Study of Car Acceleration and Deceleration Characteristics at Dangerous Route FT050

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Abstract. Individual vehicle acceleration and deceleration are important to generate vehicles speed profile. This study covered acceleration and deceleration characteristics of passenger car in Federal Route FT050 Jalan Batu Pahat-Ayer Hitam that was the top ranking dangerous road. Global Positioning System was used to record 10 cars speed to develop speed profile with clustering zone. At the acceleration manoeuver, the acceleration rate becomes lower as the drivers get near to desired speed. While, at deceleration manoeuver, vehicles with high speed needs more time to stop compare to low speed vehicle. This is because, the drivers need to accelerate more from zero speed to achieve desired speed and drivers need more distance and time to stop their vehicles. However, it was found out that 30% to 50% are driving in dangerous condition that was proven in clustering acceleration and deceleration speed profile. As conclusion, this excessive drivers are the factor that creating high risk in rear-end collision that inline FT050 as dangerous road in Malaysia.

1. Introduction

Quality of the service affects vehicles speed on a highway. Typically speed measured by wheel speed or Global Positioning System (GPS). Speed can be classified in several types such as design speed, free speed, average mean speed, operating speed and upper and lower posted speed. Traffic volume and traffic composition influences the speed of vehicles on highway [1].

Beside vehicle speed, an acceleration characteristic of vehicle was also one of factor that contributes to highway design and construction aspects. Acceleration characteristics of vehicles are subjected to type of gear transmission, power to weight ratio, vehicle average speed and also depend on loaded and unloaded states. In example, vehicle takes medium to maximum acceleration rate when it starts from rest due to the force available at rest to exceed the tractive effort by friction between tires and pavement surface. However, motorists are rarely experience the maximum accelerations on multilane highways except in emergencies situation. [1]

Brooks [2] investigate the acceleration characteristics in rural road. It was found that normally driver accelerate more when the vehicle is at rest and tend to decrease when the driver want to bring the vehicle to their desired level of speed. In this case, there will be no acceleration, the driver is comfortable in their desired level of velocity and does not want to change it. Studying the model of acceleration on a linear basis provides the best description of the behaviour of the driver.

Wallace et al., [3] stated that, driver acceleration characteristics can be measured because different drivers may demonstrate different characteristic behaviours. This is also important as it could influence into driver performance or potentially help indicate who is driving.

Adjacent to acceleration characteristics, deceleration characteristics are also play important part of analysing speed profiles. In this situation, a driver will reduce or decelerated their vehicle from last speed to zero slowly or immediately when they reach stop line.
Based on Wang [4], he has found out that acceleration and deceleration studies were based on out-dated and limitation of data collection. Beside that, most of previous outcomes could not provide accurate estimations of driver’s behaviours especially related to time and distance in acceleration or deceleration of vehicle. No doubt, different drivers may have difference perception and level of respond on where and when to start accelerate or decelerate while driving.

These studies focus on acceleration and deceleration characteristics at FT050 from Batu Pahat to Ayer Hitam since no active research at this critical location. This federal roads is the top ranking for road accidents compared to other road categories in Malaysia [5]. FT050 from Batu Pahat to Ayer Hitam (Fig. 1) having the highest numbers of accident and became one of the high risk and dangerous road in Johor [6], [7], [8], [9]. Furthermore, previous researches also support that inconsistency geometric design due to road geometric characteristics and driver behaviour significantly contribute to road accidents [10][11][12][13]. Finally, the output from acceleration and deceleration characteristics data will be used to develop speed profile clustering.

In line with this research, Malaysian Government has come out with Blue Ocean Strategy principles that have high impact in low cost and rapid execution to national development including infrastructures facilities. In order to achieve this, Malaysia needs to minimise road accidents and increase the safety level for road users. Therefore, the output from this research are strongly reliable in helping Road Safety Department (RSD), Royal Malaysia Police (RMP), Road Transport Department (RTD), Public Works Department (PWD), academicians and public users to collaborate, respond and cooperate in order to monitor, implement and enhance road safety since FT050 is one of the dangerous roads in Malaysia.

2. Objectives of the research
The objectives of this study is to gather car speed, determine speed range, propose clustering speed range and summarize acceleration and deceleration parameter and finally plot speed profile along dangerous roads Federal Route 50 (FT050, Batu Pahat to Ayer Hitam, Malaysia).

3. Method
The methodology in this study was based on car speed data of 10 trips using difference drivers. This study used GPS to record speed data per second using GPS DG-200 attached to vehicle.

3.1 Data collection
The methodology for data collections in this study is shown in Figure 2. The data was gathered using 10 different drivers and different days. The data was gathered on Monday, Tuesday and Wednesday during off peak hour. The drivers were not informed during data collection in order to eliminate the influence to driver behaviour. Finally, the car speed data will be used to produce speed profile.
3.2 Vehicle acceleration and deceleration parameters

Acceleration and deceleration rate per second was calculated from the speed difference. The acceleration and deceleration rate at the n\textsuperscript{th} second is calculated by the average acceleration and deceleration rates of the previous and successive seconds as shown in equation 1, 2, 3 & 4.

\[
\begin{align*}
    a_n &= \frac{(v_n - v_{n-1})}{3.6} \quad (1) \\
    d_n &= \frac{|v_n - v_{n-1}|}{3.6} \quad (2)
\end{align*}
\]

Where

\(a_n\) = acceleration rate at the n\textsuperscript{th} second (m/s\(^2\)), and
\(d_n\) = absolute deceleration rate at the n\textsuperscript{th} second (m/s\(^2\)), and
\(v_n\) = speed at the n\textsuperscript{th} second (km/hr)
\(v_{n-1}\) = speed at the n\textsuperscript{th}-1 second (km/hr)

4. Data analysis and results

The data analysis is based on car speed per second from 10 trips to generate acceleration and deceleration parameters that can be used to develop speed profile.

4.1 Acceleration parameters

The acceleration distance is the distance traveled from the start point to point where speeds stop increasing and the time consumed is defined as acceleration time. Acceleration rate is the ratio of acceleration distance compared to acceleration time. Table 1 shows parameters during acceleration maneuver.

| Max. Speed Range (km/hr) | Acceleration Distance (m) | Acceleration Time (sec) | Acceleration Rate (m/s\(^2\)) |
|--------------------------|---------------------------|-------------------------|------------------------------|
| 31-40                    | 77.148                    | 18.2                    | 0.6412                       |
| 41-50                    | 162.507                   | 25                      | 0.6434                       |
| 51-60                    | 362.713                   | 38.2                    | 0.4866                       |
| 61-70                    | 692.708                   | 58.83                   | 0.3605                       |

Table 1 indicates that, for all speed range at this route, acceleration distance and acceleration time increase with increase in maximum speed. This is because; driver needs more distance and time to achieve
that speed. Different to acceleration rate, which decrease with increase speeds. This is due to driver need to accelerate more from zero speed and decrease the acceleration when achieve the desired speed. This result is similar with previous researcher Wang [4], Brooke [14], and Brooke [15] for passenger car.

4.2 Deceleration parameters

The deceleration distance is the distance travels from an initial speed to a complete stop and the time consume is define as deceleration time. Deceleration rate is ratio deceleration distance compare to deceleration time. Parameters during deceleration manoeuver can be observed from Table 2.

| Max. Speed Range (km/hr) | Deceleration Distance (m) | Deceleration Time (sec) | Deceleration Rate (m/s²) |
|--------------------------|---------------------------|-------------------------|--------------------------|
| 31-40                    | 43.923                    | 10.5                    | 1.0026                   |
| 41-50                    | 128.145                   | 17.8                    | 0.9192                   |
| 51-60                    | 155.198                   | 19.25                   | 0.8865                   |
| 61-70                    | 450.896                   | 35.75                   | 0.6409                   |

Table 2 shows that, deceleration distance and deceleration time increase with increasing in maximum speed for all speed range at this route. This indicates that driver needs more distance and time to decelerate from higher speed compare to lower speed. Different to deceleration rate, which decrease with increase speeds. This is due to driver need to decelerate less from high speed and decelerate more when reach stop line. The result is similar to Wang[4], but, the result is contradicted with Bokare et al. [15], due to different situation at this route, where this route is a main road from highway to Batu Pahat town, near residential area, schools, college and university.

4.3 Speed profile

Figure 3 shows the acceleration speed profile (speed-time scatter) of car during acceleration manoeuver. It can be cluster in three zones. The first zone represent high acceleration rate, which drivers need more acceleration to achieved desire speed. Second zone represent medium acceleration rate, which drivers near to achieved desire speed. Last zone represent low acceleration, which drivers already achieved desire speed. In this result, it can be assumed that 50% of the drivers are potential in rear-end collation accident as shown at upper left of the graph speed profile. The assumption is base on the higher slope gradient in the graph speed profile. In other word, at the beginning acceleration, slope of speed time scatter is steep compare to end acceleration. A similar results is reported by Brooks in 2012 [2].
Figure 3. Acceleration Speed profiles.

Figure 4. Deceleration Speed profiles.

Figure 4 shows the deceleration speed profile (speed-time scatter) of car during deceleration manoeuver. It also can be cluster in three zones. The first zone represent high deceleration rate, which drivers decelerates less than 20s from desire speed to complete stop. It shows that 30% of the drivers are at risk group drivers which can contribute to rear-end collision too. This assumption is related to stopping sight distance, where it depends on perception reaction distance and braking distance. Based on Arahan Teknik (Jalan) 5/85[16], it is recommended that stopping sight distance is 240m for design speed 60km/hr. However in this study, deceleration distance is only 156m which is short of 44m from recommended stop sight distance. Second zone represent medium deceleration rate, which drivers needs 21 s to 40s to complete stop and 50% drivers are this group. Last zone represent low deceleration, which drivers need more 40s to complete stop, 20% drivers are this group.

5. Conclusions
This research focus on acceleration and deceleration of passenger car in Federal Route FT050. The following conclusions can be drawn:

i) Vehicles with higher maximum speed have higher acceleration time, acceleration distance, and lower acceleration rates.

ii) Vehicles with higher maximum speed have higher deceleration time, deceleration distance, and lower deceleration rates.
iii) Average acceleration distance (m) and average deceleration (m) was used to develop speed profile at this route.

**Acknowledgement**
The authors gratefully acknowledgment the Ministry of Higher Education Malaysia (MOHE) for providing financial support for the authors and to Universiti Tun Hussein Onn Malaysia (UTHM) for providing the resources needed to complete this paper.

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