness 400 samples were considered for model development.

General information of the respondents

The sample is characterized by a total number of low-income women. About half (48%) of the users are aged between 31 and 40 years, while 25%, 24%, and 3% respondents are between 18 to 30 years, 41 to 50 years and 51 to 60 years old. More than half (55) of the respondents are household workers while 16% are garments workers and 15% are day labour. Most of the respondents (68%) monthly income range is 5000 – 10000tk while 24% respondents' monthly income is less than 5000tk. 79% and 19% of the respondents daily travel expenditure is up to 20tk and between 21 – 40tk. Table 1 shows the general characteristics of the respondents.

Table 1:General charaecteristics of of the respondents

Features	Statistics
Gender	Female (100%)
Age	18~30 years old 25%, 31~40 years old 48%, 41~50 years old 24%, 51~60 years old 3%
Occupation	Household worker 55%, Garments workers 16%, day labor 15%, Sales worker 3%, Other 11%
Monthly income	<5000 Tk. (24%), 5000~10000 Tk. (68%), 10000~15000 Tk. (7%), >150000 Tk. (1%)
Travel cost	0~20 Tk. (79%), 21~40 Tk. (19%), 41~60 Tk. (1%), 61~80 Tk. (1%), >80 Tk. (0%)

1 US $ = 83 Tk.

Preliminary statistics

A five-point Likert scale ranging from 1 to 5 (where 1 is for excellent and 5 is for very poor) was used for evaluation of the paratransit SQ. Mean value ranges from 3.05 to 3.91 and standard deviations value ranges from 0.734 to 1.104 as shown in Table 2. Ease of entry and exit has the highest mean value 3.91 and travel time in holidays has the lowest mean value 3.05.

Table 2: Preliminary statistics

Item no.	Description	Mean	Standard deviation
1.	Paratransit service quality	3.53	0.940
2.	Seat comfort level	3.44	0.911
3.	Fitness of vehicle	3.59	0.933
4.	Noise level	3.69	0.864
5.	Lighting facilities	3.44	0.985
6.	Cleanliness of paratransit	3.48	0.971
7.	Ticketing system	3.64	0.987
8.	Ease of entry and exit	3.91	0.936
9.	Sitting arrangement	3.66	0.899
10.	Movement flexibility	3.72	0.941
11.	Quality of driver	3.61	0.998
12.	Speed of Paratransit	3.37	1.104
13.	Availability of paratransit	3.57	0.905
14.	Travel time office day	3.80	0.957
15.	Travel time in holiday	3.05	1.011
16.	Integration of supporting modes	3.55	0.734
17.	Security of goods	3.68	1.036
18.	Security of passengers	3.71	0.922
19.	Riding safety	3.63	0.930
20.	Travel cost comparing with other	3.40	0.951
21.	Performance for long route movement	3.59	0.973
22.	Movement flexibility in any road	3.59	0.947

Model development

The overall paratransit SQ in Dhaka city was evaluated based on low womens perception in a 5-point liker scale. The OPM was originally developed by McKelvey and Zavoina (1975). In the OPM there is an observed ordinal variable Y, which in turn is a function of another variable Y* that is not measured. Specifically, in the ordered model there is a continuous unmeasured latent variable Y*, which determines with what the observed ordinal variable Y matches. OPM can be used to estimate the probability that the unobserved variable $Y*$ falls within the various threshold limits. 21 independent variables were introduced representing the satisfaction level with the SQ factors. The value Yi of the observed variable depends on whether or not the value of Y* crossed a particular threshold, as showed by the following equation:

$Yi= \quad \mu j-1 < Yi* \leq \mu$

Model result analysis

Statistical software STATA 14 was used to develop the Ordered Probit Model as shown in Table 4.

Table 4: Ordered Probit Model (OPM) results

Serial no.	Variable names	Coefficient (β)	Std. Err.	z	P > |z|	95% Conf. interval	
01	Seat comfort level	0.996	0.136	7.31	0.000***	0.729	1.263
02	Fitness of vehicle	-0.204	0.128	-1.59	0.112	-0.456	0.048
03	Noise level	-0.201	0.112	-1.79	0.074*	-0.421	0.019
04	Lighting facilities	0.183	0.114	1.60	0.109	-0.041	0.406
05	Cleanliness of paratransit	0.344	0.114	3.03	0.002***	0.122	0.567
06	Ticketing system	0.436	0.114	3.81	0.000***	0.212	0.660
07	Ease of entry and exit	0.262	0.112	2.34	0.019**	0.043	0.481

08	Sitting arrangement	0.345	0.124	2.77	0.006***	0.101	0.588
09	Movement flexibility inside the paratransit	-0.117	0.110	-1.06	0.291	-0.334	0.100
10	Quality of driver	0.398	0.105	3.79	0.000***	0.192	0.603
11	Speed of paratransit	0.030	0.074	0.41	0.682	-0.115	0.175
12	Availability of paratransit	-0.110	0.104	-1.06	0.290	-0.313	0.093
13	Travel time office day	0.216	0.101	2.14	0.032**	-0.018	0.415
14	Travel time in holiday	0.010	0.081	0.13	0.899	-0.147	0168
15	Integration of supporting mode	0.292	0.118	2.48	0.013**	0.062	0.522
16	Security of goods	-0.137	0.123	-1.12	0.265	-0.377	0.103
17	Security of passengers	-0.103	0.125	-0.83	0.408	-0.348	0.141
18	Riding safety	-0.032	0.142	-0.22	0.823	-0.310	0.246
19	Travel cost comparing with other	0.525	0.111	4.71	0.000***	0.306	0.743
20	Performance for long route movement	-0.239	0.127	-1.88	0.060*	-0.488	0.010
21	Movement flexibility in any road	-0.124	0.141	-0.88	0.380	-0.399	0.152

Dependent variable is Paratransit service quality; P-values indicate level of significant

Note: ***$p \leq 0.009$ (high significant); **$p \leq 0.05$ (medium significant); *$p \leq 0.10$ (low significant).

Seat comfort level is the most important variable that has impact on low-income women's satisfaction about paratransit SQ. There is a probability if seat comfort level is improved then SQ might be improved. Travel cost comparing with other mode and ticketing system are the second and third significant variables having impact on low-income women's satisfaction of paratransit SQ. Reasonable travel cost of paratransit and convenient ticketing system may improve the paratransit SQ. Quality of driver, cleanliness and sitting arrangement of paratransit are the fourth, fifth and sixth significant variables respectively. There is a probability if quality of driver, cleanliness and sitting arrangements are improved, passengers would be more interested to travel by these mode. Fitness of vehicle and noise level of paratransit has great impact on satisfaction level of low-income women. Availability of paratransit is an important variable that has great impact on low-income women's satisfaction about paratransit SQ. If the paratransit service is more obtainable or accessible to the women the SQ might be enhanced. Performance for long route movement and movement flexibility in any road also has impact on low-income women's satisfaction about paratransit SQ.

CONCLUSIONS

Twenty-two SQ variables were rated by low-income women to discern current condition of paratransit service in Dhaka city. This study presents the result of an investigation into the relationship between the overall significant level of SQ and variables affecting SQ based on low income women's perception by OPM. The OPM provided the evaluation of low-income women perception among three levels (High, medium and low significant) by varying the level of satisfaction with any SQ attributes. Result indicates that twelve variables have positive coefficient (β) values indicating that they have significant influence on low-income women's satisfaction about paratransit SQ and it creates positive impact on SQ. There is a probability if these variables are improved then service quality might be improved. The estimated model indicates that passengers rating for overall service quality of transport significantly increases when they are satisfied with the service such as seat comfort level, lighting facilities, cleanliness of paratransit, ticketing system, ease of entry and exit, sitting arrangement, quality of driver, speed of paratransit, travel time office day, travel time in holiday, integration of supporting mode and travel cost comparing with other.

Lighting facilities is an important (significance in low) parameter for safety purpose in the evening/night time for the low income working womens. During returning from workplace in the evening they suffer harassment from conductors/helpers or other passenger into the paratransit. Also, the model results show that 'Lighting facilities' has positive influence on the paratransit SQ, which represents the real scenario.

Riding safety, security of goods and security of passengers are the major significant variables that influence SQ positively since safe vehicle is always preferable by the passengers. However, the result shows that riding safety, security of goods and security of passengers are insignificant variables. Also, it influences paratransit SQ negatively which does not match the real scenario.

Sitting arrangement refers the number of seats allocated for the women. Usually no seat is reserved for low-income working women in the paratransit. They can expect separate and comfortable sitting arrangement for easy movement inside the paratransit. Movement flexibility inside the paratransit indicates the space in the paratransit. Often it is packed which cause movement difficulties, especially for women.

The result is in line with the research outcomes of previous studies like Joewono and Kubota (2007). They applied SEM to assess the SQ of bus transit system of Bandung, Indonesia. Result identified that 'Comfort' as the most important observed variable. The findings of this research may help operators and policy-makers to establish strategies for improvement of paratransit service quality. Further variation in samples as adding more survey locations may help to obtain more accurate conclusion of paratransit service quality.

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PEDESTRIAN BEHAVIOUR AT ROAD CROSSING AND SIDEWALKS AT AND NEAR SELECTED INTERSECTIONS IN DHAKA CITY

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ABSTRACT
Pedestrian road-crossing and sidewalk using behaviour at intersections are important for analysing safety and convenience of intersections for pedestrians. Here pedestrian road-crossing behaviour has been studied at Motijheel and Kakrail intersections and pedestrian sidewalking behaviour has been studied near the sidewalks of Shahbag intersection. Pedestrian behaviour with pessenger boarding-alighting of buses, road-crossing characteristics for different traffic condition, and utilization of foot overbridge have been analysed. The frequency and characteristicsof pessenger boarding-alighting of buses, utilization of foot-overbridge, pedestrian road crossing speed, obstacles, waiting behaviour etc has been analyzed with respect to vehicle speed and headway with direct observation and video recording. Related pedestrian opinions on safety and problem faced by them have been studied by questionnaire survey. Planned allocation of boarding-alighting area for buses can improve the pedestrian road crossing behaviour at intersections. Level of service analysis was done with the sidewalks near Shahbag where 5 out of 8 sidewalks were of category F. From level of service condition and questionnaire survey it can be concluded that Providing good surface condition, standard width for sidewalks and allocating particular location for vendors and stallscan improve the sidewalk using condition.

Keywords: Pedestrian behaviour; road crossing; sidewalk; crossing speed; foot overbridge.

INTRODUCTION
Pedestrian behaviour at intersection is related to overall traffic flow, delay in intersection, safety, various infrastructures for pedestrians etc. So understanding pedestrian behaviour in a particular intersection is important to understand overall condition of an intersection. In this purpose we studied pedestrian road crossing and sidewalking behaviour at selected intersections in Dhaka city. Two types of pedestrian behaviour were taken into cosideration i.e. pedestrian road crossing behaviour at Kakrail and Motijheel intersections, and pedestrian sidewalk using behaviour near Shahbag intersections. The behavioural study was done by observation from video recording and by questionnaire survey.

Early studies showed that bus stops should have a minimum distance from the intersection sothat the boarding and alighting of pessengers can not add to the delay (Diab et al., 2015; Gu et al., 2014).Previous studies on utilization rate of foot overbridges showed that, it depends on different factors like crossing location(Sisiopiku, Akin 2003), the convenience of crossing facility (Sharples, Fletcher, 2001) etc. A study in Malayasia analysed the pedestrian willingness to use foot overbridge instead of crossing the

roadwhere one of the finding in their study was the utilization of pedestrian bridges in commercial area is very low and it was in the range from 5% to 66% (Rizati et al., 2013). The problems due to boarding and alighting of buses at intersections and the utilization rate of this foot overbridge were analyzed by data taken from vedio recording and questionnaire survey.

Pedestrian gap acceptance behaviour is important as it deals with the decision making to cross the road by pedestrians. The factors influencing pedestrians'decision making for road crossing i.e. vehicle velocity (Shaaban, Abdel-Warith, 2017), effect of rolling gap (Brewer et al, 2006), type of vehicle and waiting time (Sun et al., 2003), with effect of parked vehicles etc has been investigated in different studies (Himanen, Kulmala, 1988; Oxley et al. 2005). In heterogenous traffic condition like Bangladesh, where jaywalking is very common, platoon and directional effects are seen where the pedestrians in group, leading pedestrians, or pedestrians coming from opposite directions influence the road crossing. In a study in Indiathese effects are foundand they are established as reasons for the daviation of pedestrian speed (Marisamynathan 2014).

The level of service is considered as the walking condition and environmental condition of footpath. It is related to the factors that are related with the movement of pedestrians, comfort and safety e.g. sidewalk space, pedestrian flow rate incorporating pedestrian speed, density and volume. At Shahbag intersection there are 8 footpaths. By HCM (highway capacity manual) method we measure the level of service (Highway Capacity Manual, 2000). The level of service is marked by LOS A to LOS F. LOS A is the ideal condition for pedestrian and LOS F is the poorest condition for pedestrian.

METHODOLOGY

For all three intersections, data were collected by video recording, measurement of geomatric dimensions, questionnaire survey, and some field observation.

Data Collection

The video recording of Kakrail intersection was done from a fifth floor of an incomplete building near the intersection, which was situated at Kakrail-Malibag leg (see Fig.1). The video was taken at different time from 11AM to 5PM in a day. At Motijheel intersection video recording was taken from 16th floor of Sena Kalyan Bhaban building (see Fig.2). From the video tape the velocity of vehicles, pedestrian velocity, vehicle gap, location of pessenger loading-unloading and pedestrian road crossing charecteristics data were collected. Number of buses stopping or slowing down at intersection, non-compliant pedestrians, pedestrian using foot overbridges, pedestrian jumping over barriers have were counted. The video recording of peak hour between 3.30 pm to 6.30 pm had been taken at Shahbag intersection for sidewalk using study (see Fig.3). The video was taken for 15 minutes for each sidewalk. From the video analysis we count per min flow for pedestrian to measure the velocity (ft/s), space (ft^2/p), flow rate (p/min/ft) and V/C ratio.

For pedestrian road crossing study width of all approach roads had been measured for measuring pedestrian road crossing velocity. To measure the velocity of vehicle a length was measured along all the approach roads. For sidewalk using study the sidewalk width was taken by using odometer. The effective width was measure by subtracting the side friction from the existing width.

Around 60 people at each intersection were interviewed for questionnaire survey and video recording at different time of a day. For road crossing study questions were asked on their road crossing way, using overbridges, causes of road crossing, location of taking bus, risk felt by them for road crossing and risk felt by them while getting on or off the bus. For sidewalk study questionnaire survey was done to know

the problems faces by pedestrian, about their safety and security while using footpaths, what challenge they faced while using it and their willingness and unwillingness of using sidewalks.

At motijheel intersection, the number of pedestrians using foot overbridge and jumping over the barricade at different time has been counted from direct observation. For sidewalk study the surface condition, the presence of vendors, presence of obstacles was observed.

Fig. 1: Kakrail Intersection

Fig. 2: Motijheel Intersection

Fig. 3: Sidewalk near Shahbag Intersection

Using extracted data from video recording

For studying pedestrian behaviour with pessenger boarding-alighting of buses number of buses stops at intersections was counted at different times. The speed during lowering the speed was also measured with the help of the geomatric data taken from the intersection. For studying the pedestrian crossing characteristics at different traffic condition, vehicle speed, headways of vehicles, pedestrian road crossing speed, waiting behaviour and obstacles faced by pedestrians were measured with the help of the geomatric data taken from the intersections.

From the video analysis pedestrian flow was taken for 15 min intervals. Then pedestrian unit flow rate was calculated by taking 15min flow rate and divided by effective width of each sidewalk. For a particular length the time taken by pedestrian to pass this length was measured. From these data the speed of pedestrian was calculated. For space calculation a standard space was taken then and the number of pedestrian of that space was observed. By inverting that the space for each pedestrian was measured. For volume per capacity ratio a particular area was considered. Then the max number of people occuping that space and the number of people actually entering this space was calculated. After considering all those criteria the LOS of all the sidewalks were estimated.

RESULT AND DISCUSSION

Pedestrian behaviour with respect to boarding-alighting of buses

From questionnaire survey it is found that 80% of pedestrians crosses at intersection to avail buses and their loading and unloading locations are at intersection, whereas at Kakrail intersection only 25% pedestrian crosses the road for buses as buses do not slow down here. 65% pedestrians told that they do not get bus easily at Kakrail intersection as there is already no room there, and 60% pedestrians told that it is very risky to get on and off the bus as drivers do not slow down and they are reluctant to take passengers from here. 30% pedestrians told that they prefer to take bus from other intersections. Counting the number of buses stoping or slowing down from several different time intervals at each intersection it is ovserved that, at Motijheel intersection 40 to 45 buses stop at intersection for loading and unloading pessengers at 10 minuites interval, whereas at Kakrail intersection 20 to 25 buses stops at 10 minuits interval. It is also noted that, at Motijheel intersection most of the buses stop while pessengers get on or get off the buses for at least 5 seconds, whereas at Kakrail intersection 60 to 70% bus do not stop but just

slow down to 1 to 2 km/h. 20 to 30% buses stop at intersection for 3 to 5 seconds, mostly if the traffic flow is less.

Pedestrian road crossing characteristics for different traffic condition

At Motijheel intersection road crossing occurs at three approaches, where at Fakirapul to Shapla Chattar approach pedestrians cross the road by using foot overbridge or by jumping over the barricade. But at Tikatuli to Shapla Chattar approach and Daynik Bangla More to Shapla Chattar approach pedestrians cross the the road by walking. At tikatuli to Shapla Chattar approach red time and green time is observed. But pedestrian flow does not follow any pattern depending on wheather it is red time or green time. At Daynik Bangla More to Shapla Chattar approach there is always green time. Pedestrians are seen to cross the road from different locations through out all the time without stopping at any particular condition. At Kakrail intersection a pattern is observed where red time is always observed, and many pedestrians wait until beginning of red time. The reason behind pedestrian crossing the roads without considering the traffic condition of the road at Motijheel intersection and not maintaining any particular location is because vehicle speed is low and there is enogh headway between two vehicle there. On the other hand In Kakrail intersection headway and speed varies at different traffic condtitions. Pedestrian road crossing characteristics for different traffic conditions at both the intersections is given in Table 1. Here pedestrian road crossing speed, road crossing characteristics, obstacles faced by pedestrians and waiting behaviour with respect to vehicle speed and headway is shown. It is observed that pedestrians face two types of problems while crossing the road i.e. speed and lower headway. When speed is more then the speed governs as problem while road-crossing, and when speed is less the the headway is less, and this lower headway governs as problem while crossing the road. From questionnaire survey it is found that, pedestrians do not face that much problem and feel unsafe while crossing the road, and in case of Kakrail intersection pedestrians 87% pedestrians feel unsafe while crossing the road.

Table 1: Pedestrian Road-crossing Characteristics at Different Vehicle Speed and Headway

Intersection	Traffic Condition	Vehicle Speed (km/h)	Headway (m)	Pedestrian Road Crossing Speed (km/h)	Crossing Characteristics	Waiting Behaviour
Motijheel	green time	12.5 to 14.5	3 to 4	3.5 to 7.2	mostly individual crossing	no waiting time
	red time	0	0			
Kakrail	red time	0	0	3.5 to 7.2	individual crossing	no waiting time
	saturation flow	5.4 to 7.4	1.5 to 2	2.7 to 3.5	mostly in group	wait until a group is formed
	free flow at approach road or at upstream	10.8 to 18	2 to 3	3.5 to 5.4	both in group and individually	wait for a while and cross if no group is formed
	free flow at downstream	25.2 to 32.4	4 to 6	0	No crossing	wait until red time

Utilization of foot overbridge

Motijheel intersection is a controlled roundabout because there is a barricade sothat pedestrian cannot cross and use the overbridge. There is a foot overbridge at Motijheel intersection. From direct observation

data it has been found that, inspite of there being a foot overbridge 25 to 40% pedestrian choose to jump over the barricade instead of using that. On the other hand 60 to 75% people use the foot overbridge. From questionnaire survey it is found that, people jumping over the barricade do not use the overbridge for saving time and labour. It is also found that 95% of these road crossers were male and their age was in between 15 to 30 years. On the other hand the pedestrians using overbridge told that they use overbridge for safety and it is hard for them to jump over the barricade. There is a foot overbridge near Kakrail intersection, just near a school, provided for the safety of the students. From questionnaire survey, it is found that, only 6 percent people use that foot overbridge instead of road crossing occasionally. Many pedestrians using foot overbridge told that, it is arduous for them to use it, but they are to use it as they cannot jump over the barricade. Many told that, the environmental condition is poor in the foot overbridge as many vendors sits here to sell different thigs, and many sleeps here at night.

Pedestrian behaviour at sidewalks

Level of service of different sidewalks near Shahbag intersection is given in Table 2. The facilities for pedestrians using sidewalks are not up to the mark. The effective width of sidewalks is much less than the actual width because of side friction and their condition is very poor. There are many venders, stalls and the foot overbridge. Stairs on the footpath grasp most of the width. The level of service of the sidewalks for pedestrians was studied.

Table 2: Level of Service of Different Sidewalks near Shahbag Intersection

Footpath	**effective width (m)**	**Flow rate (p/min/ft)**	**Space (ft^2/p)**	**Speed (ft/s)**	**V/C ratio**	**LOS**
TSC to Shahbag	2.06	8	31	4.2	0.36	C
Shahbag to Kataban	186	10	17	3.8	0.48	D
Kataban to Shahbag	1.17	33	5	2.1	variable	F
Shahbag to Bangla Motor	1.29	31	5	2.03	variable	F
Bangla Motor to Shahbag	1.33	33	6	2.4	variable	F
Shahbag to IEB Shahid Minar Chottor	2.52	9	26	4.3	0.38	C
IEB Shahid Minar Chottor to Shahbag	1.03	31	7	2.1	variable	F
Shabag to TSC	0	not applicable*	not applicable*	not applicable*		F

Questionnaire survey revealed that, problem faced by pedestrians as mentioned are 80% inadequate width, 35% poor surface condition, 42% side friction, 27% reduced speed and 30% overcrowded footpath.

Calculation of LOS for the footpath of Shahbag to TSC could not bedone because it was fully occupied by vendors. So, the effective width of this footpath is zero. In case of LOS F all walking speeds are severely restricted, forwardprogress is made only by shuffling, frequent unavoidablecontact with other pedestrians is unavoidable, cross-and reverse-flow movementsare virtually impossible, flow is sporadic and unstable, space ismore characteristic of queued pedestrians than of moving pedestrianstreams. In case of LOS D freedom to select individual walking speed and to bypassother pedestrians is restricted, crossing or reverse-flow movementsface a high probability of conflict, requiring frequent changes inspeed and position, provides reasonably fluid flow butfriction and interaction between pedestrians is likely. In case of LOS C space is sufficient for normal walking speeds, and forbypassing other pedestrians in primarily unidirectional streams. Reverse-direction or crossing movements can cause minor conflicts, and speeds and flow rate are somewhat lower.

CONCLUDING REMARKS

At intersections Kakrail and Motijheel significant percentage of pedestrian road crossing occurs to avail boarding-alighting of buses. A planned location for boarding and alighting at a reasonable distance from intersections can reduce pedestrian crossing and increase safety. As at Motijheel intersection foot overbridge utilization rate is very low and many faces problem using it, introducing pedestrian crossing and removal of the barricade can be a suitable option. In case of sidewalk allocating particular location for vendors and stalls, providing good surface condition, and providing standard width for sidewalks can improve the level of service of sidewalks and pedestrian sidewalking condition.

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ROAD SAFETY ASSESSMENT USING RHD SAFETY AUDIT GUIDELINES AND iRAP METHODOLOGY

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ABSTRACT
Road safety has emerged as one of the most challenging issues in Bangladesh like other low and middle income countries. In this research "Guidelines for road safety audit, May 2005" of RHD is used for auditing and iRAP methodology is used for calculating star ratings to assess the road safety status. Geometric and Road attributes data were collected from four locations of N1 and N5 highway. Both the highways fit a classic linear settlement model as they pass through several built up areas where there are significant roadside developments, high side frictions and large number of pedestrian movements. Damaged road markings, absence of road signs, absence of crash barriers, absence of guideposts and illegal parking of trucks were common problematic components of all the sections on both N1 and N5 highways. There were also other issues on several sections such as water logging in shoulders, damaged road dividers, illegal bus stoppage etc. Star Ratings for these highway sections were found 3 stars or less for pedestrians, motorcyclists and bicyclists. The rating for vehicle occupants was relatively better which shows more provisions for vehicle occupants than other road users.

Keywords: Road safety; National highways; RHD safety audit guidelines; iRAP Star Rating.

INTRODUCTION
It is abundantly clear that, many low and middle income countries like Bangladesh are now experiencing a serious road safety crisis. The situation is predicted to worsen in the coming years unless the critical problem, of epidemic nature, is seriously addressed with significant improvements in the relevant sectors in a sustainable manner (Hoque et al., 2012). According to World Health Organization (WHO), nearly 20,000 deaths from road traffic crashes are estimated to occur annually in Bangladesh, although around 4000 deaths are officially reported. Nearly 80 percent of road traffic fatalities are attributed to Vulnerable Road Users (VRUs) - pedestrians, bicyclists, motorcyclists, and users of informal and unsafe motorized and non-motorized transport. The tragic premature loss of healthy lives is costly. Permanent disabilities and property damages are exacerbating poverty reduction efforts particularly in rural areas including rural sections of national and regional highways. The road environment factors are particularly prevalent with major roadway defects in design and layout, shoulders, road sides, bridges and approaches, delineation devices and lack of access controls. Unregulated private/business access to inter-urban highways leads to endless linear settlements resulting in high risks for pedestrians and other vulnerable road users (Hoque et al., 2012).

METHODOLOGY

Road Safety Audit

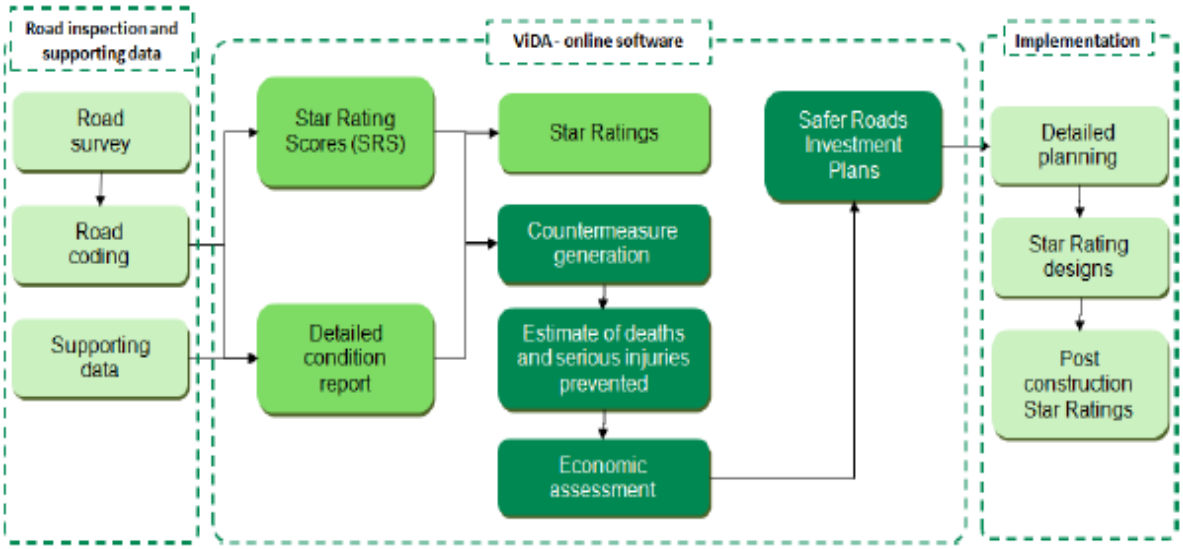
Road safety is a global concern. Accident can be prevented and reduced by safety auditing. Road safety audit is "a formal examination of a future road or traffic project or an existing road, in which an independent, qualified team reports on the project's crash potential and safety performance". Road safety audit is the way to find out problems in roads and highways. Following steps were followed for safety audit:

iRAP Methodology

The International Road Assessment Program (iRAP) is a registered charity dedicated to saving lives through safer roads. iRAP works in partnership with government and non-government organizations to:

- ✓ Inspect high-risk roads and develop Star Ratings and Safer Roads Investment
- ✓ Provide training, technology and support that will build and sustain national, regional and local capability.
- ✓ Track road safety performance so that funding agencies can assess the benefits of their investments.

The Star Ratings and Safer Road Investment Plans are intimately linked, as shown in Figure. This provides an overview of the components colored in light-green; the components in dark-green are addressed in a subsequent phase, titled Safer Roads Investment Plans: The iRAP Methodology. This outlines show the inspection carried out, the features that are recorded and how the Star Rating is achieved. The iRAP road inspection, Star Rating and Safer Road Investment are as follows (iRAP Methodology Factsheet 1, 2018):



Site selection

We collected data from normal highway section, intersection, near school and near bazaar. For field investigation we selected two highways - Dhaka-Aricha Highway (N5) and Dhaka-Chittagong Highway (N1). From each highway 4 section was investigated which include normal section, intersection, school and bazaar. Data were collected from four location of Dhaka-Aricha Highway (After Amin Bazar Bridge, Boliarpur Bazar, Savar Cantonment Public School & College and Nabinagar intersection). Also data were collected from four locations of Dhaka-Chittagong Highway (Doniya, Shiddhirganj Samsul Hoque Khan School and College, Signboard and Shanarpar).

Field Investigation and Data Collection

Different types of data were collected. Visual investigation and photos were taken. Geometric data like lane width, shoulder width, median width was measured. Traffic speed was measured. The highway passes through several built up areas, especially commercial areas with extensive linear developments. Checklists of RHD Audit Manual & iRAP methodology completed by following Data-

(a) Road Alignment and Cross Section
(b) Auxiliary Lanes
(c) Intersections
(d) Lighting
(e) Signs
(f) Markings
(g) Clear Zones, Crash Barriers, Fences
(h) Traffic Signals
(i) Pedestrians and Non-motorized Traffic
(j) Pavement
(k) Vehicle Parking
(l) Provision for Heavy Vehicles
(m) Miscellaneous

DATA ANALYSIS AND PROBLEM IDENTIFICATION

After the field observations were completed, the data was used to create Star Ratings for each road user type (see Table 1). From the results, it is clear that among the road users, motorcyclists, bicyclists and pedestrians are the more vulnerable (iRAP Methodology Factsheet-9, 2018).

Table 1: iRAP Star Ratings (out of 5) of Different Sections

Road No.	Section	Vehicle Occupant Star Rating	Motorcyclist Star Rating Score	Bicyclist Star Rating	Pedestrian Star Rating
N5	Amin Bazar Bridge	3	3	1	1
	Boliarpur Bazar	4	3	1	1
	Savar Cantonment Public School and College	4	3	1	3
	Nabinagar Intersection	3	2	1	3
N1	Doniya	3	3	1	1
	Samsul Hoque Khan School and College	3	3	1	2
	Signboard Intersection	1	1	1	1
	Shanarpar Bangali Market	3	3	1	2

Audit results & iRAP ratings indicate there are many safety issues in both highway sections where we investigated. Different section has different types of issues (see Table 2).

Table 2: Problematic Components of Different Sections

Road No.	Section	Problematic Components
N5	Amin Bazar Bridge	Pavement, Crash Barrier, Shoulder, Sign, Marking, Drainage (See Fig. 1).
	Boliarpur Bazar	Pavement, Crash Barrier, Shoulder, Sign, Marking, Illegal Parking, Bus stoppage, Pedestrian movement, Road crossing, Divider, Lighting (See Fig. 2).
	Savar Cantonment Public School and College	Sign, Illegal parking, Bus stoppage, Shoulder, Divider, Speed breaker, Drainage.
	Nabinagar intersection	Footpath, Service road, Sign, Marking, Damaged foot over bridge, Drainage, Signal, Bus stoppage.
N1	Doniya	Pavement, Illegal Parking, Shoulder, Marking, Sign (See Fig. 3).
	Samsul Hoque Khan School and College	Marking, Sign, Divider, Crash Barrier, Bus stoppage, Pavement (See Fig. 4).
	Signboard Intersection	Shoulder, Marking, Signal, Pavement, Road Crossing, Sign, Drainage, Bus stoppage, Lighting.
	Shanarpar Bangali Market	Pavement, Crash Barrier, Shoulder, Bus stoppage, Parking, Sign, Drainage, Lighting.

Fig. 1: Drainage Problem and Damaged shoulder near Amin Bazar Bridge (Dhaka-Aricha Highway)

Fig. 2: Road crossing problem in Boliarpur Bazar (Dhaka-Aricha Highway)

Fig. 3: Illegal parking in Doniya (Dhaka-Chittagong Highway)

Fig. 4: Damaged Road Divider- through this vehicle moving and damaging pavement and pedestrian crossing road risking life in front of Samsul Hoque Khan School and College (Dhaka-Chittagong Highway)

SUGGESTED REMEDIAL MEASURES

Remedies depend on section condition. The systematic implementation of low-cost road and traffic engineering measures is a highly cost-effective method of creating safer patterns of road use and correcting faults in the planning and design of the roads that have led to traffic crashes. Low-cost road and traffic engineering measures consist of physical measures taken specifically to enhance the safety of the road system. Ideally, they are cheap, can be implemented quickly, and are highly cost-effective.it includes:

- Physical changes to roads to make them safer (e.g. the introduction of skid resistant surfacing);
- The improvement of road geometry;
- Improved lighting, signs and markings;
- Changes in the operation of junctions, for example, by installing small roundabouts, changing the signal control or improving signs and markings;
- Introducing bicycle facilities;
- Reducing the likelihood and severity of run-off road and head-on crashes by widening shoulders, installing roadside safety barriers and median barriers;
- Reducing the likelihood and severity of pedestrian crashes by installing crossing facilities and footpaths;
- Reducing the risk of all crash types by managing speed to within tolerable limits.

For high benefits to be achieved relative to costs, a systematic and multidisciplinary approach to identify sites, to implement low-cost road and traffic engineering measures, and to evaluate outcomes is required, as well as an efficient organizational framework.

CONCLUDING REMARKS

Road infrastructure and environmental deficiencies are particularly prevalent in accidents and casualties and engineering safety on the road has clearly emerged as a priority issue in Bangladesh. Aspects of road infrastructure safety improvement in the context of safe system approach are therefore outlined in this paper. In particular, the paper discusses road inspection and assessment of national highways in Bangladesh by demonstrating the application of road safety audit and iRAP methodology.

ACKNOWLEDGMENTS

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EFFECTS OF NON-MOTORIZED VEHICLES ON A SELECTED INTERSECTION IN DHAKA CITY FOR NON LANE BASED HETEROGENEOUS TRAFFIC USING VISSIM 5.3

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ABSTRACT
Heterogeneous traffic composed of both motorized vehicles (MV) and non-motorized vehicles (NMV) that are a common feature of urban Bangladeshi roads. Popular NMVs include rickshaws, rickshaw-van and bi-cycle. NMVs generally occupy the outermost or curb-side lanes and at intersection get mixed with the motorized vehicles. That's why the conventional models fail to analyse the situation completely. The default behavioural parameters such as driving behaviour, lateral distances, overtaking tendency etc. of VISSIM 5.3, a lane based microscopic traffic simulation software are modified and calibrated for effectively simulating the existing non lane based mixed traffic condition at Mirpur-10 intersection. Field data reveals that NMVs occupy average 20% of the total number of vehicles for all the legs. Simulated raw data shows that intersection capacity significantly drops and average vehicular speed reduced by 25%, number of vehicles reduced by 30%, lateral occupancy increased by 2.37% and queue delay time increased by 33.75% with respect to various parameters. This paper also reveals the comparison of speed, number of vehicles, lateral occupancy, queue delay time between existing mixed traffic condition and lane based traffic condition. So special measure or restriction of NMV at major intersections may be an effective solution to improve this existing condition.

Keywords: NMV; intersection; VISSIM 5.3; lateral occupancy; queue delay time.

INTRODUCTION
Dhaka is a large and densely populated metropolitan area. It has one of the most diverse road transportation systems in the world. This system consists of both motorized vehicles (viz. bus, mini-bus, car, CNG, baby taxi, motorcycle etc.) and non-motorized vehicles (viz. rickshaw, rickshaw van, bicycle etc.) modes. Non- Motorized Transports (NMVs) plays significant role in catering to the transport demand in metropolitan Dhaka. But, these modes of transport are given very little consideration in the transport planning phase and are almost ignored in the planning of metropolitan road network and intersections. That's why the flow of mixed or heterogeneous traffic is quite complicated. This mixed flow of vehicles leads to many problems, like conflicts at intersections, when number of non-motorized vehicle increases which adversely affects the speed and flow of other vehicles. Another feature of this traffic is the absence of lane marking and lane discipline. The lane widths are also not constant. Analytical modelling of such traffic is in nascent stage. Micro-simulation is favoured to study and model heterogeneous traffic (Mathew et al., 2010). Microscopic simulations are widely used in transportation operations and management analysis because "Simulation is safer, less expensive and faster than field implementation and testing" (Park et al., 2002).It is a useful tool to effectively analyse and evaluate proposed improvements and alternatives. For example an intersection can be simulated for different signal timing plans and its effect found before implementing it.

VISSIM which is used in this study is a microscopic, behaviour-based multi-purpose traffic simulation software to analyse and optimize traffic flows. It can model traffic as well as flow of pedestrians. It can analyse public and private transport operations making it a useful tool for evaluation of various alternatives for transportation planning (VISSIM 5.30 User manual). It has a user friendly GUI with 2D and 3D visualizations. The road networks in VISSIM can be created either as lane oriented or space oriented i.e. vehicles can move anywhere in the road without lane restrictions. Any number of vehicle types can be created and overtaking of vehicles can be allowed on both the sides. All these features help in modelling heterogeneous traffic. There are many advantages of VISSIM over other micro-simulation software. VISSIM has the ability to model the interaction between the various modes of transit with automobile traffic, ability to generate vehicles randomly and flexibility in modelling complex geometries (Moen et al., 2000). VISSIM is better in terms of ease of use and does not require cumbersome coding (Park et al., 2002). Any model created in VISSIM needs to be calibrated so as to sufficiently represent field conditions. In calibration the default parameter values are changed till the error between the actual and simulated measure such as flow or travel time is less than the required threshold value. Calibration is the process in which the input parameters are refined so that the model accurately replicates observed traffic conditions (Yu et al., 2006).

The study area is the intersection of Mirpur-10 roundabout, located in Dhaka metropolitan area. The study area includes four link roads connected with various infrastructures, cantonment and shopping mall. Dhaka cantonment, Mirpur DOHS is located in north direction, Sher-e-Bangla National Stadium in on west, Mirpur-13, 14 residential area is on east and lots of government offices, hospital, institutes are located in the south direction which makes it one of the busiest intersections in Dhaka. The motivation behind this study is that less study on non-motorized vehicles and mixed traffic has been done in Dhaka context and no study has been done for the microscopic simulation to analyse the effects at intersection. So this paper aims at analysing the characteristics of the non-motorized traffic flow and its effect on the mixed traffic at intersection by microscopic simulation

METHODOLOGY

The main objective of this study is to find significant parameters and calibrate VISSIM through an automatic mechanism. After validation, the calibrated model can be used to find out various parameters that are affected by non-motorized vehicle at the intersection. The steps are as following:

Data Collection

Data of heterogeneous traffic flow such as traffic volume, vehicles composition, speed, and signal timing of the chosen road along with geometric data are collected. The vehicle flow input is given in start of leg near first foot over bridge and the outflow is found by placing 4K digital camera at selected 4 locations at peak time 9.00AM-11.00AM and 5.00PM-7.00PM. The research area is manually signalized intersection. It is intersected by two roads of two-way two lane. East-west direction road and north-south direction road both are assumed major road. The width of each lane is not fixed but average 3.25m. Two hours of data in the morning peak and evening peak are collected.

Building VISSIM Model

Detailed network geometry is coded through VISSIM graphical user interface (GUI).To make model representative of the real field, both MV (bus, truck, car etc.) and NMV (rickshaws, bi cycle etc.) are defined. There is no enforcement of lane discipline which results non-lane based traffic situation in the study area .Though it is quite difficult to model non-lane based flow but modifying different parameter values (driving behaviour, lateral distance etc.) in VISSIM with sophisticated programming, it is possible to build the intersection model. After coding the model, the base model is run with Wiedemenn 74 car following driver behaviour model. Signal timings obtained from field are also input.

After creation of the model, the vehicle composition input for various legs are given according to the collected data. This is followed by specifying the various routes Leg1, Leg2, Leg3 etc. through which vehicles travel. Five types of vehicles are created to replicate field traffic composition. For example, Vehicles composition of Kazipara Leg1: (1) Motorbike (19.0%); (2) Passenger car (38.0%); (3) CNG

(14.0%); (4) Bus (17.0%); and (5) NMVs (12.0%). Local vehicles are modelled in 3D Studio-Max first and then converted into VISSIM recognizable vehicle element by V3DM. Coded VISSIM model is shown in Fig. 1.

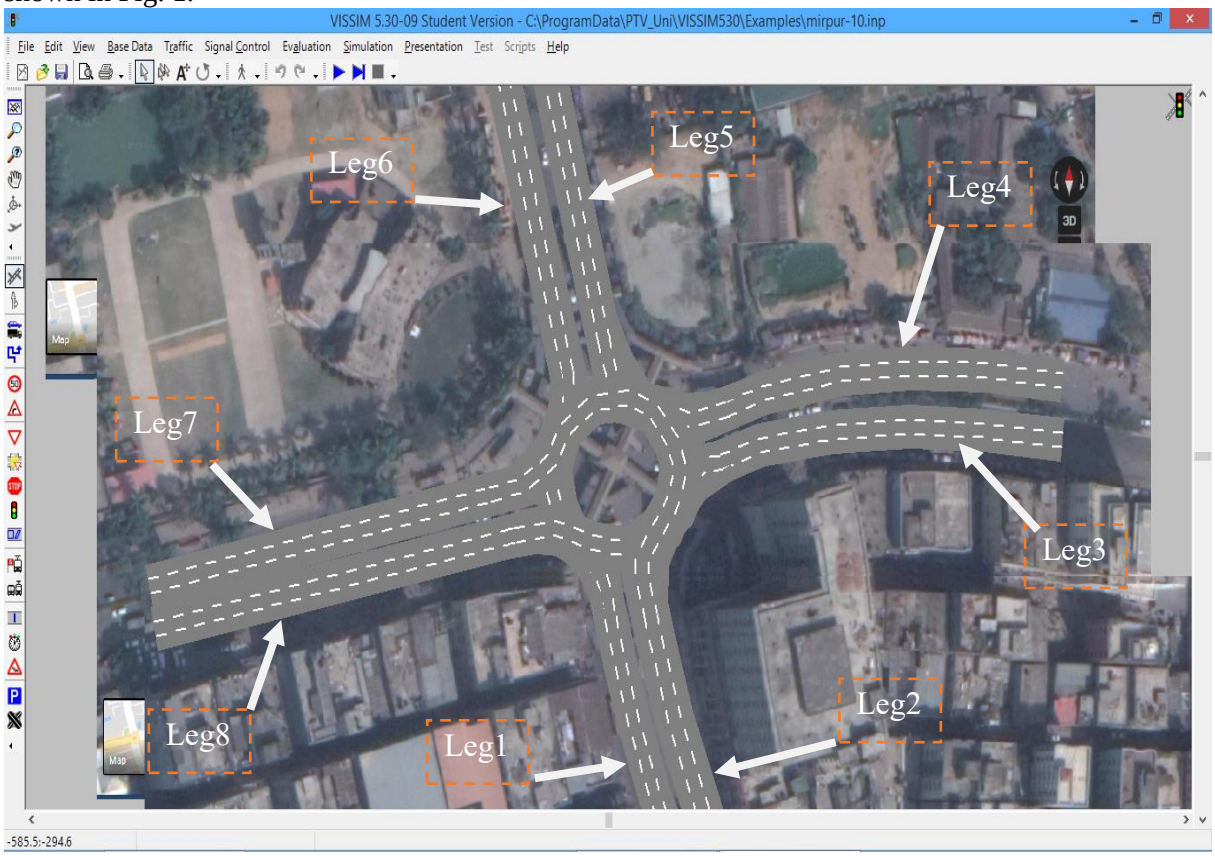

Fig. 1: Coded VISSIM Model of The intersection (Mirpur-10 Intersection)

Model calibration

Calibration is the process in which various parameters of the simulation model are adjusted till the model accurately represents field conditions. VISSIM has a COM interface which can be used to calibrate VISSIM externally through a code. Algorithm, a random search and optimization technique is used to generate random sets for parameters within specified bounds and the calibration code is run till it finds the least mean absolute percentage error value between the actual and simulated measure (Siddharth et al., 2013). Fig. 2 shows the difference of number of discharged vehicles between actual field and calibrated model.

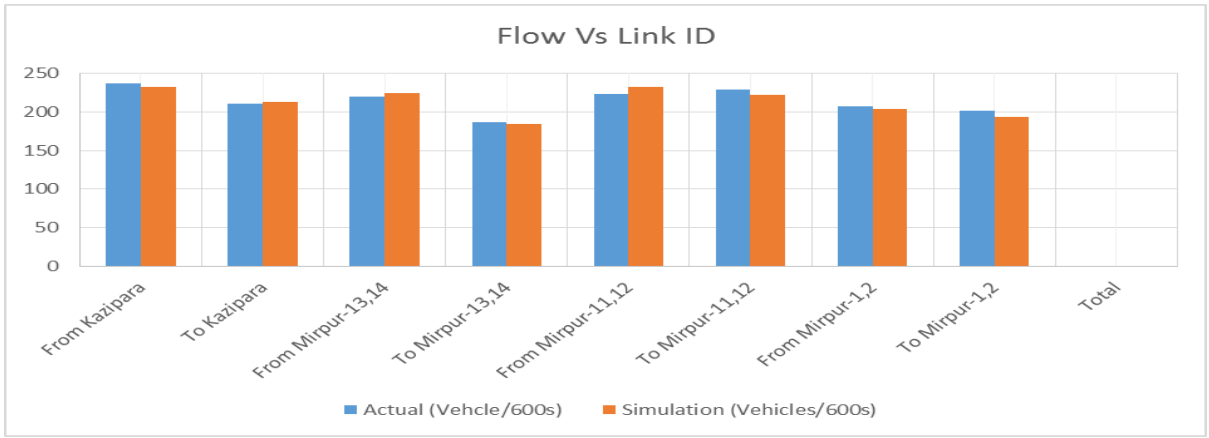

Fig. 2: Difference between Actual field data and Simulation data

Modified Driving Behaviour

VISSIM has several parameters that can be changed during calibration. But all the parameters in VISSIM may not affect the output of the present model in a significant way. Sensitivity analysis is used to find the parameters which have a significant effect on the model. Different calibrated values from calibrated VISSIM model are given in Table 1.

Table 1: Calibrated and Default value of VISSIM parameter

Parameter	**Calibrated Value**	**Default value**
	Car Following	
Standstill Distance(m)	*0.5*	1.5
Headway Time(s)	1.2	0.9
	Lane Changing	
Overtake reduced speed area	Allowed	Not Allowed
	Lateral	
Desired Position at Free Flow	Any	Middle of Lane
Observed vehicles on next lanes(s)	Allowed	Not Allowed
Consider next turning direction	Allowed	Not Allowed
	Minimum Lateral Distance(m)	
Distance at 0Km/h	0.6	1
Distance at 50Km/h	0.8	1
	Overtake on Same Lane	
On Left	Allowed	Not Allowed
On Right	Allowed	Not Allowed

Model Validation

The calibrated models are then evaluated with a new set of data under untried conditions, including the input volumes, traffic composition, and other required data. This study adopts the Geoffrey E. Heaver (GEH) statistic to compare field traffic volumes with those obtained from simulation data. As a general guideline for model validation, GEH values less than 5 indicate good fit (UK highway agency).Several simulations run with different parameter for confirmation. Table 2 shows that GEH value of the microscopic model is 2.863 which indicates a well calibrated model and represents the field traffic condition with remarkable accuracy.

Table 2: GEH statistical analysis for Validation

Segment	**Actual (Vehicles/600s)**	**Simulation (Vehicles/600s)**	**Actual Simulation difference (vec/hr)**	**% Difference**	**GEH**
From Kazipara	237	232	30	2.1097	0.3264
To Kazipara	210	213	-3	-1.4285	0.2062
From Mirpur-13,14	220	224	-24	-1.8181	0.2684
To Mirpur-13,14	187	184	18	1.6042	0.2202
From Mirpur-11,12	223	232	12	-4.0352	0.5966
To Mirpur-11,12	229	222	42	3.0567	0.4661
From Mirpur-1,2	207	204	18	1.4492	0.2092
To Mirpur-1,2	201	193	48	3.9800	0.5699
Total				4.93	2.863

DATA ANALYSIS AND DISCUSSIONS

Analysis indexes in this study are variation of speed, number of vehicle discharge, average delay, and lateral occupancy. Fig. 3 shows the variation of speed of different vehicles under three different conditions (at present condition, at Non-lane base traffic without NMV, at Lane based traffic without NMV). It is seen that average speed reduction is 33% at present condition non lane based traffic condition in comparison with the other conditions. Similarly large variation is observed for discharged number of vehicles showed in Fig. 4 where average 30% vehicles deceases and Legs 6, 7, 8 show the most deviated results.

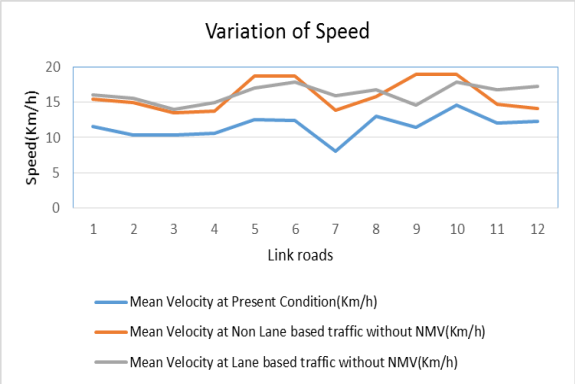

Fig. 3: Variation of Speed

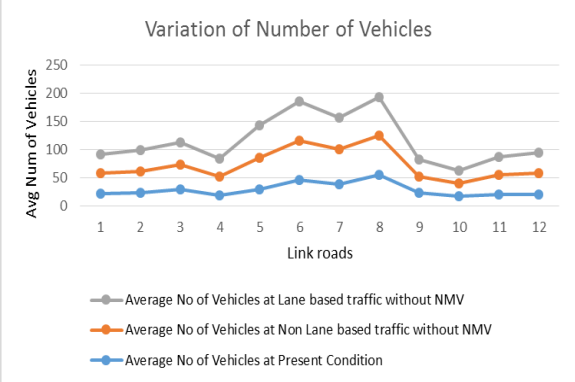

Fig. 4: Variation of Number of Vehicles

Fig. 5 represents the variation of lateral occupancy where variation is very negligible. At Kazipara (Leg 1) shows little bit higher at present condition but rest of the legs are approximately same compared with other two conditions. Average queue delay time at present condition increased by 33.75% with respect to other condition for the presence of NMVs is represented in Fig. 6. Leg 3 shows the lowest queue delay effects and Leg 8 has the highest value. So it can be said that various parameters are directly affected for the presence of NMVs.

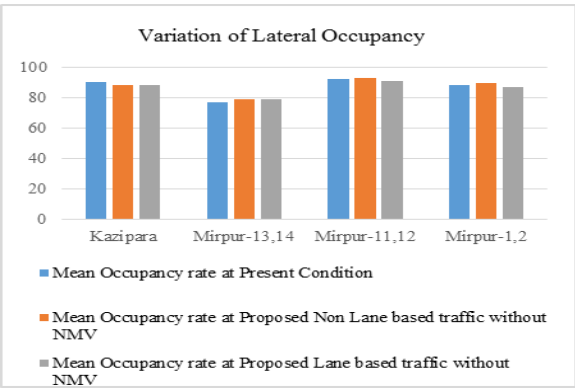

Fig. 5: Variation of Lateral Occupancy

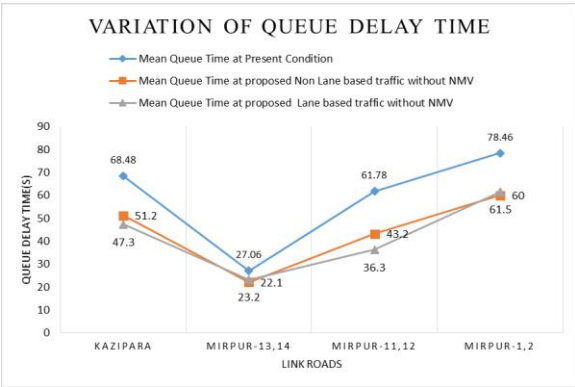

Fig. 6: Variation of Queue delay time

CONCLUDING REMARKS

From Fig. 3, 4, 5 & 6 it is found that the presence of NMVs makes an adverse effect on the traffic flow at intersection. Speed and number of vehicles decreases at a particular flow rate with the increase of NMVs. Lateral occupancy is not significantly affected by NMVs but queue delay time at present condition is the highest delay time value. So special techniques, such as separate lane or restrictions of NMVs at major and highly congested intersections may be feasible and practical solutions for the improvement of this present traffic situation, that need separate study for implementation.

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IDENTIFICATION OF KEY SAFETY ASPECTS IN DESIGNING METRO RAIL FOR DHAKA CITY

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ABSTRACT
For the first time in Dhaka elevated MRT (Mass Rapid Transit) system is going to be introduced to reduce traffic congestion. This paper explores the key safety aspects of a MRT system in the context of Dhaka. The safety of rail traffic depends on a number of factors: technical condition of the railway infrastructure, the rolling stock, the organization of rail traffic, professional qualifications and performance by employees. However, review revealed that most accidents in MRT happened due to various reasons such as: derailment, failure of computerized braking system, sharp turns in track etc. Further investigation shows that, Standard gauge (1435mm) faced least accidents comparing with others. Coning of wheels and rigidity of wheel axle shaft prevents the train derailment. Size and shape of locomotives has impact on safety. Accident in elevated system may cause disruption of service at both elevated and surface level. Whereas, accidents in underground system may cause failure only at underground level. Moreover, headway has impact on train collisions. Most of the MRT system picks 4-8 minutes headway in peak hours and 12-20 minutes in off peak hour. Thus, these features are to be investigated very carefully and comprehensively for introducing Metro rail in Dhaka City.

Keywords: MRT; Safety aspects; Dhaka Metro Rail.

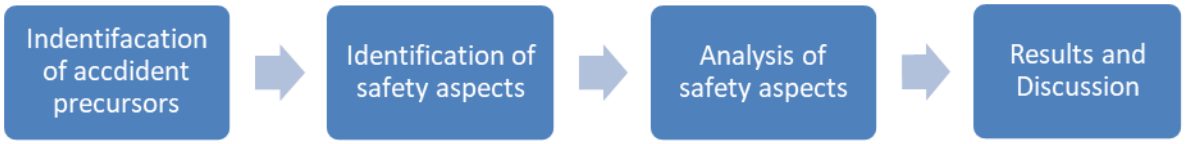
INTRODUCTION
Safety should be the major concern for any transportation mode. While planning, designing and constructing a project safety should first be ensured. MRT (Mass Rapid Transit) is getting popular among huge populous cities in the world. Huge traffic congestion in roads during peak hours, hours of waiting, wasting time of people has led to think men of this railway system within a city. As it only transits people within the city only, it is called metro rail. Many cities around the globe has chosen MRT for rapid transit of a large number of people. So, it can be said that the transportation system of major cities now largely depends on the MRT. As huge number of people are affiliated or involved with this transportation system, safety of MRT should be the first concern before planning and designing any element of it. MRT carries a greater number of people at a time than any other mode of transportation, so a little negligence in providing safety could turn into a disaster. Big cities are building MRTs for more than a hundred years. So existing technologies, methods and considerations for design are well defined. But these safety aspects could be researched and modified to built a safer MRT system. Reported causes of metro rail injury accidents and fatalities include:

- Collisions
- Derailments
- Track causes
- Human factors

- Equipment causes
- Rail yard accidents
- Miscellaneous factors

METHODOLOGY

Following flow chart will guide us though the paper



Accident Precursors

Definition of an accident precursor is any event or group of events that must occur for an accident to occur in a given scenario. Some accident precursors of MRT might be faulty components, operation and management failure, passenger actions etc. Accident precursors and top events are shown in Table 1.

Table 1: Accident precursors and top events

Precursor category	Precursor per category	Top event
Human performance operator technical failures	Broken wheels/axles on RS. Cracked rail, Exceeding speed limits	Derailment
	Arcing, Person on platform caught in train doors, Right side signal failures, Wrong side signal failures	Electrocution
Passenger Actions	Congestion, Fall between platform and train, Fall onto track all reasons, Person hit by train, Passenger carrying dangerous/flammable goods	Collision, Passenger/train interface(PTI)
Fire	Smoke in station, smoke on track, smoke on train	Fire, heat, exhaustion
Malicious or illegal action	Act of vandalism, Passenger carrying dangerous/ flammable goods, Trespass, Substantial objects on track	Explosion, violence, Panic, flooding,
Management Action	Station closed	Panic

The relation between accident precursor, top event, injury and fatality for some leading metro is shown in Fig. 1.

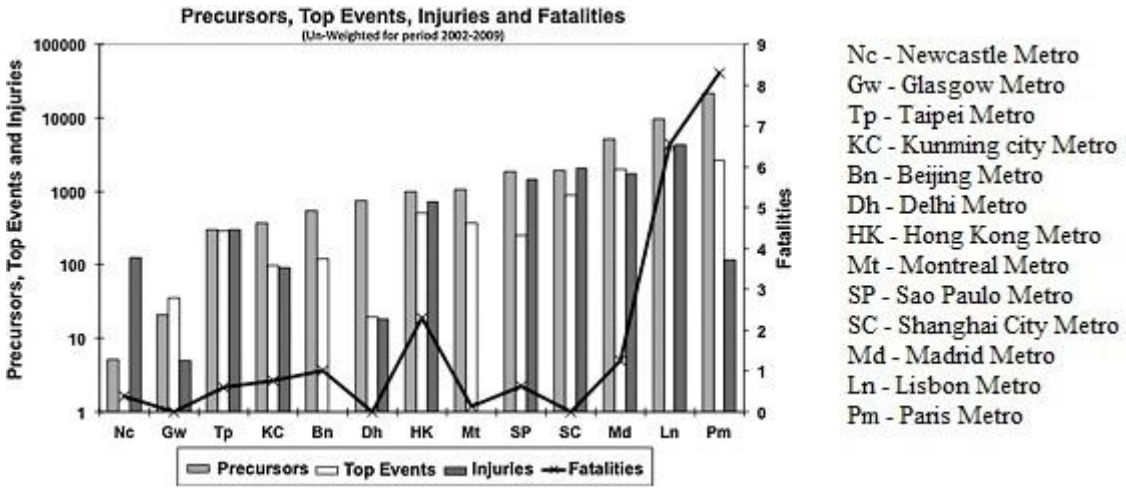


Fig. 1: Relation between accident precursors, top events and fatality

Identification of safety aspects and their analysis

1. Track system and geometry

Among the parameters of track geometry gauge length is one of the safety aspects of metro rail-based system. In Dhaka no right of way has been reserved for the construction of future metro transit system. The alignments have to follow the major arterial roads and also have sharp curves and right angles bends. As broad gauge needs higher radius of curvature, it might be risky on sharp turns. Narrow gauge rail is usually designed as light rail, speed and load hauled could not increase. Metro rails are high volume train, so it may be difficult for narrow gauge line to carry huge volume of passengers. Around 4000.4 km of system length is been taken in consideration from longest and busiest subways. A comparison between gauge lengths is shown in the Fig. 2.

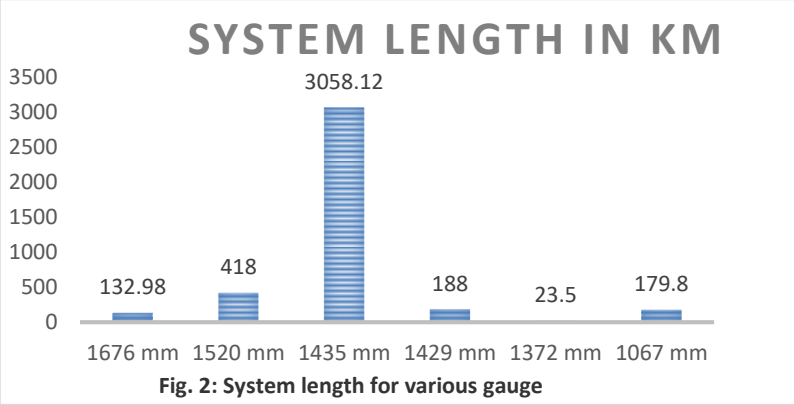


Fig. 2: System length for various gauge

Mostly the Tokyo subway uses a gauge of 1067mm, 1372mm and 1435 mm. Among these only 1067 mm track faced a mishap killing 5 and wounded at least 55. The accident report says that the train derailed because of narrow gauge and facing a high curvature after coming out of tunnel. Among these the Delhi Metro uses gauge of 1676mm. That faced two back to back accidents within one month of period. Analysis showed that Delhi metro also uses the standard gauge in other lines but none of those standard gauge lines faced fatal accidents. Under construction metro in Dhaka thus has selected gauge of 1435 mm for MRT line-6.

Speed is a major parameter of safety. The probability of accident is proportional to the speed. So speed limit should be calculated very carefully using some parameters. The permissible speed on a curve shall be calculated taking account of the following factors:

a) The radius of the curve.
b) The applied cant.
c) The permitted values of cant deficiency.
d) The dynamic roll-over resistance of the train.

Derailment of Train can be classified in two categories, one of them is sudden derailment and the other one is flange climbing. Sudden derailment is the result of instantaneous failure of track of vehicle components while running or due to the impacts with any obstruction falling on the track. Wheel flange climb derailment generally occurs due to wheels climbing onto the top of the rail head and further running over the rail. While wheelset travel on the track it executes various oscillations due to coning of wheels, suspension characteristics of rolling stock, track irregularities, elastic characteristics of track etc. Several flange climb safety criteria have been proposed. Among them Nadal formula (see Eq(1)) is widely been accepted. But the Nadal formula assumes the wheel remains perpendicular to the rail, it does not take into account hunting oscillation of the wheelset or the movement of the wheel flange contact point against the rail so Wagner formula (see Eq(2)) is introduced. Charlet formula (see Eq(3)) analyzes the equilibrium of forces at the moment of incipient derailments, Charlet consider the force pattern for both wheel of the same axle.

Nadal Formula: $$\frac{L}{V} = \frac{\tan(\delta)-\mu}{1+\mu*\tan(\delta)} \quad (1)$$

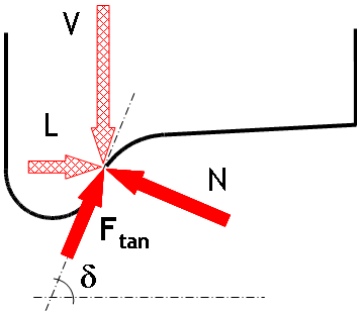


Fig. 3: Lateral and vertical force action on rail

for δ=68° and μ = 0.25 Calculated value of $\frac{L}{V}$ is 1.4. For a certain factor of safety $\frac{L}{V}$ should not exceed 1. It is one of the criteria for assessing stability of rolling stock. From Nadal Formula we can see that the stability depends on coefficient of friction and flange angle as well as the lateral and vertical loads. Coefficient of friction μ, depends on the various condition of tracks. For dry rail μ=0.33, for wet rail μ=0.25, for lubricated rail μ=0.13 and for rusted rail μ=0.6. Apart from these parameters there are other factors influencing Nadal Formula which are stated below:

- Greater eccentricity increase derailment proneness as flange safety depth reduces.
- Persistent angular running
- As positive angularity increases derailment proneness, persistent angularity leads to greater chances of derailment.

Wagner Formula: $$\frac{L}{V} = \frac{\tan(\delta)-\mu*\cos(\beta)}{1+\mu*\tan(\delta)*\cos(\beta)} \quad (2)$$

Sometimes vertical force may not be completely vertical, so Wagner assumed V is at an angle β with the vertical. If V is completely vertical then cos(β) =1.

Charlet Formula: $L \not> 2V - 0.7Q$ Here Q is the nominal wheel load

The formula states that even if the lateral load 'L' becomes infinitesimally small, L≈ 0. The safety condition is: $0.35Q \not> V$ (3)

Hence, above equation states that the instantaneous wheel load should not drop below a value equal to 35% of the nominal wheel load, or the wheel offloading should not be more than 65%.

Elevated or Underground MRT system bears safety issues. Elevated MRT system derailment can cause disruption of service in both elevated and surface level. Elevated MRT derailment will cause serious kind of fatality. So, it is highly recommended to check any flaws for derailment. In Dhaka city the MRT system proposed is going to be elevated so such safety factors must be kept in mind. On the other hand, underground MRT system accidents may disrupt service at underground level only. Any construction incident will not arrest traffic at surface in such cases. One of the advantages of grade separated MRT regarding safety is that it can avoid any kind of collision with traffic at surface level. Both the surface traffic and grade separated MRT can easily flow spontaneously without affecting each other.

2. Rolling stocks

As far as the kinematic envelopes of the rolling stocks on the curves are concerned, these are dependent on the overall length of a rolling stock, distance between pivot centers and the curve radius. Kinematic envelop includes the effect of tilt, sway and track cant. As higher length of coaches needs more coning of wheels and they have higher chances of derailing in sharp turns. Despite being able to carry more passengers by long coaches, they are avoided due to mentioned safety reasons. Usually lengths of the coaches are kept 20-24m. As standard gauge is widely accepted, the rolling stock of such line is readily available.

Axle lengths are very much vulnerable as they hold the wheels. Change in length of axle may lead to derailment of trains. So, axles shall be designed using a recognized proven method taking account of, as a minimum, the following:

a) maximum operational speed and cant deficiency
b) maximum stresses that satisfy non-finite fatigue life requirements
c) characteristic of loads applied to the axle, including vehicle loads, track inputs, wheel tread damage, transmission components and forces, braking forces etc
d) loading regimes which could adversely affect the axle life, such as torsional vibrations
e) the geometry between the axle features
f) the effects of interference fits on the axle
g) effects of impact damage to the axle surface.

Wheels bear some important safety factors. It is the coning of wheels that keeps the rail on track. So, any wearing and tearing in wheel may lead to derailment. So, Wheel design shall include assessment of the most severe thermal loadings induced through braking and the most severe repeated braking cycle to be experienced by the vehicle, including an additional stop to represent peak thermal loading during the cycle. As a minimum the following effects shall be taken into account, in addition to those considered for the axle:

a) thermal effects on the wheel to axle fit
b) thermal strains imposed by friction brake components
c) the full range of wheel dimensions permitted
d) effects of thermal and mechanical interaction between the brake disc and the wheel.

Brake discs shall be designed properly because without properly working of brakes it is impossible to operate any vehicle. The process shall cover all the proof and fatigue loads and other design factors predictable throughout the required design life. The thermal and mechanical loads transmitted to the mounting arrangement shall be consistent with those used in the wheel and/or axle design. As a minimum the following effects shall be taken into account:

a) mechanical loads appropriate to the input from track and vehicle
b) centrifugal loads, for example on fasteners of split discs
c) braking loads
d) effects of thermal and mechanical interaction between the brake disc and the mounting on the wheel or axle.

3. Operation and maintenance

Headway is one of the operational tasks of MRT system. If headway is not properly designed two trains could collide as urban transit system follows a very close schedule. Also, peak hour headway design is related to safety issue as huge passenger get on board at a very short time. Peak hour headway design should be such that no hustle may occur during boarding of the passengers. Traffic dynamics in urban rail transit can be expressed by an interaction of departure instant, running time, and dwell time. The development of the proposed model is based on the following assumptions.

1) There is only one type of train running on the single-track line. Overtaking is not allowed in the line.
2) Passenger arrivals at stations follow Poisson distributions.
3) The control model handles all operating vehicles. The optimal arrival time and estimated departure time is sent to trains when they stop at stations.
4) The speed profile is calculated by onboard equipment based on the optimal arrival time and estimated departure time.

Headway can be properly designed using following equation:

$$h_{k,i} = P_{k,i} - P_{k-1,i} \quad (4)$$

$$P_{k,i} = e_{k,i} + t_b\lambda_i(e_{k,i} - P_{k-1,i}) \quad (5)$$

$$P_{k-1,i} = a_{k-1,i} + t_b\lambda_i(a_{k,i} - P_{k-2,i}) \quad (6)$$

h= headway between two successive trains a = arrival time
P = departure time of train t_b = average passenger boarding time
e = optimal arrival time λ_i = passenger arrival rate at station

Worldwide metro/subways use peak hour headway 4-8 minutes. Accident due to headway design and operation is rare to find because of their punctual operational activities. But punctuality of railway in our country is highly neglected, so it is an important issue for Dhaka Metro Rail.

Operation and maintenance of tracks, rolling stocks, axles, wheelsets etc are very important safety aspects. As operation and maintenance failure has led to serious accidents all over the world. In 1996 a metro operator was killed due failure of computerized braking system at Washington Metro. In 2004 at Woodly park station a metro rail rolled back and hit an in-service train. So, rollback protection might be necessary in some cases. On August 5, 1993 two trains collided with each other at Clementi, resulting in 132 injuries. The collision occurred because a work train that did maintenance work earlier had spilled oil onto the tracks. Accidents can be caused by following operational and maintenance failures and defects:

a) Un-suitable brake performance for route characteristics
b) Brakes not properly checked or tested
c) Brakes not correctly set with respect to load or speed of brake application
d) Mishandling of train en route (i.e. over speeding)
e) Obstruction on track

For safe use regular examination and inspection of all components of the metro rail are necessary by the authority. Also, inspection of operation and maintenance by stuff should be observed regularly by governing bodies.

RESULT AND DISCUSSION

From above identification of safety aspects, we can observe that for Dhaka city it is optimum to use standard gauge (1435mm), as narrow gauge cannot transit huge population safely. Broad gauge needs large radius of curvature which is not possible to provide because no right of way has been reserved for the construction of future metro transit system. The alignments have to follow the major arterial roads and also have sharp curves and right angles bends. Factors that lead to derailment should be regularly checked. As elevated MRT is being used in Dhaka, its derailment should be prevented using railing at both sides of the track. Estimated peak hour headway for Dhaka MRT now is 4.5 minutes which is in align with other metro/subways. Overall operation and maintenance of MRT should be properly done, any negligence in duty may bring huge mishap.

CONCLUDING REMARKS

Metro rail-based transportation system is getting popular day by day. Worldwide a huge number of people is using MRT in daily basis. Also, conventional rail system is facing many accidents in recent times. Thus, these features are to be investigated very carefully and comprehensively for introducing Metro rail in Dhaka City.

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TRAFFIC CONGESTION MONITORING IN THE SELECTED TRANSPORT AXIS OF CHITTAGONG CITY

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ABSTRACT
Over the last few years, the transportation problem of Chittagong City has visibly been deteriorating gradually. This study is dedicated to analyzing present traffic congestion in the selected major transport axis of Chittagong city. The traffic study has been conducted on the five most important intersections (Tigrepass, Agrabad, Barik Building, Nimtoli, and CEPZ) by taking into consideration their commercial value and the movement of traffics. Observation of operational conditions indicates that the road continuously suffers from unrestrained movements of pedestrians, motorized and non-motorized vehicles. Again, from the estimated Annual Average Daily Traffic (AADT) data, it is found that the maximum peak period traffic flow is above 4000 PCU/Hour at Agrabad intersection designating overcrowded road. From the journey speed study, it is found that the average travel speed on the selected roadway is about 10 to 15 K.P.H. throughout the day dropping below 10 K.P.H. during the peak hour indicating severest congestion. The traffic capacity study of the existing roadway showed that the traffic capacity of the roadway is less than the present demand at major survey locations and providing a level of service (LOS)-F with existing traffic flow.

Keywords: Chittagong City; traffic congestion; Annual Average Daily Traffic; travel speed; Passenger Car Unit; Level of Service.

1 INTRODUCTION

In general, traffic congestion on transport networks is a state that happens due to the increase in use and is measured by speed drops, increase in travel times and vehicular queuing. Congestion is mainly occurred due to the increased travel demand resulting in the vehicular interactions and fall of the travel speed of the traffic stream.

Traffic flow issues in urban areas are being studied by many researchers throughout the world and some of the studies are reported in the literature. The traffic jamming and travel delays at a rotary intersection in an Indian city were studied and suggested to redesign roundabout and traffic signal timing and to construct flyover, cloverleaf, underpass and uplifted roundabout (Patel, 2014). Muhammad Ali and Faraj measured congestion by evaluating the LOS of the road by determining the rate of traffic flow of the road as well as free flow rate (Muhammad Ali and Faraj, 2013). To minimize traffic congestion and travel delays at city road, intersections should be signalized and parking at road intersections should be strictly prohibited (Aderamo AJ, 2012). Habib evaluated some planning alternatives (rickshaw and auto-rickshaw elimination, improvement of bus service, minor improvement at bottlenecks of the road networks, introducing rail transit using the existing rail lines with suitable access modes) to relieve traffic jamming and resultant air pollution (Habib, 2002).

2 BACKGROUND

Chittagong is the major port city and the gateway of Bangladesh and is considered as a major economic hub of Bangladesh. For different reasons, many government officials and general people are continuously using Chittagong Airport for moving to the capital city and overseas countries. Moreover, the southern part of Chittagong city is also very important for many offices and amusement areas (Agrabad, CEPZ, Patenga). On the way to Chittagong Airport from the city, the presence of country's largest port, two export processing zones (CEPZ and KEPZ) and diversion of intercity through traffic (Tigerpass, Barik Building, Nimtoli) also deteriorated the traffic congestion at several intersections. But, due to traffic congestion on the roads, it is very hard to reach the areas on time.

According to a report ("Coastal Road Project of Chittagong - Assignment Point," n.d.), the road network in Chittagong city is not adequate compared to the traffic volume on the road, and there are traffic safety issues due to a lack of sidewalks in addition to chronic congestion. According to the JBIC Pilot Study for "Formation for Multi-sector Infrastructure Development in Chittagong" project, the Sheikh Mujib Road has the highest volume of traffic in Chittagong City. The road's 12-hour motorized traffic volume is as high as 44,000 vehicles. Travel speeds were surveyed by JICA in 2008 along the section extending from Patenga to the City Gate, via the M. A. Aziz road, Port Connecting Road, and Dhaka-Chittagong Highway. The degree of traffic congestion was highest during the evening peak hour with travel speeds of 10km/hour or slower. This study is aimed to investigate the current conditions of the selected road intersections of Chittagong city considering congestion point of view.

3 ROADWAY CONDITIONS ALONG THE STUDY AREA

The study is designed to analyze traffic performance on CDA Avenue Road to M. A. Aziz Road, particularly the transport axis starting from Lalkhan Bazar intersection and ended near Butterfly Park, Patenga. Among the 10 intersections available along the road axis, Tigerpass, Agrabad, Barik Building, Nimtoli, and CEPZ are selected for detail traffic engineering assessment. The study roadmap indicating five selected intersections is shown in Figure 3-1.

Figure 3-1: Map of the Selected Road Network of the Study Area (Source: Google Map)

Traffic composition of this roadway is dominated by various kinds of vehicles such as freight carrying lorry, buses, trucks, covered vans, private car, jeep, bike, taxi, rickshaw, etc.

4 TRAFFIC STUDY

A traffic survey is a detailed examination and analysis of a transportation system supported by traffic data survey. In order to identify the major causes of congestion and nature of the problem at the selected intersections (Tigerpass, Agrabad, Barik Building, Nimtoli, and CEPZ), extensive traffic survey was undertaken, including directional traffic count study and travel speed survey.

4.1 Traffic Count Study

There are two available methods for performing traffic volume counts; namely (1) manual count method and (2) automatic count method.

Manual Counts Method: Manual counts are recorded using one of three methods: tally sheets, mechanical counting boards or electronic counting boards. In this study, the tally sheets method is used.

In this method, recording data onto tally sheets is the simplest means of conducting manual counts. The data can be recorded with a tick mark on a pre-prepared field form.
Automatic Count Method: Automatic counts are recorded using one of three methods: portable counters, permanent counters, and videotape. In this study, the videotape method is used. In this method, observers can record count data by videotaping traffic. Traffic volumes can be counted by viewing videotapes recorded with a camera at a collection site.
Traffic Data Collection and Processing: The traffic counts were undertaken from August 4 to August 20, 2015. Different groups of surveyors were employed to strategically selected traffic count locations for manual counts at different hours of the day over the total network.

Seasonal Variation Factor: From Classified Traffic Count we can get the Average Daily Traffic (ADT) and the ADT is adjusted with the seasonal variation factors to get the AADT.

Table 4.1 shows the seasonal variation factor adopted by the Roads and Highway Department (RHD).

Table 4.1: Seasonal Variation Factor (RHD, 2005)

Vehicle Type	Adopted Value	Vehicle Type	Adopted Value	Vehicle Type	Adopted Value
Heavy Vehicle	1.103	Auto Rickshaw	0.952	Micro Bus	0.952
Truck	1.103	Motor Cycle	0.952	Car/taxi	0.952
Bus	0.952	Bicycle	0.952	Cycle/Rickshaw /Van	0.952

Passenger Car Unit (PCU) Values: In respect to passenger car unit, weightage to various types of vehicles is very important, because of their different operating characteristics and impact on the flow of traffic. As prescribed by geometric design standards of RHD following weightage were given to different vehicles in determining AADT for the studied road is given in Table 4.2.

Table 4.2: PCU Values of Different Vehicles (RHD, 2000)

Type of Vehicles	Weightage	Type of Vehicles	Weightage
Rickshaw	2.0	Mini bus/ Pick-up	2.0
Motor Cycles/ Cycle	0.75	Buses	3.0
Hand Drawn Vehicles	4.0	Trucks	3.0
Cars/ 3 wheelers	1.0	Trucks 3 axle	3.5
Micro Bus/ Vans/ Jeeps	1.25	Lorry/ Tailor units (more than 3 axels)	4.0

4.2 Travel Speed Survey
Journey time surveys were conducted to get the actual travel time through the study area in the base year 2015. Data was collected by Floating car method. Vehicle mounted GPS devices were used for this purpose.

5 RESULT AND DISCUSSION
This section presents the analysis of traffic study data performed at the selected intersections for all directions traffic. From the traffic count data, PCU/Hour and AADT were calculated and travel speed study data were tabulated in order to show journey time and speed at various locations of the roadway. Finally, PCUs and travel speeds observed on various road intersections were compared to traffic capacity as per UK guidelines and Highway Capacity Manual (HCM) to find out the level of service (LOS) and to understand existing traffic congestion on the selected roadway.

5.1 Assessment of Traffic Volume
The daily classified traffic data was processed for ADT considering PCU for different vehicles and then ADT is adjusted with the seasonal variation factor to get the AADT. A line graph is shown in Fig.5-1 is plotted to give an overview of the hourly variations of estimated AADT over the entire road network representing traffic flow in both directions of the road.

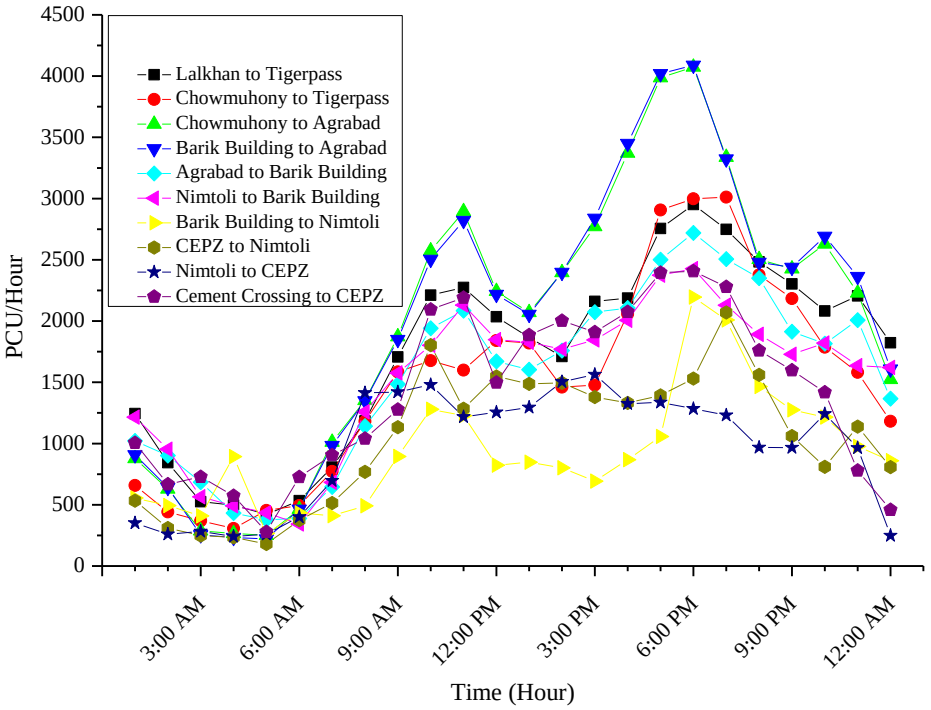

Fig.5-1: Estimated AADT on the study road (Both-ways)

From the above graph, it is seen that the morning peak mainly spans from 9 am to 12 pm and the evening peak extends from 4 pm to 7 pm at almost all the studied intersections. The most congested morning peak basically occurs at Agrabad intersection at 10 am; the most congested evening peak ensues at 6 pm which is also at Agrabad intersection. It is also seen that Agrabad intersection experienced the highest peak hour volume of traffic (over 4000 vehicles).

5.2 Assessment of Journey Time and Speed

Travel speed survey was carried out at the different time of the day (peak and off-peak) to measure the time consumed for traveling from WASA to Airport by using a private car in Table 5.1 describes the results of the journey time survey at the base year 2015.

Table 5.1: Journey Time Survey (Vehicle Type: Private Car)

Loop No	Survey Route		Survey Time			Travel Distance (km)	Travel Speed (K.P.H.)
	Starting Point	Finishing Point	Starting	Finishing	Travel Time		
1	WASA	WASA	8:04	11:08	3hr4 min	30.8	10.04
2	WASA	WASA	12:14	14:44	1 hr 40 min	30.8	18.48
3	WASA	WASA	16:07	18:37	2 hr 30 min	30.8	12.32
4	WASA	WASA	18:00	19:48	1 hr 48 min	30.8	17.11
				Avg. Time	2 hr13 min	Avg. Speed	14.49

5.3 Demand and Capacity of Roadway

The capacity of a facility is defined as the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time period under prevailing roadway, traffic and control conditions (Highway Capacity Manual, 1985). The Highway Capacity Manual (HCM) has introduced the concept of "Level of Services" to donate the level of facility one can derive from a road under different operating characteristics and traffic volume. When capacity gives a quantitative measure of traffic, LOS tries to give a qualitative measure. The intention of LOS is to relate the traffic service quality to a given rate of traffic. HCM divides the quality of traffic into six levels ranging from level A to level F. Considering the complex nature of traffic conditions and the lack of consistent data, the HCM recommends the following LOS for such streets as shown in Table 5.2.

Table 5.2: HCM Recommended Level of Service (LOS)

Level of service (LOS)	Operating Characteristics
A	Free flow relatively, with some stops likely to occur. Average overall speed is 40 K.P.H. or more.
B	Stable flow, with delay, not unreasonable. Average overall speed is 30 K.P.H. or more.
C	Stable flow, with significant delays which may be acceptable. Average overall speed is 25 K.P.H. or more.
D	Approaching unstable flow, with tolerable delays. Average overall speed is 15 K.P.H. or more.
E	Unstable flow, with average overall speed, is below 15 K.P.H. but moving.
F	Forced flow, jammed conditions. Stop-and-go movement.

From Table 5.1 and Table 5.2, it is found that the travel speed is around 10 to 15 K.P.H. throughout the day which drops below 10 K.P.H. during the peak hour indicating chronic congestion with LOS F quality service in the study area.

The practical capacities recommended by the U.K. Standards for Urban Roads are given in

Table 5.3. From the traffic count survey data, PCU per peak hour for the studied area has been determined and the calculated value with their traveled width of the road section has been depicted in Table 5.4.

Table 5.3: Practical Capacities Recommended by U.K. Standards (H. M. S. O., 1966)

Width of the carriageway	2-lane			3-lane		4-lane			6-lane
(m)	6.00	6.75	7.30	9.00	10.00	12.0	13.5	14.6	22.0
Description	PCU/Hour (Both directions of flow)					PCU/Hour (One direction of flow)			
All-purpose roads with no frontage access, no standing vehicles permitted and negligible cross traffic	1200	1350	1500	2000	2200	2000	2400	2200	3600
All-purpose street with high capacity junctions and 'no waiting' restrictions	800	1000	1200	1600	1800	1200	1500	1350	2500
All-purpose street and capacity restricted by waiting vehicles with junctions	300 to 500	450 to 600	600 to 750	900 to 1100	1100 to 1300	800 to 900	1000 to 1200	900 to 1000	1600 to 2200

Table 5.4: Peak PCU/hr. at Various Section

Road Section	Traveled width (m)	Peak PCU/Hour	Road Section	Traveled width (m)	Peak PCU/Hour
Lankhan Bazar to Tiger pass (4L2W)	7.50	2951	Agrabad to Tiger pass	7.0	3012
Tiger pass to Agrabad (6L2W)	9.85	4074	Barik Building to Agrabad	10.74	4088
Agrabad to Barik Building (6L2W)	10.74	2719	Nimtoli to Barik Building	7.43	2428
Barik Building. to Nimtoli (4L2W)	7.43	2196	CEPZ to Nimtoli	9.25	2070
Nimtoli to CEPZ (6L2W)	9.25	1336	Airport to CEPZ	11.34	2407

From
Table 5.3 and Table 5.4, it is clearly observed that most of the carriageway width of the selected intersections are not properly maintained as per the UK guidelines for urban streets. Almost all of the studied intersections are overloaded with present observed traffic capacity and reached in a state of forced movement and severely

congested area.

6 CONCLUSIONS

This study has brought into focus the issue of traffic congestion on the selected road intersections of Chittagong city. Along the selected streets, there are uncontrolled intersections at frequent intervals. These roadway sections allow two-way traffic providing a huge volume of mixed traffic allowing parking at the intersections. The morning peak primarily spans from 9 am to 12 pm and the evening peak mostly starts at 4 pm and ends at around 7 pm at almost all the studied intersections. Based on the limited number of scopes and variables studied, the following conclusions can be drawn;

- The PCU/Hour during the peak hour at the studied five intersections are twofold to threefold higher than the recommended value of PCU/Hour as per UK standards.
- The average journey speed on the roadway is about 10 to 15 K.P.H. throughout the day plummeting below 10 K.P.H. at the peak period expressing severest jamming.
- Traffic volume of the road is higher than the roadway intersection capacity and the road experiencing forced flow, packed conditions, and stop-and-go movement indicating LOS-F quality service.

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A STUDY OF ROAD USERS MANEUVERING DURING DEVELOPMENT CONSTRUCTION ACTIVITIES ON EXISTING ROADS

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ABSTRACT
Roads are an integral part of transportation system. A developed road network not only reduces the cost of transportation, both in terms of money and time, but also helps in the integrations of various regions within the country. But sometimes road network can be obstructed by various development works such as road widening, re-surfacing of existing roads, flyover & metro-line construction and re-alignment of utility lines. Due to these activities, the lane width of existing roads reduces drastically. As a result, high volume of traffic has to pass within a shorter road width causing heavy traffic congestion which leads the road users to untold sufferings. The present study identifies the obstacles for the maneuvering of road users during development of construction projects. It also includes the identification of adverse impacts created by various construction activities on roads. The study areas around 2 no gate and Kaptai Rastar Matha of Chittagong city were selected for this investigation. From the field investigation it has been observed that illegal parking, construction materials on sites, keeping shopping materials by shop keepers, pavement distress near construction zones, water-logging at construction sites, disposal of garbage along roads etc. leads to excessive traffic congestion and hampers the maneuvering of road users. The study has also been continued through comparison of the standard code of conduct with present situation of the site. Moreover, these construction activities effect on environment, health, social life, economy and communication systems. Hence, some remedial measures have been suggested to ensure safe and smooth maneuvering of road users at development construction sites.

Keywords**:** Maneuvering, Development activities, Guidelines, Traffic congestion, Road users.

INTRODUCTION
A high-quality road network is essential not only for connecting key urban centers but for improving connectivity of more isolated local communities for whom many public transport options are limited or not available. Roads connect remote communities with the areas where employment options are more concentrated and services and facilities more readily available (Kadiyali,2008).
In recent years due to the increasing population, the number of vehicles on the road is increasing accordingly. The existing road network becomes insufficient to accommodate the vehicle boom. If the vehicle demand is larger than the road capacity, congestion will occur. When congestion is present, the road network cannot longer fulfill its task. Due to traffic congestion the economic progress is at stake and the sufferings of general mass know no bound. So development of road network is needed to control of such type of problem. But these activities lead the road users to untold sufferings. Besides, these activities

minimize the original lane width of existing roads and disrupt the usual traffic flow. Moreover, occupancy of footpaths, placing garbage disposals and construction materials on the roads shortens the existing road width. But it is necessary that vehicles and construction equipment have to be placed at a fixed place for road user's safety (ETSC' 2011). Signs, barriers and markings should be used at construction sites. Presence of adequate traffic controller has to be ensured at construction sites (FHWA'2009). Toxic air and dust pollution generated from construction sites can cause chronic diseases like asthma, bronchitis, nasal allergy and rhinitis etc. **Fig. 1** shows some sort of problems faced by road users (EPA'1996). Overall economy, productivity and health issue of the country are greatly affected. Hence, the main purpose of the study is to observe the existing road condition surrounding the development construction activities, to identify the developed impedances for road users and to compare the present situation regarding safety of road users with the maneuvering guidelines.

Fig. 1: Different sorts of problems faced by road users during development construction activities in Chittagong City

METHODOLOGY

The investigation is carried out on the study area in the following manner which is shown in **Fig. 2**.

Fig. 2: Work plan of the present investigation

For this investigation, site has to be observed physically. During site investigation- the impedances and impacts have to be observed during construction of various development activities. Photographs and videos have to be taken at some extents. Moreover, the present situation has to be compared with various documents related to work zone safety, environmental assessment during construction, code of conduct and so on.

MANEUVERING GUIDELINES

During road construction project, some standard terms and rules have to be followed. Some important guidelines provided by Roads and Highway Department (RHD), Environment Protection Authority (EPA), Federal Highway Administration (FHWA) and European Transport Safety Council (ETSC) rules have been discussed below.

a) Materials to be stacked properly

Materials brought at site shall not be stacked at random. The Contractor shall stack all these materials as directed by the Engineer. **(RHD'2002)**

b) Contractor is liable for damages arising from non-provision of lights, fencing

The contractor shall provide all necessary fencing and lights at his own cost required to protect the public from accident and shall be bound to bear the expenses of defense of every suit, action or other proceedings at law that may be brought by any person for injury sustained owing to neglect of the above

precautions and to pay any damages and cost which may be awarded in any such suit, action or proceedings. **(RHD'2002)**

c) Vehicle and Construction Equipment

Vehicles and construction equipment should also be chosen adhering to safety criteria. When employers are planning their work zone careful consideration is needed to determine in advance which equipment is needed. **(ETSC'2011)**

d) Waste Minimization

Solid wastes generated by construction activities, offices and mess-rooms should not be placed along the road. Collecting lubricating oil from the construction vehicle fleet and sending it to a recycler. **(EPA'1996)**

e) Signing, Barriers and Markings

Generally traffic cones and barriers are used to demarcate the work zone but cannot be used as a barrier to protect workers. Good practice now aims to reduce as much as possible workers activity in work zones. **(ETSC'2011)**

f) Information to the Public on Road works

A timely warning about road works enables drivers either to cancel the journey, change the route or prepare themselves for delays. Site managers should prepare a communication campaign in advance of the works. Implementation in GPS navigators of live information on RWZs offers important assistance in providing real time and reliable information to the public. **(ETSC'2011)**

g) Presence of Adequate Traffic Controller

Presence of traffic controller has to be ensured at construction sites. A traffic police must not direct traffic through a worksite, unless the worksite has an approach speed of 60 km/hour or less and ensure that the 'PREPARE TO STOP' sign is erected correctly, at the beginning of the shift. **(FHWA'2009)**

h) Noise and Vibration

Noise from vehicles and powered machinery and equipment on-site should not exceed the manufacturer's specifications, based on the installation of a silencer. Equipment should be regularly serviced. Attention should also be given to muffler maintenance and enclosure of noisy equipment. **(EPA'1996)**

i) Dust Control

Implement a dust prevention strategy, developed at the project planning stage. Take dust suppression measures, such as promptly watering exposed areas when visible dust is observed. Install wind fences wherever appropriate. **(EPA'1996)**

SITE SELECTION

In order to monitor the present situation surrounding the various development works, a brief physical situation was required. The study areas around 2 No. Gate and Kaptai Rastar Matha of Chittagong city were selected. Various impedances due to the construction of Akhtaruzzaman Flyover near 2 No. gate and re-alignment of waterlines of CWASA near Kaptai Rastar Matha was observed as a part of this investigation.

OBSTACLES TO THE ROAD USERS MANEUVERING

While performing various development activities, the normal maneuvering of the road users are disrupted. The situation is made worse by various impedances. Illegal parking, construction materials on sites, keeping shopping materials by shop keepers, pavement distress near construction zones, water-logging at construction sites, disposal of garbage along roads etc. leads to excessive traffic congestion and hampers the maneuvering of road users. It becomes more severe due to lack of proper signing, closure of footpaths and roads without any announcement, absence of adequate traffic controllers at construction sites etc.

Placing of Construction Materials on Roads

Placing of construction materials here and there is a very common picture in construction sites. Most of the times the materials are put outside safety fences which is illustrated in **Fig. 3.** As a result, a disruption occurs in the flow of traffic, which often leads to traffic congestion. But, RHD clarifies that construction

materials & equipment have to be placed at a fixed place which is mentioned above in maneuvering **guidelines (a)**.

Disposal of Garbage, Waste near Construction Site

EPA suggests that waste materials should not be placed along construction site mentioned in maneuvering **guidelines (d)**. But it is often seen that waste materials and garbage are dumped over the road, rather than dumping the wastes in the bin **Fig. 4.** As a result a significant portion of road remains unused while the congested portion leads to heavy traffic gridlock.

Fig. 3: Construction materials

Fig. 4: Disposal of garbage

Fig. 5: Illegal parking

Illegal Parking on Construction Zone

Due to proper implementation of laws, negligence of law enforcing agencies and lack of parking spaces, it is a very common scenario that construction, local vehicles are seen parking along construction projects. Illegal parking further reduces the existing traffic capacity of the existing roads to a great extent which is shown in **Fig. 5.** But ETSC suggests that vehicles should not be placed along construction zone referred in maneuvering **guidelines (c)**.

Placing of Shopping Materials on Footpaths by Shopkeepers

Due to lack of proper implementation of law, it is often seen that, shopkeepers keep their shopping materials on footpath. As a result, the walking space of the pedestrians drastically reduces. Moreover, it slows down the vehicles on the roads along construction sites. As a result, the whole road becomes congested.

Closure of Footpaths and Roads without Any Announcement

Most of the cases, construction agencies in Bangladesh do not have proper accountability. As a result without considering the movement of passengers and pedestrians, they close the footpaths and roads without any kind of announcement which is illustrated in **Fig. 6.** Moreover, it is done without providing an alternative route for the road users. As a result, pedestrians, passengers and drivers suffer to a great extent. But ETSC mentions that road users have to be informed about road works which is clarified above in maneuvering **guidelines (f)**.

Lack of Proper Signing, Barriers & Markings

It is obligatory to place advance warning signs, cone tapers, barriers and with proper speed limits and other essential directions which is mentioned above in maneuvering **guidelines (e)**. But, most of the cases no warning signs or speed limits are mentioned on the roads.

Absence of Adequate Traffic Controllers

In spite of being an over-populated country, there is not too many well-trained traffic police on the road. Due to lack of adequate traffic controllers, traffic mismanagement is created traffic jam on the roads which is shown in **Fig. 7.** In this case, FHWA points out in the maneuvering **guidelines (g)** that adequate number of traffic controllers has to be present at construction sites to control traffic movement.

Water-logging in Construction Site

Sometimes due to sedimentation of silts from construction materials, side drains gets clogged and eventually leads to water-logging. Drainage congestion and water logging increase due to the lack of regulation and proper maintenance of the drainage along development activities sites. Water-logging gradually reduces vehicle speed and thus leads to traffic gridlock which is shown in **Fig. 8.**

Fig. 6: Closure of roads and footpaths

Fig. 7: Absence of Traffic controller

Fig. 8: Water-logging

ADVERSE IMPACTS DURING CONSTRUCTION ACTIVITIES

Road development activities can promote sizeable economic and social benefits. But if poorly planned or implemented, development activities can provoke serious cost overruns, corruption, economic and environmental impacts.

Environmental problem

During these activities, heavy construction equipment is needed. In the running time of these equipment, a unbearable sound is generated which causes untold sufferings to the road users. For reducing noise pollution, there is no proper initiatives such as careful handling of materials; modern, quite power tools, equipment and generators. But, EPA points out some suggestions in **guidelines (h)**. Moreover, a huge amount of dust generated from construction sites pollutes the air which is shown in **Fig. 9.**

Health problem

During road construction, usually road users are occupationally exposed to a variety of substances such as natural and man-made mineral, various dusts, diesel exhaust which is illustrated in **Fig. 9.** Many of these substances are known to have adverse effects on road users' health. As a result, they are suffering from some chronic diseases such as lung cancer, nasal cancer, bronchitis & skin diseases etc. To relieve from this problem at some extent, EPA refers some suggestion in **guidelines (i).**

Economic problem

Development activities boost a community's economy. Improving transportation networks provides economic benefits to nearby properties. But at the time of construction activities, the lane width of the existing roads reduces drastically. As a result, traffic passes within a shorter road width which causes heavy traffic congestion which is shown in **Fig. 10.** For this traffic congestion we have to face losing working-hours, extra transportation cost, vehicle operating and maintenance cost and extra fuel cost etc.

Social problem

During road construction activities, it plays negative impacts on businesses, recreational facilities, hospitals, police centers, road user's safety, security, fire stations, power cuts and water-logging problems which is illustrated in **Fig. 11.** These impacts include parking issues, customer access, delivery access and other public and private properties.

Fig. 9: Health problem Fig. 10: Communication problem Fig. 11: Social Problem

REMEDIAL PROPOSALS

While performing various development activities, the normal maneuvering of the road users are disrupted. The situation is made worse by illegal parking, construction materials on sites, pavement distress near construction zones, water-logging at construction sites, disposal of garbage along roads etc.
Remedial proposals to minimize the maneuvering problem are given below.

- ✓ A proper temporary by-pass should be provided during road construction activities.
- ✓ Traffic should be diverted to an alternative route to ensure smooth passing of road users.
- ✓ Construction materials and equipment have to be prohibited at by pass.
- ✓ Parking at by-pass and nearby roads should be restricted.
- ✓ Placing of shopping materials and disposal of garbage at by-pass should be prohibited.
- ✓ Signs, flags, warning lights should be used to direct road users at the time of road construction activities.
- ✓ Proper information to road users on risky construction activities should be provided.
- ✓ Proper training to the construction workers on safety and code of conducts has to be given.
- ✓ Road development works have to be completed in time.
- ✓ Construction works should be prioritized at night so that social and family life of passengers and pedestrians is less affected.
- ✓ Dust, noise and vibration generated from construction sites should be reduced by using water, fence and barriers.

CONCLUSION

From the above discussions some conclusions have been summarized below.

- Available road width should be used properly by maintaining and managing carefully and legislatively for smooth maneuvering of the road users.
- Rules and regulations related to construction activities should be followed properly.
- Generally road construction activities are prolonged due to lacking of coordination between various organizations.
- Ongoing development activities affects on environment, social life, health issue, business sector, roads and communication systems etc.
- During these construction activities, road user's safety should be prioritized firstly.
- Above all, different sorts of awareness program, rallies related to road user's safety should be organized regularly.

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