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Analysis of Speed Variations at School Zones in Bangladesh

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School zones have been identified as vulnerable area due to lack of safety measures observed in Bangladesh. To ensure the safety of school going children, reduction of vehicle speed near school area is essential. For this purpose, average speed variation of vehicles in different time, different days of a week both on highway and arterial are investigated in this research. t-test was performed considering 90% confidence interval for both equal and unequal variances. Results indicate that average speed varies significantly between highway and arterial at different times and different days. Based on the results, countermeasures are proposed to improve road safety scenario in school zones.

Keywords: Safety measure, school zones, children safety, t-test, countermeasure, speed

1. Introduction

The problem of deaths and injuries as a result of road traffic crashes is acknowledged to be a global phenomenon in all over the world. Particularly developing countries are undergoing a severe road safety problem as a consequence of rapid growth in population, motorization, and urbanization. Over 90% of the world's fatalities on roads occur in low and middle income countries. The financial loss is about US$518 billion, which is far more than the development assistance allocated for these countries (Raihan et al 2017). In terms of pedestrian accidents, 0.4 million people die every year in all over the world and over half of these deaths occur in low-income countries (Ahsan et al 2012). In Bangladesh, pedestrian casualties while crossing the road is about 32.15%, of which 76.07% have turned into fatal in severity. If the age difference is considered then around 30% of hitted pedestrians are below 16 years old (ARI Report 2013).

School zones have high levels of pedestrian activity that are particularly vulnerable in the event of a crash. In Bangladesh, each year at least 3000 people are reported to be killed in road accidents; of the total pedestrian death nearly one-third is school going children under 16 years of age (Hoque et al 2006). Global reports on the annual incidence of school zone injuries have ranged between 1.4 and 27.3 injuries per 100 students (Yang et al 1998).

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In Bangladesh, a few numbers of schools are situated beside highway whereas most of the schools are mainly located adjacent to a local as well as arterial road. However, the most vulnerable conditions are found in those schools which are situated beside highway and arterial if high speeding nature of those roads is considered. Ahsan et al (2012) found that child fatalities are highest during 10-12 noon comparing with those of other time period of a day. About 57.4 percent of adult fatalities occurred within the period of 8 am to 5 pm whereas 78.8 percent of children fatalities occurred in that 9-hour period.

A significant and sensitive safety issue in school zones is over speed of vehicles (Roper et al. 2006). Vulnerable road users are much more susceptible to accidents when vehicle speeds are high and can even suffer fatal injuries in accidents with motor vehicles at moderate speeds. Young children do not have the skills to stay safe in traffic. They hardly have any experience to judge the speed and distance of an oncoming vehicle (Anjuman and Siddiqui 2007). High speed of motor vehicles at intersections and mid-block locations are also vulnerable to the child pedestrians (Bennet and Yiannakoulias 2015).

Thus, for the improvement of present safety condition of school zones, it's urgent to analyze the vehicle speed variations at the school zones. Over speed of vehicles in arterial and highway are alarming fact for the safety of school children. Also, vehicle speed is not same in various days of a week as well. It is necessary to identify which time, which day and which type of road is in more vulnerable condition from speed perspective. Studies on the speeding behavior of vehicles are found in literature which mostly dealt with the effect of road infrastructure (Elvik and Vaa 2004), effect of different mode of transportation (McDonald et al 2011) at the school zones, however, consideration of starting and closing hours of schools, effect of different days of a week and effect of different type of roads were ignored in almost all of the cases.

The main objectives of this study are:

a) To find out the speed variation of different vehicles at highway and arterial road at school zone.
b) To find out the variation of speed in different peak hours of school zones.
c) To find out the vehicle speed variation in different days of a week.

The paper is organized as follows: Section 1 deals with Introduction and Section 2 focuses on Literature Review, Section 3 includes Study Area and Data Collection, Section 4 contains Methodology. Results and Discussion are provided in Section 5 and Conclusion is in Section 6.

2. Literature Review

Several studies have been carried out addressing pedestrian safety, especially the school children, at the school zones. Past studies revealed that the effectiveness of school zone speed limits suffers from poor driver compliance (TRB Special Report 254, 1998). Hawkins and Rose (2006) stated that drivers may feel distracted from school

speed limits due to the diversions linked with the school zones hours promoting increased vehicular and pedestrian traffic, higher proportions of turning traffic, and longer queues. Ash and Saito (2007) organized a survey on the attitudes and concerns of drivers on their compliance of reducing the speed in the school zones in Utah. The survey results showed that the presence of children is the most dominant factor that directly influences drivers' speed at school crossings. Simpson (2008) evaluated the effectiveness of school zone flashers in USA and to determine whether the speed compliance is improved or not in the school zones. Speeding at school zones is investigated by some studies. In the early 90's McCoy and Heimann (1990) focused on the impact of road marking, road signs, and other speed management techniques in assistance with speed reductions in the school zones. Roper et al. (2006) determined that if road sign is used, around half of the total percentages of arrived vehicles exceed the speed limit at school zone in New South Wales. Kattan et al (2011) revealed that children is a contributing factor in lowering vehicle speed at the school zones as well as road characteristics, for example, the use of speed display signs, fencing, fewer lanes, and longer school zones also play role to reduce vehicle speed. Recently, Zhao et al (2016) conducted a study on the effectiveness of traffic sign at the school zones and investigated the efficiency of traffic control devices using average speed, relative speed difference, standard deviation of acceleration, and 85th percentile speed.

Hoque et al (2006) investigated the risk of children in road traffic crashes in context of Bangladesh. This study showed that child casualties peaked during 10-12 noon with the high level of their involvement in traffic incident. The time period seems to be related with school activities. Anjuman and Siddiqui (2007) studied the road safety situation for children in Bangladesh and found that female children are more involved in road traffic accidents than male child. Reduction in accidents and injuries is possible through consciousness of safety and application of countermeasures applying traditional three E's- Engineering, Enforcement, and Education. Also, children safety education is presented as a long term preventive measure against road incidents.

Thus, from the above discussion, it is clear that there is enough knowledge regarding the speed limits and countermeasures towards the school zones in context of developed countries, however, there is not enough study observed in developing countries' condition. Also, speed variations in different peak hours and in different days of week are not considered in any of these studies which may have effect on perceptions of drivers' in changing speed. This research can fill this gap, in many cases, that will bring light on pedestrian and driver's behavior, perception, and also it is expected to contribute in proactive pedestrian safety management while the pedestrians are in the crossing loop.

3. Study Area and Data Collection

Two school zones at highway and arterial are selected based on the presence of pedestrian path, speed bump, traffic police, road signs, zebra crossing, and foot over bridge provided at that site. The worst four sites are selected from the initial selection of total 12 sites (6 sites for both highway and arterial each).

The research conducted based on the comparison of speed at different locations. Data was examined for weekdays when school is open and in vacation. Weekends and bad weathered days are excluded from data collection. Three distinct time periods were examined: morning school peak, noon school peak and evening peak. Morning school peak is defined from 7:00 to 8:00 am. At this time vehicles are entering the school to drop students off or to park in the school parking lot. The noon school peak hour is from 12:00 to 1:00 pm which is the ending hours of morning shift and starting hour of day shift of some of the schools and regarded as the busiest time because there are vehicles entering the school to drop students as well as some vehicles are picking up students and leaving the school. The evening peak is from 5:00 to 6:00 pm. At this hour, majority of the vehicles adjacent to school are picking up students or leaving school. The primary concerned variable will be the mean speed of the vehicles traveling near the school zones at highway and arterial. Speed gun is used for measuring the speed of different vehicles near selected schools. The work was carried 3 different days in a week i.e., Sunday- starting day, Thursday-ending day and a typical weekday for estimating the vehicle speed.

4. Methodology

Several methods have been found in the literature that was used to analyze speed patterns in nearby or within school zones. Ash and Saito (2007) performed qualitative study by conducting questionnaire survey of drivers' opinion and attitude on speeding their demographic characteristics were also considered in the study. In their research, Anjuman and Siddiqui (2007) performed hourly distribution, Simpson (2008) used spot speed study, Yang et al. (2009) used Chi-square test, Bennet and Yiannakoulias (2015) performed logistic regression and Pfeffer et al (2010) used ANOVA test to study different factors with various dimensions and objectives on speed phenomena, school zone and crossing facility. However, no study has used average speed and speed comparison as variables in their analysis to show the variations of speed in different time of the day around school zones. To do the comparisons, t-test was performed in this research. t-test has been used to differentiate between two average speed. Both equal and unequal variances have been used in the analysis. Both cases are elaborately discussed in the following sub-sections.

4.1Testing Differences between Two Means: Equal Variance

The null and the alternate hypothesis of two average speed μ_1 and μ_2 of two population are as follows:

$H_o: \mu_1 - \mu_2 = 0$ (1)

$H_1: \mu_1 - \mu_2 \neq 0$ (2)

A test statistic for a difference between two population means with equal variances is given by

$$t^* = \frac{(\overline{x_1} - \overline{x_2}) - (\mu_1 - \mu_2)}{\sqrt{s_p^2 (\frac{1}{n_1} + \frac{1}{n_2})}} (3)$$

where, the term (μ_1 - μ_2) is the difference between μ_1 and μ_2 under the null hypothesis. The sample size of population 1 and population 2 are n_1 and n_2 respectively. The degrees of freedom of the test statistic in this equation are (n_1 - n_2 + 2), which are the degrees of freedom associated with the pooled estimate of the population variancess_p^2

$$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_1 - 2} \quad (4)$$

The confidence interval for a difference in population means is based on the t distribution with (n_1-n_2 + 2) degrees of freedom. A (1-α) 100% confidence interval for the difference between two population means (μ_1 - μ_2), assuming equal population variances is

$$\overline{x_1} - \overline{x_2} \pm \sqrt{s_p^2 (\frac{1}{n_1} + \frac{1}{n_2})} \quad (5)$$

4.2 Testing Differences Between Two Means: Unequal Variance

As previous the null and the alternate hypothesis of two population means μ_1 and μ_2 are shown below:

H_o: μ_1- μ_2 = 0 (6)

H_1: μ_1- μ_2 ≠ 0 (7)

A test statistic for a difference between two population means with unequal population variances is given by

$$t^* = \frac{(\overline{x_1} - \overline{x_2}) - (\mu_1 - \mu_2)}{\sqrt{(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2})}} (8)$$

where, (X_1 - X_2) is the average sample difference between the observation 1 and observation 2, s_1 and s_2 is the sample standard deviations of these differences, and the

sample size, n_1 and n_2 is the number of unpaired observations of sample 1 and sample 2 respectively. t - distribution with degrees of freedom given by

$$df = \frac{(\frac{s_1^2}{n_1}+\frac{s_2^2}{n_2})^2}{\frac{(\frac{s_1^2}{n_1})^2}{n_1-1}+\frac{(\frac{s_2^2}{n_2})^2}{n_2-1}} (9)$$

A (1- α) 100% confidence interval for the mean difference (μ_1-μ_2) is

$$\overline{x_1} - \overline{x_2} \pm t_{\frac{\alpha}{2}} \sqrt{(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2})} (10)$$

5. Results and Discussion

Taking 90% confidence as the cut point while differentiating between means (for both equal and unequal population variances), three analyses is performed by using STATA 12.

Speed comparison among morning, noon and evening peak are performed for Sunday, typical Weekday and Thursday given in Table 1.

Table 1: Average Speed Comparison between Different Time Periods in a Particular Day

Time 1 vs. Time 2(Particular Day) Morning:M, Noon:N, Evening:E	P-value (equal variance)	P-value (unequal variance)
Site 1: Gazipur Police Line School (Highway)		
M vs E (Sunday)	**0.0109**	**0.0196**
M vs N (Sunday)	0.5174	0.5181
E vs N (Sunday)	**0.0198**	**0.0284**
M vs E (Typical week day)	0.4425	0.4425
M vs N (Typical week day)	0.1475	0.1551
E vs N (Typical week day)	0.5523	0.5555
M vs E (Thursday)	0.1897	0.1904
M vs N (Thursday)	**0.0888**	**0.0958**
E vs N (Thursday)	**0.0030**	**0.0038**
Site 2: Khaleda Rashid Educare, Board Bazar, Gazipur (Highway)		
M vs E (Sunday)	**0.0001**	**0.0001**
M vs N (Sunday)	0.1368	0.1430
E vs N (Sunday)	**0.0067**	**0.0080**
M vs E (Typical week day)	0.4075	0.4128
M vs N (Typical week day)	**0.0524**	**0.0546**
E vs N (Typical week day)	**0.0944**	**0.1090**
M vs E (Thursday)	0.5503	0.5518
M vs N (Thursday)	**0.0118**	**0.0247**
E vs N (Thursday)	**0.0004**	**0.0020**
Site 3: Model Academy School, Mirpur (Arterial)		
M vs E (Sunday)	0.8751	0.8753
M vs N (Sunday)	0.1618	0.1618
E vs N (Sunday)	0.1589	0.1607
M vs E (Typical week day)	**0.0003**	**0.0008**
M vs N (Typical week day)	0.1207	0.1232
E vs N (Typical week day)	**0.0012**	**0.0017**
M vs E (Thursday)	**0.0198**	**0.0271**
M vs N (Thursday)	0.8123	0.8125
E vs N (Thursday)	**0.0154**	**0.0017**
Site 4: Sher-E-Bangla Nagar Government Boys' High School (Arterial)		
M vs E (Sunday)	0.9133	0.9134
M vs N (Sunday)	0.7647	0.7650
E vs N (Sunday)	0.7117	0.7117
M vs E (Typical week day)	**0.0072**	**0.0074**
M vs N (Typical week day)	0.1740	0.1771
E vs N (Typical week day)	**0.0403**	**0.0410**
M vs E (Thursday)	0.1353	0.1455
M vs N (Thursday)	0.7462	0.7464
E vs N (Thursday)	**0.0432**	**0.0491**

From Table 1 it is observed that on Sunday, average speed of vehicles at evening varies with the other two time periods of morning and noon beside highways. At evening there is a noticeable number of personal vehicles is shown near the school zone which are waiting for the students. Most of the school of Bangladesh don't have specific parking zone. As a result the vehicles are parked on the road. So the effective width of road decreases. On the other hand all institutions such as schools, industries, offices, banks close almost at the same time at evening. Thus, the traffic volume is higher in that period and this high volume of traffic have to pass through a narrow width of road at school zones. The result also shows that at the morning and noon the starting and closing hour of school is not conflicting with starting and closing time of offices, banks, industries etc. On typical weekday, the average vehicle speed at evening peak of school zone near arterial varies significantly with the other two periods of morning and noon because of the same reasons mentioned for Sunday. On Thursday the average vehicle speed at noon varies significantly with evening and morning for the school zones adjacent to highway and arterial. As Thursday is the last working day of a week, the movement of people is high in various institutions. At morning and evening the movement of rickshaw is higher at school zone comparing with that of noon. Sometimes it creates heavy traffic jam at school zones. Moreover, the road crossing tendency of pedestrian is comparatively higher both at morning and evening. Though adequate number of traffic police is not available at noon for duty comparing with other two time periods, however, at noon the drivers face light traffic volume which helps to speed up their vehicles and consequently the average speed may vary.

Table 2: Average Speed Comparison between Different Days of Week

Day 1 vs Day 2 Sunday: S; Typical weekdays: Tw; Thursday: T	**P-value (equal variance)**	**P-value (unequal variance)**
Site 1: Gazipur Police Line School		
S vs Tw	**0.0048**	**0.0050**
S vs T	0.0384	0.0388
Tw vs T	0.3505	0.3505
Site 2: Khaleda Rashid Educare, Board Bazar, Gazipur		
S vs Tw	0.5591	0.5591
S vs T	0.7267	0.7267
Tw vs T	0.8084	0.8084
Site 3: Model Academy School, Mirpur		
S vs Tw	**0.0000**	**0.0001**
S vs T	0.5046	0.5047
Tw vs T	**0.0000**	**0.0001**
Site 4: Sher-E-Bangla Nagar Government Boys' High School, Sher-E-Bangla Nagar		
S vs Tw	**0.0019**	**0.0020**
S vs T	0.9105	0.9105
Tw vs T	**0.0016**	**0.0016**

Comparison among different days of a week is shown in Table 2.According to the results of t-test, statistically significant differences are observed of average speed while comparing between Sunday and Typical weekday. It is because Sunday is the first working day in Bangladesh. All institutions resume after weekend. So the vehicle as well as pedestrian flow is quite high on Sunday at school time near school zones comparing with those of other typical weekday and thus traffic volume of Sunday varies with that of Typical Weekday. We also found significant difference in average speeds between typical weekday and Thursday for only the school zones adjacent to arterials. Traffic congestion is usually much higher on Thursday as this is the end day of week. The number of bus increases on highway at that day and on the other hand the volume of rickshaw, autos and private vehicles increases in arterial roads near the school zones. Moreover, the presence of this slow-moving vehicle greatly slows down other vehicles. On the other hand, on narrow roads, a large vehicle can face difficulty in maneuvering and slow down smaller vehicles. The rickshaw also takes up half the road space. These entire traffic scenarios probably create the differences of average speed between Thursday and typical weekday.

Table 3: Average Speed Comparison between School Zone besides Highway and Arterial

Road Type 1vs. Road Type 2	P-value (equal variance)	P-value (unequal variance)
Arterial vs. Highway	**0.0000**	**0.0000**

Speed comparison in the school zones near Highway and Arterial is given in Table 3. It is observed that the average speed varies significantly between highway and arterial. It has been noticed that Highway is wider than Arterial, so there is more space for free flow of vehicles in Highway. On the other hand, the density of vehicle in Arterial exceeds the vehicle density of Highway. The smaller vehicles (e.g. rickshaw, auto, CNG etc.) are less in numbers on highway than arterial. The irregular road crossing tendency of pedestrian is much higher in Arterial than this of Highway which hampers the movement of vehicles. On the contrary, the street hawkers and food vans are seen in a large number at Arterial than on Highway. They also create little blockage of road width, which affects the vehicle speed of Arterial.

6. Conclusion

It is observed that average vehicle speed depends on different time period of different days at different road types. It is also noticed that the average vehicle speed of the same road varies from day to day. Special safety measures should be taken to improve the driving condition of the road particularly emphasizing on certain time periods or days.

Based on the analysis and results, some important findings are as follows: on Sunday, average speed of vehicles at evening beside highways varies with the other two time periods i.e., morning and noon. On a typical weekday, the average vehicle speed at evening peak in school zones varies significantly with the other two periods i.e., morning and noon. On Thursday the average vehicle speed at noon varies significantly at

evening and morning adjacent to the school situated beside highway and arterial. Statistically significant differences are observed in case of average speed while comparing between “Sunday and Typical weekday” and between “Typical weekday and Thursday”. Average speed also varies significantly between highway and arterial. The benefit of this study is that preventive measures can be taken on potential crash sites based on speed studies without having any crash history.

By analyzing the data and observed results, some recommendations have been drawn for the policy makers. The irregular road crossing tendency of pedestrian is much higher in Arterial comparing with that of Highway which impedes the movement of vehicles near schools situated beside arterial. Serviceable footpath should be ensured for the safe movement of pedestrian at school zones especially which are beside arterials. Zebra crossing and foot over bridges should also be provided. On Sunday, average speed of vehicles on highway at evening varies with the other two time periods i.e., morning and noon. At evening the speed of vehicle is less comparing with other two time periods. Because in evening at closing time of school, a noticeable numbers of personal vehicles are observed near school zone waiting for the students. Most of the school of Bangladesh don’t have specific parking zone. For the parking of personal vehicles the roads beside schools have been occupied. To solve this problem specific parking zone for every school is needed. It is observed that an adequate number of traffic police is not available at noon, as a result the drivers operate their vehicle carelessly and over speeding is often noticed. Therefore, proper monitoring is required for all time periods.

According to the finding of our study, average vehicle speed varies significantly between highway and arterial. Perhaps, the presence of street hawkers and food vans at arterial narrowing the effective width of road which affects the vehicle speed of arterial. Specific space should be provided for the hawkers and food vans instead of allowing them to place their goods on roads. Parents as well as children should be more cautious while crossing the roads near schools particularly at evening on the last day of the week when the vehicle density is much higher comparing with other time period. Some road safety education program should be launched by the school authority to enhance road safety awareness among the school children.

The research has been conducted considering several limitations. The finding of this study would be much more strengthened if there were more observation; however, due to limited manpower and budgetary constraint it was difficult to collect more data. Several road infrastructure features i.e. number of lanes, speed limit, road width have not been considered for this study. Apart from the above mentioned variables frequency of transit, driver characteristics, pedestrian behavior, trip purpose, transit network, parking price were not incorporated in the study. Driver characteristics and behavior affect the speeding in school zones and should be introduced in future studies.

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