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Analysis of Speed Behaviour of Drivers on a Rural Highway in a Developing Country[1]

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Abstract

This paper deals with the speeding behaviour of vehicles on a two-lane bi-directional highway in a heterogeneous traffic environment. Data has been collected using the floating car method from a major national highway in Bangladesh. Speed data extracted second by second has been analysed for a range of short road segments. Different attributes related to speed and speed behaviour has been analysed. The major contribution of this paper is the identification and quantification of significant attributes influencing speed choice in each small segment of road in a heterogeneous traffic environment. Finally, an ordinary-least-square (OLS) regression model to estimate segment mean flow speed has been proposed.

1. Introduction

A driver's choice of speed is affected by many factors and there is an extensive literature on this topic, e.g. (Moses and Mtoi, 2013, Ivan et al., 2009, Figueroa Medina and Tarko, 2005). Most of the literature mainly deals with free flow speed on a network comprising different types of roads. The main objective of this paper is to identify the factors affecting the speed behaviour of drivers and to develop a model for estimating average speed of traffic stream in particular segments of a two-lane bi-directional highway in developing countries.

Data has been collected for a 13km section of a two-lane bi-directional major national highway (N4) in Bangladesh. Field observation, including subjective and objective approaches and an instrumented floating vehicle, was used to collect speed and related data. This paper reports on the analysis of the data obtained using a vehicle instrumented with three cameras and observers. Speed data extracted second by second has been analysed for a range of short road segments. Speed profiles for each 200m segment were analysed and descriptive speed related statistics are put forward. The most significant attributes influencing speeding behaviour have been identified using different sensitivity analysis. Those attributes include traffic flow by vehicle composition, road and roadside environment, as well as traffic operational characteristics. A correlation has been established between vehicle speed and these influencing attributes. Finally, the potential future applications of the model are highlighted.

2. Data Collection Methodology

The primary data for the study reported here was collected using mainly field observation and the 'floating vehicle' method. An instrumented vehicle (microbus) was used to gather data on

[1] This is an abridged version of the paper originally submitted for ATRF 2017. For further information about this research please contact the authors.

overtaking and risk-taking behaviour, as well as to monitor vehicle speed continuously. Two in-vehicle cameras were attached to the front dash-board and rear side of the vehicle to track the movements of leader & follower. Another camera was purposefully set to record the speedometer reading. The third camera enabled the continuous monitoring of vehicle speed on a second-by-second basis. Simultaneously, two observers recorded all overtaking events and any other risky driver's behaviour.

3. Selection of Appropriate Segment Length

The instrumented vehicle speeds were extracted from the video footage of speedometer. The speed related data was verified using a two-step process to minimise the error. Following a random cross-check of the full dataset, a trip based time-speed scatter plot was used to identify anomalies and any sudden change in speed. Adjustments were made using alternative video data.

A number of speed-related statistical attributes, such as maximum, minimum, standard deviation, speed difference, the average speed for the respective segment length were used in order Different standard sensitivity analysis were made to determine the most appropriate small segment length for speed analysis purposes which is termed as segmentation. The results show that a 200-meter segment length is the most appropriate, taking into account the statistical analysis and the minimum required overtaking distance.

4. Analysis and Results

The study reported here considered 20 typical trips by a floating vehicle considering different times of day to cover overall road and traffic environment. The summation of total travel distance considered for the detailed analysis is around 256km, or around 4.3 hours of travel. Speed data was extracted second by second for each trip. This speed data has been analysed from different perspectives. A brief summary of that analysis is given in the following subsections.

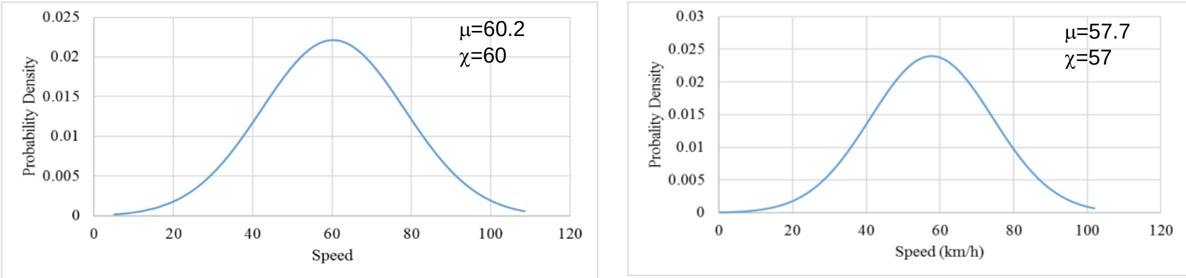
4.1. Overall speed profiles

The posted speed limit for the selected road section is 80 kph. Both the TMS and the SMS were observed to be significantly different from that posted speed. The spot speed or TMS of the floating vehicle reached over 100 kph and the SMS in different trips ranged from 53 to 73 kph. The mean SMS for the entire study section is 59 kph (60 kph west-east and 58 kph east-west). The difference in SMS between the two directions is found statistically significant (p-value is almost zero (4.68E-19), $z > z_{\text{Critical two-tail}} > z_{\text{Critical one-tail}}$; $F > F_{\text{crit}}$).

4.2. Overall distribution of speeds

The total time and distance spent travelling, for each speed range and by direction, for all 20 recorded trips. Although the overall mean speed is well below 80kph, the survey vehicle spent/travelled, on average, 13 percent of the time and 20 percent of distance at speeds above 80 kph. Around 24 and 17 percent of total distance travelled at speeds over 80 kph, in the west-east and east-west directions, respectively. Distributions of speeds by direction were found to be normally distributed (Figure 1).

Figure 1: Normal distribution of speed by direction



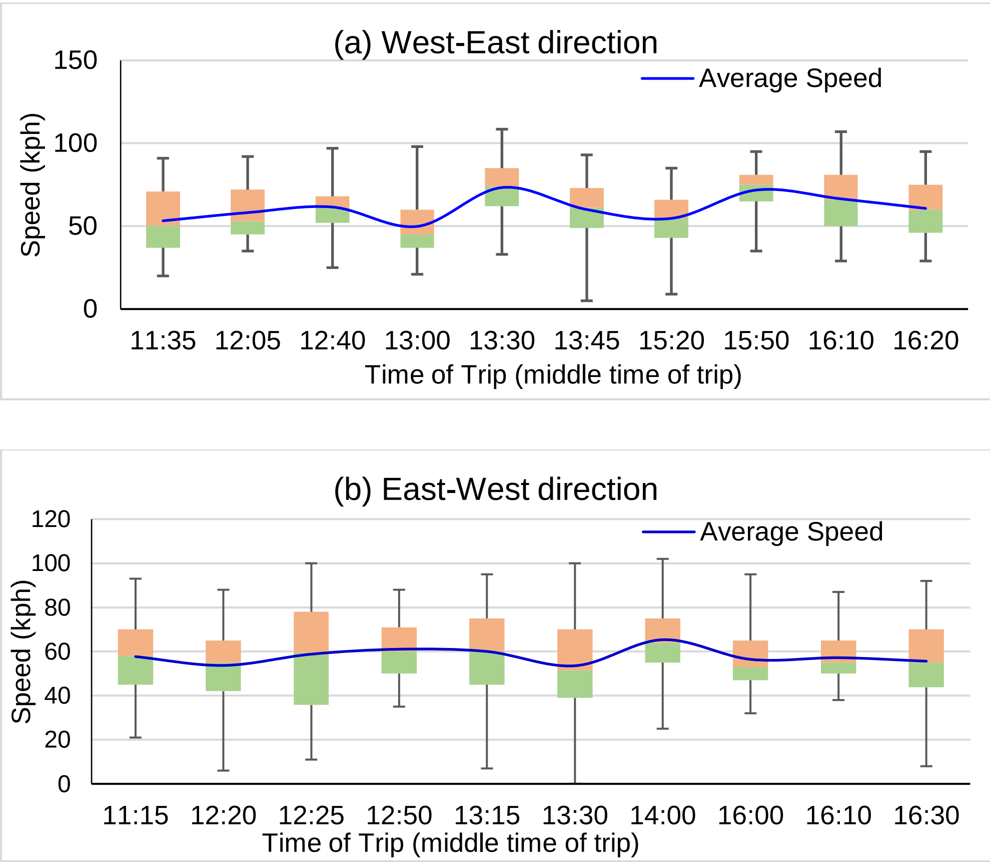
(a) West-East Direction

(b) East-West Direction

4.3. Speed profile of individual trip

The individual speed profiles by the time of the trip and by the direction are shown in Figure 5. The range of speeds by time of the trip is also shown. The range of speeds is almost the same for all trips. However, there are significant differences between the 25th and 75th percentile. As can be seen in Figure 5, the variation of average speeds in the west-east direction is higher than the corresponding variation in the east-west direction.

Figure 5: Trip speed profiles by direction



4.4. Segment Analysis

A total of 200-meter long 69 segments were considered for the analysis. Although there is noticeable variation in speed between different segments, the ranges of speeds are consistently similar. The SMS overall means are 65 kph and 62 kph in the west-east and east-west direction respectively. Although the mean speeds show similar profiles in both directions, the differences were found to be statistically significant (z>z Critical two-tail>z Critical one-tail;

P(Z<=z) one-tail=0.017 and P(Z<=z) two-tail=0.035). Segments 40 to 52 (7.8 to 10.2 km) are showing the highest SMS in the entire section and it reaches up to 80 kph.

4.5. Acceleration and deceleration changes

The frequency of deceleration and acceleration at different ranges of speed change (m/s^2), was quantified. There are almost 42 and 35 deceleration events have been found in the W-E and E-W directions, respectively where the deceleration rate was below -2.0 $metres/sec^2$ and classified as potential conflicts. Moreover, among the 697 events where deceleration rates were between $-2m/s^2$ and $-1m/s^2$, 24 percent of occurred from initial speeds above 70kph, which are considered critical from the safety point of view.

5. Factors Affecting Speed Choice

The study attempted to identify the factors that affect the operating speed choice for each road segment. A total of 30 independent variables related to road geometry, road environment, and traffic operation were analysed for four statistical measures of speed levels, namely: average; minimum; maximum; and 3rd quartile speed. Ordinary list-square regression was used to identify the significant speed influencing factors. Fourteen actors were found to be significant for different speed levels. Among them, eight are related to traffic flow, four to geometric and two to the roadside environment.

6. Segmental Speed Model

After the different combination of factors, the best specification of the regression model for calculating mean speed, Vms, of a particular road segment, for the two-lane highway under study is the following:

$$\begin{aligned}\mathrm{Vms} = 69.14 &- 2.05 \times \mathrm{Bo} - 11.21 \times \mathrm{Bs} - 2.87 \times \mathrm{To} - 12.65 \times \mathrm{Ts} - 5.83 \times \mathrm{O4Ws} - 1.53 \times \mathrm{Ao} \\ &- 1.86 \times \mathrm{No} + 3.56 \times \mathrm{Shg} - 5.61 \times \mathrm{Shb} + 3.30 \times \mathrm{Cs} + 6.37 \times \mathrm{Ma} - 4.52 \times \mathrm{Mpd} \\ &+ 8.48 \times \mathrm{RNl}\end{aligned}$$

Where,

Bo = Bus (Opposite Direction)

Bs = Bus (Same Direction)

To = Trucks (Opposite Direction)

Ts = Trucks (Same Direction)

O4Ws = Other 4Wheelers (Same Direction)

Ao = Auto & M/C (Opposite Direction)

No = NMV (Opposite Direction)

Shg = Good Shoulder (very good and functional/other)

Shb = Bad Shoulder (bad/other)

Cs = Culvert (Submerged/other)

Ma = Major Access (Yes/other)

Mpd = Medium Pedestrian (no frequent crossing/other)

RNl = Road side NMV (low/other)

Eleven out of 13 parameters included in the model are significant with a 99% confidence level.

The performance of the model was tested using 10-fold Cross Validation technique in which the observed results for a separate trip were compared with those obtained using the model estimates. Pearson correlation (r) between the observed and estimated speed is +0.8 and adjusted R-Square value is 0.63 which is statistically significant. Therefore, the model appears to provide a reasonable average with no apparent bias.

7. Summary and Conclusions

The results reported here from a part of a broader study on overtaking behaviour and probability of safety risk in a two-lane highway in heterogeneous traffic environments of developing countries. The choice of driver speeds was analysed in detail using floating vehicle data. The results show that both the TMS and the SMS are significantly different from the posted 80 kph speed limit. The quartile and mean speeds are also significantly varied in different times of the day in the different direction. Over speeding is a common phenomenon, which ranges up to around 110 kph. The abrupt change of speed induced by speed differential is also a common and concerning issue in this highway section.

The current study has also analysed the speed profile for each individual segment of 200m length. Although a similar road environment applies to the study section, the analysis shows that speeds vary considerably across segments. The factors influencing were quantified in detail. The results of the analysis provide an understanding of the main speed influencing factors related to driver speed choice behaviour.

A regression model has been developed to estimate segmental mean speeds for the road section under study. The model includes thirteen variables, of which seven are related to traffic flow, four to road geometry and two to the roadside environment. The model has been validated by comparing the observed and estimated speed results. One of the major advantages of this model is that it can measure flow mean-speed in any critical segment of the road within a very short period.

Some areas of improvements that could be addressed in further studies include: (a) collection of speed data based on other instrumented vehicle types such as buses and heavy vehicles; extended the analysis to include variables related to the demographic profile of drivers; as well as more road geometry and design variables. Finally, the current study will serve as the basis for the development of relationships between speed behaviour and the probability of crashes, in such traffic environments.

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