Comparative Speed Study: A Way to Improve Road Safety Condition

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***Abstract*—With the development of science and technology people experience a large number of motor vehicles which is the main and easier way of travelling for people and carrying goods from one place to another. Roads, highways and streets are fundamental to transportation system and over 70% of passenger travel and much of goods mover is over the highways. However, at the same time we are sacrificing a large number of valuable human lives or being severely injured each day around the world. Road crashes are the major cause for it. It is a leading cause of deaths and serious injuries. Several studies justifies that speed is the major cause related to the risk of getting involved in a road accident. However, very few speed related studies done in the developing countries context, for example, Bangladesh. Specifically, the road safety authority of this country does not aware how speed data can be effectively used to enhance safety. This paper investigates the speed scenario of a particular roadway section of Mirpur Road as a pilot project. The speed data of various types of vehicles that use this particular roadway were taken for this study. To get a complete speed scenario of this road section data were taken on both weekdays and weekends in four different time periods that include morning peak (8.00a.m-9.00a.m), off-peak (11.00a.m-12.00p.m), evening peak (6.00p.m-7.00p.m) and night time (9.00p.m-10.00p.m). Unpaired T- test analysis was performed considering 90% confidence interval for both equal and unequal variances. It is found that compared with other time periods vehicle speed varies in the morning-peak at weekdays and in the evening-peak at weekends. The speed of car, bus and truck significantly varies between two different days. Some measures that demand priority consideration in improving road safety are increasing road width, deploying traffic police in particular time periods, build speed bump, provide adequate streetlight, installing optimum number of speed limit sign etc.**

***Index Terms*—Road crashes, Speed, speed bump, t-test, road safety.**

I. Introduction

Road crashes are a leading cause of deaths and serious injuries around the world. According to a statistics [1], worldwide an estimated 1.2 million people are killed in road accidents each year and as many as 50 million are injured. Projections indicate that these figures will increase by about 65 percent over the next 20 years unless there is new commitment to prevention. It also said that road traffic accidents as the 6th place (was the 9th in 1990) of a major cause of death worldwide, will rise to become the 3rd leading cause of DALYs (Disability Adjusted Life Years) lost by 2020. Deaths and injuries from road crashes are problems for both developed and developing countries. However, the road crash scenario of developing country is much worse comparing with this of developed countries. Over 80% of traffic fatalities occur in so called developing and emerging countries, even though these countries account only about one third of the total motor vehicle fleet. Accident rate in developing countries are often 10-70 times higher than that of developed countries [2]. Developing countries suffer staggering annual loss exceeding US$ 100 billion for road accidents, which is nearly equivalent to the double of all developing assistance [3].

Bangladesh, a developing country, is also facing severe problems due to loss of life from road crashes. Here more than 2,000 people are killed in road accidents every year, which are about 6 persons every day [2]. According to Bangladesh Road Transport Authority (BRTA), Bangladesh has a fatality rate of 55 persons per 10,000 vehicles. It is almost 25 times higher comparing with that of most of the developed

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countries, 8 times higher than that of Thailand and 3 times higher than that of India [4].

Hoque et al. [5] identified several contributing factors of road crashes in Bangladesh. The most significant factors are adverse roadside environment, poor detailed design of junctions and road sections, excessive speeding, overloading, dangerous overtaking, reckless driving, carelessness of road users, failure to obey mandatory traffic regulations, variety of vehicle characteristics and defects in vehicles. BRTA in its investigation identified fifteen major causes of road trauma in Bangladesh [6]. Reckless driving and overspeeding have been reported as the most frequent causes of accident.

A good number of studies have shown that high speed is one of the major causes of crashes. Abegaz et al. [7] identified that over speeding have highest effects on the occurrence of sever and fatal crashes and termed it a powerful predictor of crash injury severity. Knight et al. [8] mentioned that driving at high speed is often perceived to be less risky than drink driving. However, they pointed out that this perception about speeding may contribute to increase the crash rates on rural roads involving young, local drivers. They suggested that interventions are required in form of educational programmes which aim to reduce the rural road crash rate. He et al. [9] described that in Guangdong Province, after using speed detection equipment, motorway fatalities due to speeding in 2005 decreased by 32.5% comparing with 2004. Evans [10] reported that a 1% increase in speed increases the fatality risk by 412%. Soole et al. [11] found that reductions in crash rates have been associated with the enforcement of laws for maintaining suggested speed limit. Van Petegem and Wegman [12] informed that about 50% of all road traffic fatalities and 30% of all traffic injuries in Netherlands take place on rural roads with a speed limit of 80 km/h. Quddus [13] observed that 1% increase in speed variation is associated with a 0.3% increase in accident rates, ceteris paribus. Reduced speed limit also play an important role in crash reduction and their effect are widely discussed in the literature [14-16].

From the above discussion it is clear that high speed of vehicles plays crucial role on road crashes both in developed and developing countries context. Despite its importance very few speed related studies have been conducted in Bangladesh for the sake of improving safety condition. Specifically the road safety authority in Bangladesh does not know how the measured speed of vehicles can be effectively used for improving road safety scenario. Therefore, the objective of the study is to demonstrate through a case study how the speed measurement of different vehicles can be used to improve the safety condition on a particular roadway location.

For developing remedial measures against crashes the traditional practice is to identify the crash hotspots or blackspots at first. A good number of studies are observed in the literature which basically deals with how these crash blackspots can be identified efficiently [17- 21]. However, the shortcomings of this approach is that you have to wait for the crash occurrences on a particular location and then implement remedial action to fix them which is eventually a post active approach. This study, on the other hand, proposes a method which is proactive in nature. That means identify the crash prone locations before crash occurrences and adopt counter measure based on the finding of comparative speed study of different vehicles in different time periods.

To fulfill the objective, at first the study will show how the accident prone location can be identified from a particular road segment by rigorous field investigation. As the road safety budget is usually limited for a developing country like Bangladesh, priority selection of critical locations among competing sites is required at first. Then following works will be carried out in case of speed measurement:

1) Measuring the speed of different motor vehicles using a speed gun at different days.
2) Comparing average speed between different time periods in a particular day for all vehicles.
3) Comparison of average speed between days for a particular vehicle.

Finally, different safety measures will be proposed based on the finding of this study to improve safety scenario of the selected location. This study will inform the policy makers to show a way how the speed data can be effectively employed to improve the road safety condition of a selected location.

II. Methodology

A. Site Selection

For better understanding the speeding characteristics of a roadway it is necessary to study on several roadway segments. However, due to limitation of resources

TABLE 1: Comparison among six survey sites

Parameters	Site1	Site2	Site3	Site4	Site5	Site6
Street light	No	No	No	No	No	No
Shoulder width	Ok	Not Ok	Not Ok	Ok	Ok	Ok
Sight distance	Good	Bad	Good	Bad	Good	Good
Clear road marking	Not visible	Not	Not	Not	Visible	Visible
Speed breaker	No	No	No	No	No	No
Sharp curve	Less risky	Risky	Less	Risky	Less	Less

Fig. 1: Considered six different sites

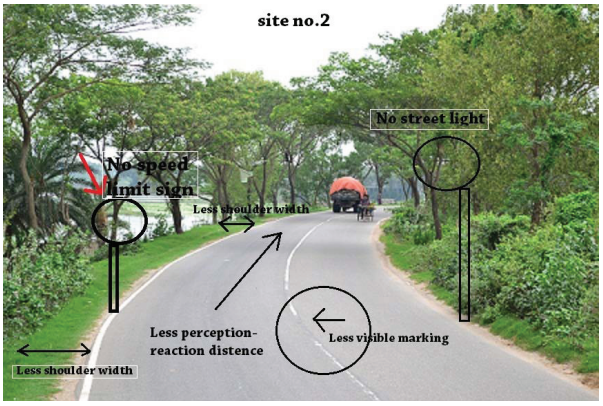

Fig. 2: Finally selected site for data collection

we have considered only a single location of a roadway segment as a pilot project.

In this pilot project, Mirpur Road, a very important road in Dhaka city road network has been selected which connects Mirpur area with Dhaka-Mymensingh highway. In the preliminary survey for choosing site location, we investigated from Kamar para, near Abdullahpur to Rupnagar Police Station, which is about 11 km. Six locations have been selected after comparing with other locations on this road based on existing safety considerations. For data collection purpose a single location has been chosen from these six locations. Table 1 shows the comparison among six survey sites. The selection process of the final location is described in brief below:

There are some common problems in these six site locations of the roadway identified:

1) No street lights: There are no street light in this road, so vehicles have higher chances of involving crashes at night.
2) Less shoulder width: Recommended shoulder width is usually as follows:
   - At least 10 ft for heavily traveled and high speed highways.
   - At least 4 ft for (preferable 6 to 8 ft) for low-type highways.

   In many places the shoulder width does not abide by recommended width.
3) Short sight distance: There are many sharp curves in this roadway. Trees at both side of the road block drivers sight distance.
4) Less distance for perception-reaction: Vehicles move at very high speed on this road. Therefore, longer stopping sight distance, breaking distance, passing sight distance is required.
5) No speed limit signs: The drivers of bus, truck and other vehicles have a tendency to over speeding on this road as there is no restriction of speed visible.
6) No road divider: Often the drivers of bus, truck and other vehicles want to overtake illegally. However, no road divider is observed.
7) No speed breaker: Theres not even a single speed breaker in the entire roadway which increases the over speeding tendency of the driver.
8) Sharp curves: There are many sharp curves which drastically reduce the perception reaction distance.

TABLE 2: Data collection schedule

Day	Time	Time	Time	Time
Sunday (1st Working day of a week)	Morning peak (8.00a.m-9.00a.m)	Off-peak (11.00a.m-12.00p.m)	Evening peak (6.00p.m-7.00p.m)	Night (9.00p.m-10.00p.m)
Monday	Morning peak (8.00a.m-9.00a.m)	Off-peak (11.00a.m-12.00p.m)	Evening peak (6.00p.m-7.00p.m)	Night (9.00p.m-10.00p.m)
Friday (Weekend)	Morning peak (8.00a.m-9.00a.m)	Off-peak (11.00a.m-12.00p.m)	Evening peak (6.00p.m-7.00p.m)	Night (9.00p.m-10.00p.m)

9) Less visible road marking: In many places of the road the pavement marking have been erased or became less visible due to inadequate maintenance.

B. Data Collection

Data has been collected at different hours of a day and in different days of a week. Table 2 shows the data collection schedule.

- Using the speed gun, speed of different vehicles has been measured.
- The work has been carried in 3 different days in a week.
- Two weekdays (Sunday and Monday) and one weekend (Friday is the weekend in Bangladesh) have been selected for collecting speed data.

C. Statistical Analysis

1) Testing Differences Between Two Means: Equal Variences: There are several hypothesis testing options among them t-test is very much familiar. The most common test for the difference between two populations means μ_1 and μ_2 is the one presented below where the null hypothesis states that the two means are equal.

μ_1 , μ_2= Average vehicle speed of all vehicles in a particular time period in a particular day (in case of Table 3)

μ_1 , μ_2 = Average vehicle speed of a particular vehicle in a particular day (in case of Table 5)

$$H_0 : \mu_1 - \mu_2 = 0 \tag{1}$$

$$H_1 : \mu_1 - \mu_2 \neq 0 \tag{2}$$

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

$$t^* = \frac{(\bar{X_1} - \bar{X_2}) - (\mu_1 - \mu_2)}{\sqrt{s_p^2(\frac{1}{n_1} + \frac{1}{n_2})}} \tag{3}$$

where the term $(\mu_1 - \mu_2)$ 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 variance s_p^2.

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

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 ($(\mu_1 - \mu_2)$), assuming equal population variances is

$$(\bar{X_2} - \bar{X_2}) \pm t_{\frac{\alpha}{2}} \sqrt{s_p^2(\frac{1}{n_1} + \frac{1}{n_2})} \tag{5}$$

2) Testing Differences Between Two Means: Unequal Variences: The most common test for the difference between two populations means μ_1 and μ_2, is the one presented below where the null hypothesis states that the two means are equal,

$$H_0 : \mu_1 - \mu_2 = 0 \tag{6}$$

$$H_1 : \mu_1 - \mu_2 \neq 0 \tag{7}$$

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

$$t^* = \frac{(\bar{X_1} - \bar{X_2}) - (\mu_1 - \mu_2)}{\sqrt{(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2})}} \tag{8}$$

Where $(\bar{X_1} - \bar{X_2})$ 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. Equation 8 has approximately a t distribution with degrees of freedom given by

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

A (1- α) 100% confidence interval for the mean difference $(\mu_1 - \mu_2)$ is

$$(\bar{X_1} - \bar{X_2}) \pm t_{\frac{\alpha}{2}} \sqrt{(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2})} \quad (10)$$

III. Data Analysis and Discussion

Speed data has been taken for Car, Microbus, Jeep, CNG Auto rickshaw, Motor cycle, Pickup van, Small bus, Bus and Truck in two weekdays (Sunday and Monday) and one weekend (Friday). Data were taken for morning peak (8.00a.m-9.00a.m), off-peak (11.00a.m-12.00p.m), evening peak (6.00p.m-7.00p.m) and night (9.00p.m-10.00p.m) for each day. Taking 90% confidence as the cut point while differentiating between means (for both equal and unequal population variances), two analyses is performed:

1) Average speed comparison between different time periods in a particular day for all vehicles.
2) Average speed comparison between days for a particular vehicle.

A. Average Speed Comparison Between Different Time Periods

Speed comparison among morning-peak (MP), off-peak (OP), evening-peak (EP) and night (N) are performed for Sunday, Monday and Weekend. The comparison between different time periods of weekdays and weekend is presented in Table 3.

From Table 3 it is observed that on Sunday, average speed in morning peak varies with the speed of other three time periods. It is because Sunday is the first working day in Bangladesh. All institutions such as schools, colleges, industries, offices resume after weekend. Working people and students whose hometown is outside Dhaka (majority from Gazipur and Savar area) use this road to enter Dhaka for job purpose. On the contrary, perhaps a person who entered Dhaka by using this road at morning peak doesnt return during evening pick. Also, it has been observed that in off pick period the traffic volume is light and in night time the number of trucks increases on the roadway. These entire traffic scenarios probably create the differences of average speed between morning peak in Sunday and other time periods.

There is no significant speed variation observed between off pick period and night time in all three days (Sunday, Monday and Weekend). Low traffic volume in these two time periods may be the reason of this finding.

Average vehicle speed at morning peak on Monday differs from noon/off-peak and evening pick. Unlike Sunday people do not enter Dhaka city after passing weekend at their hometown. However, the traffic volume is still high at morning peak as the peak spreading is not observed among the commuters. During evening and at night time people are afraid of using this road perhaps because of safety consideration as no street light is seen. Moreover, vandalism, burglary and car hijacking are often reported from the commuters. Therefore, the traffic volume is significantly low in these two periods.

On weekend, average vehicle speed at evening peak differs from morning pick, off pick and night time. In weekend all the offices are closed. People are usually enjoying and relaxing in weekends. Thus, they tend to stays at home in morning and enjoy the evening by going outside. Hence, the traffic volume is perhaps significantly low at evening peak during weekend comparing with other time of the day which may create differences in average speed.

B. Average Speed Comparison Between Days for A Particular Vehicle

For a particular vehicle, comparison among Sunday, Monday and weekend was carried-out. Comparison among different days for a particular vehicle is shown in Table 4. Comparison of average speed for each type of vehicle in different days are shown in Table 5.

There is a change observed in mean speed for different vehicles among Sunday, Monday and weekend. According to the results of t-test, statistically significant differences are observed for speed of some vehicles while comparing average speed between "weekend and Sunday"; "weekend and Monday" and "Sunday and Monday".

While comparing speed between weekend and Sunday, significant difference is noticed for car, microbus and motorcycle. The possible reason is that on weekend the road is not used by many commuters especially

TABLE 3: Comparison of average speed between different time periods of weekdays and weekend

Time1 vs. Time2 (particular day) MP - Morning Peak OP - Off-peak EP - Evening Peak N - Night	P value* (For equal variance)	Statically significant = $\surd$ Statically Insignificant = $\times$	P value** (For unequal variance)	Statically significant = $\surd$ Statically Insignificant = $\times$
MP vs. OP (Sunday)	0.0027	$\surd$	0.0029	$\surd$
MP vs. EP (Sunday)	0.0001	$\surd$	0.0001	$\surd$
MP vs. N (Sunday)	0.0001	$\surd$	0.0001	$\surd$
OP vs. EP (Sunday)	0.0085	$\surd$	0.0085	$\surd$
OP vs. N (Sunday)	0.1344	$\times$	0.1358	$\times$
EP vs. N (Sunday)	0.3295	$\times$	0.3324	$\times$
MP vs. OP(Monday)	0.0097	$\surd$	0.009	$\surd$
MP vs. EP (Monday)	0.0015	$\surd$	0.0015	$\surd$
MP vs. N (Monday)	0.8028	$\times$	0.8107	$\times$
OP vs. EP (Monday)	0.5585	$\times$	0.5546	$\times$
OP vs. N (Monday)	0.7922	$\times$	0.8162	$\times$
EP vs. N (Monday)	0.0237	$\surd$	0.0293	$\surd$
MP vs. OP(Weekend)	0.9249	$\times$	0.9281	$\times$
MP vs. EP (Weekend)	0.0547	$\surd$	0.066	$\surd$
MP vs. N (Weekend)	0.4753	$\times$	0.485	$\times$
OP vs. EP (Weekend)	0.0207	$\surd$	0.0206	$\surd$
OP vs. N (Weekend)	0.4228	$\times$	0.4224	$\times$
EP vs. N (Weekend)	0.0432	$\surd$	0.0411	$\times$

* H_0: average speed time1 = average speed time2
** H_1: average speed time1 $\neq$ average speed time2

TABLE 4: Mean speed (km/hr) for each type of vehicles on different days

Days	Car	Microbus	Jeep	CNG Auto rickshaw	Motorcycle	Pickup	Small Bus	Bus	Truck
Sunday	54.72	57.04	57.47	49.61	57.20	51.00	54.52	58.35	52.39
Monday	56.87	54.83	55.19	52.63	51.92	51.61	52.25	52.07	36.06
Weekend	57.06	59.90	59.57	48.68	52.14	52.14	55.22	58.55	51.94

office goers. Therefore, the road is free from heavy traffic and other obstructions. Hence the drivers face no problem to increase speed at that time. As a result the drivers of car, microbus and motorcycle usually run at a higher speed than weekdays.

However, the situation is different for Sunday. Sunday, being the first working day of the week, the number of vehicles increases which carry mostly office commuters. Therefore the traffic volume is heavy which hinders the speeding of all vehicles. Many people from outside Dhaka spend their weekend in their hometown and join their job on Sunday using

TABLE 5: Comparison of average speed between days for a particular vehicle

Vehicle Type (Day 1 vs. Day2) S=Sunday, W=Weekend, M=Monday	equal variance) P-Value* (For	Statically significant = ✓ Statically Insignificant = ×	unequal variance) P value** (For	Statically significant = ✓ Statically Insignificant = ×
Car (S vs. W)	0.0747	✓	0.0826	✓
Micro (S vs. W)	0.0634	✓	0.0607	✓
Jeep (S vs. W)	0.2258	×	0.2106	×
CNG (S vs. W)	0.5327	×	0.5347	×
Motor Cycle (S vs. W)	0.0061	✓	0.0109	✓
Pickup (S vs. W)	0.4873	×	0.4906	×
Small bus (S vs. W)	0.6737	×	0.6731	×
Bus (S vs. W)	0.8699	×	0.8693	×
Truck (S vs. W)	0.8185	×	0.8153	×
Car (M vs. W)	0.8997	×	0.8987	×
Micro (M vs. W)	0.0006	✓	0.0005	✓
Jeep (M vs. W)	0.0234	✓	0.023	✓
CNG (M vs. W)	0.0451	✓	0.0444	✓
Motor Cycle (M vs. W)	0.9147	×	0.9223	×
Pickup (M vs. W)	0.7973	×	0.7918	×
Small bus (M vs. W)	0.0988	✓	0.1048	×
Bus (M vs. W)	0.0002	✓	0.0004	✓
Truck (M vs. W)	0.0001	✓	0.0001	✓
Car(S vs. M)	0.1052	×	0.1063	×
Micro(S vs. M)	0.1407	×	0.1422	×
Jeep(S vs. M)	0.2511	×	0.2557	×
CNG (S vs. M)	0.147	×	0.1363	×
Motor Cycle (S vs. M)	0.0501	✓	0.043	✓
Pickup (S vs. M)	0.7848	×	0.779	×
Small bus (S vs. M)	0.2356	×	0.234	×
Bus (S vs. M)	0.0003	✓	0.0007	✓
Truck (S vs. M)	0.0001	✓	0.0001	✓

* H_0:average speed day1 = average speed day2
** H_1: average speed day1 $\neq$ average speed day2

this route. This large number of people is carried by mainly buses. Movement of these large vehicles on this single lane road prevents to maintain design speed. This may be the reason for reducing the speed of smaller vehicles.

Again on Monday, being the following day after Sunday, the traffic flow follows a regular pattern which helps to increase speed. While comparing the speed data of microbus, jeep, CNG auto rickshaw, bus and truck, statistically significant differences are observed. Particularly in case of buses and trucks, there is a huge difference in mean speeds between weekend and Monday. On that particular route buses and trucks are always found heavily loaded. During weekdays, their number increases as travel demand increases for transporting people and goods. Though the road surface condition is good, however, being a two lane road and having frequent curvature makes delay to detect on coming vehicles from opposite direction. These conditions often forced drivers to reduce their

TABLE 6: Recommendation for the policy makers

Safety Measures	Justification from the findings of the study
Increasing road width	Significant speed variations among vehicles are observed and overtaking tendency increases due to speed variation among different vehicles. To facilitate overtaking the road width should be increased and median should be constructed which may reduce the chance of crashes.
Deploying of traffic police in particular time periods	Average speed varies in weekdays morning peak and weekends evening peak compared to other time periods. Therefore, proper monitoring is required for these two time periods.
Speed bump	At low traffic volume there is a possibility of crashes between high speed vehicle and low speed vehicle. Speed bump should be introduced so that the speed differential may be reduced and excess speeding can be controlled on weekend.
Provide street-light	Speed is significantly different at evening peak and night time in weekdays and night time in weekend compared to other time periods.
Providing attainable maximum speed limit sign	According to our data, average speed in Sunday, Monday and weekend is 54.24, 52.52, 57.25 km/hr respectively. However, maximum allowable speed limit is 40 km/hr imposed by BRTA.

speed to ensure safety. Due to unavailability of traffic police on certain locations, a sudden stop or U-turn by a larger vehicle forces other vehicles to reduce speed particularly on weekdays. However, during weekend the drivers face light traffic which helps to speed up their vehicles.

IV. Conclusions

In summary, it can be concluded from this study that average vehicle speed depends on both time period of a day and type of vehicle. In addition, it is observed that speed variation depends on which day of a week considered. It can be hypothesized that when average speed of the vehicles on a particular time period is significantly different compared with that of other time periods in a day, the possibility of crashes increases because the road environment changes. It is also observed that the average speed of the same vehicle varies from day to day.

Similarly it can be inferred that when the average speed of a same category vehicle varies between two different days, the likelihood of crashes will increase since the road environment may be different in different days. This study tries to explain the reasoning of speed differentials. Special safety measures should be taken to improve the driving condition of the road particularly emphasizing on certain time periods or days.

By analyzing the data and observed results, some recommendations have been drawn for the policy makers. Some general requirements are discussed based on the key findings from our analysis. Table 6 represents those recommendations.

Comparing with other methods the benefit of this study is that without having any crash history preventive measures can be taken on potential crash sites for avoiding future crashes. However, the shortcoming of this study is that the sample size is limited and speed data has been collected for only few days. 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 not possible to collect more data.

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