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Scene Barrier Effects on Vehicle Deceleration Rate during Primary Accident in a Suburban Area

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Abstract – *This study uses a simulation of primary accident to investigate the scene barrier effects on vehicle deceleration rate in the suburban area to assess driver behaviour. Several conditions were designed and experimented to determine the capability of scene barrier, which included free flow traffic without an accident, an accident without scene barrier and an accident with scene barrier. The vehicle deceleration rate was investigated by collecting speed-time data in normal traffic zone and rubbernecking zone. Results found that the average vehicle deceleration rate reached as high as - 1.93 km/h/s in rubbernecking zone compared to normal traffic zone (as high as - 0.49 km/h/s) especially when an accident was simulated without the scene barrier. Introduction of scene barrier during the simulated accident improved traffic flow and reduced rubbernecking phenomena by improving the average vehicle deceleration rate in rubbernecking zone by up to 43.0 %. However, sudden deceleration cannot be totally eliminated during the simulated accident with the scene barrier due to driver behaviour. For optimization of braking time during a primary accident, a study of the algorithm of Autonomous Emergency Braking (AEB) system is necessary.*

Keywords: Road accidents, rubbernecking, driver's behaviour, vehicles deceleration rate, traffic congestion

1.0 INTRODUCTION

Malaysia is no stranger to road accidents. According to the 2016 Transport Statistics published by the Ministry of Transport (2017), the state of Selangor recorded the highest number of road accidents followed by Johor and Kuala Lumpur. Official records also reveal more than half a million road accidents taking place until 2016 (Ministry of Transport, 2017). For every 100,000 people, an average of 25 deaths were estimated due to road accidents alone. In addition, lane blockage or road congestion has been identified as the primary cause of accidents as curious drivers tend to be distracted by the road accident. Such a phenomenon is called "rubbernecking", which refers to the tendency of drivers either in the adjacent or opposite lane to slow down as they pass by an accident to see what is happening (Chung & Recker, 2013). This behaviour not only invites sudden or unnecessary slowdown in traffic but also let the drivers' vision be drawn to the accident scene rather than on the road ahead. Consequently, inattentive driving may lead to a secondary accident, such as collision due to unsuccessful braking (Park & Haghani, 2016).

Snelder et al. (2013) found rubbernecking effects as one of the delays caused by accidents. Apart from causing delays on adjacent lanes, road accident may cause a traffic jam on the opposite lanes. This occurrence shows that drivers are easily distracted even by the accident that occurs on the opposite side (Snelder et al., 2013). Moreover, a study on Britain's motorways (M6) found that 29 % of slowdowns were due to accidents, while breakdowns were blamed on rubbernecking among drivers on the opposite lanes (Gallagher, 2015). In placing more emphasize, Chung & Recker (2013) studied traffic congestion caused by rubbernecking at freeway accident sites. Each accident is classified into three characteristics, including accident type, accident location, and accident severity. It was found that for every 1 % increase in the five minutes' occupancy in the direction of the accident location, the rate of rubbernecking delay would increase by 4.2 % (Chung & Recker, 2013).

When an accident occurs, deceleration rate of a vehicle begins as it enters the rubbernecking zone. Chen et al., (2012) studied behaviour of vehicles upon entering the rubbernecking zone caused by clean-up work by setting up 1000 m of normal traffic zone and 250 m of rubbernecking zone. The clean-up work has simulated the relationship between speed reduction of vehicles (1-p) and rubberneckers (r). The result showed that speed reduction of vehicles (1-p) increases as the percentage of rubberneckers (r) increases (Chen et al., 2012). Colon et al., (2013) predicted that a scene barrier would be a simple way to reduce the effects of rubbernecking. An experiment was conducted to examine the effects of traffic crash scenes on driver behaviour and visual attention. Several conditions during the accident were designed and experimented, namely without barrier, partial barrier and full barrier. Overall findings of the study indicate that the vehicle crash scenes can be a source of vehicle distraction, as more driving errors occurred when a crash was present. When the crash was obscured by the partial or full barrier, the drivers were observed to pay less attention to the accident scenes. The observation proved that scene barrier may be a viable way to mitigate driving distraction, reduce traffic jam and prevent another road crash (Colon et al., 2013). This claim can be supported by a similar research by Masinick et al. (2014).

Based on the literature review, rubbernecking phenomena can be reduced by preventing the drivers from looking at the accident scene. The scene barrier is suggested to block the drivers' vision of the accident scene and improve the pace of traffic. In general, this scene barrier is able to lessen rubbernecking phenomena, remove unnecessary slowdown and prevent secondary/tertiary accidents. Due to insufficient scientific validation, an experiment is proposed to ascertain the effects of scene barrier during a primary accident in Malaysia. The average vehicle deceleration rate will be compared based on various case studies, namely free flow traffic without an accident, an accident without scene barrier and an accident with scene barrier. This paper shall focus on an experimental study in a suburban area, specifically around UniMAP Main Campus in Perlis.

2.0 METHODOLOGY

2.1 Route Selection

For the experimental study in a suburban area, two main routes to schools and other facilities were selected in UniMAP Pauh Putra campus, namely "Jalan PPK Pembuatan – PPK Mekatronik" and "Jalan Institut Kejuruteraan Matematik – Dewan Kuliah". Both routes are T1-1 carriageway road type and have sufficient length for data collection. Google Maps were used to locate the Global Positioning System (GPS) coordinates for the location of data collection, which included normal traffic zone and rubbernecking zone. Figure 1 shows the selected routes in the suburban area (UniMAP Main Campus).

Route 1:
Jalan PPK Pembuatan – PPK Mekatronik.

Location of data collection:
6.462985, 100.351807
(near main gate).

Route 2:
Jalan Institut Kejuruteraan Matematik – Dewan Kuliah.

Location of data collection:
6.457937, 100.352779
(near second gate).

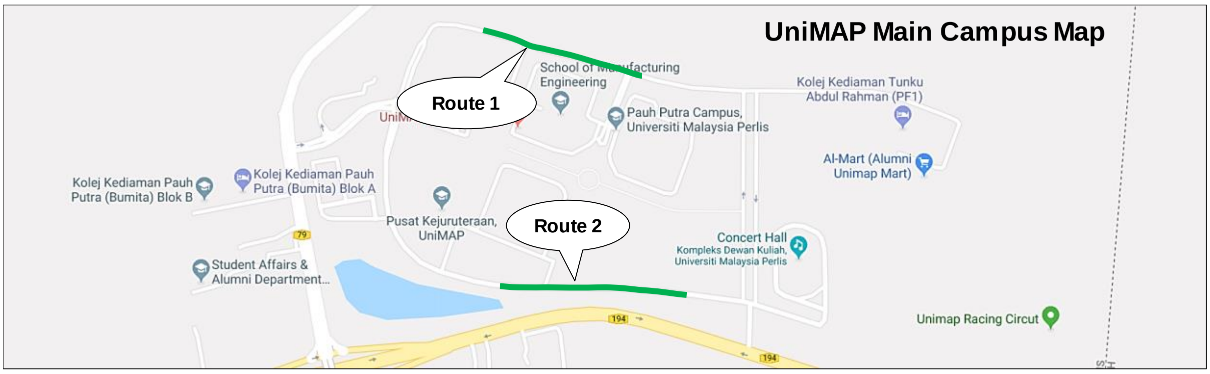


Figure 1: Selected routes for the suburban area study (UniMAP Main Campus)

2.2 Data Collection

To investigate vehicle deceleration rate in a simulated accident location, a test car is used to imitate the behaviour of a target car. The chase car method as described in et al. (2015) was adapted for speed-time data collection. A GPS device (OBDII) was plugged in a test vehicle to record the speed-time data when chasing a target vehicle along the selected routes. A trained driver was responsible to chase selected target vehicle carefully and to maintain the target vehicle's speed throughout the data collection period. A co-driver will assist with the direction and data collection to ensure the car is carefully driven. As shown in Figure ***2***, ordinary passenger car is preferred to be chased along the selected routes, whereas sports cars, lorries, buses or heavy vehicles shall be avoided.

When pursuing the target car, the driver must comply with the two-second rule to keep the trailing distance secure at any speed (Murphy, 2017). The co-driver will also monitor the distance between the chasing car and the targeted car to ensure the driver maintains a safe distance consistently in every data collection. This procedure is important throughout the data collection especially in normal traffic zone to avoid sudden acceleration and sudden braking. A total of 24-speed profiles were collected in this study. Each route has 2 directions, 3 case studies and 2 number of samples as summarized in Table 1. All the case studies are described in Figure 3.

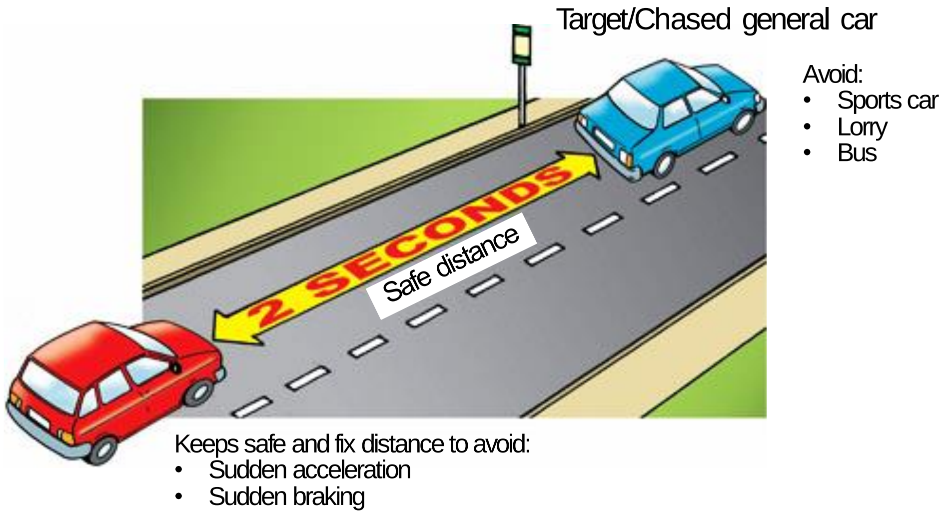
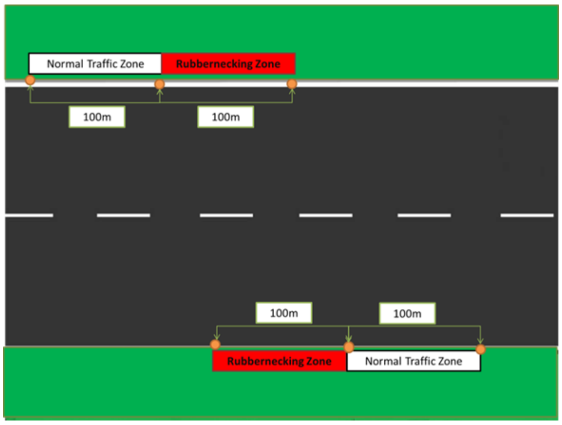


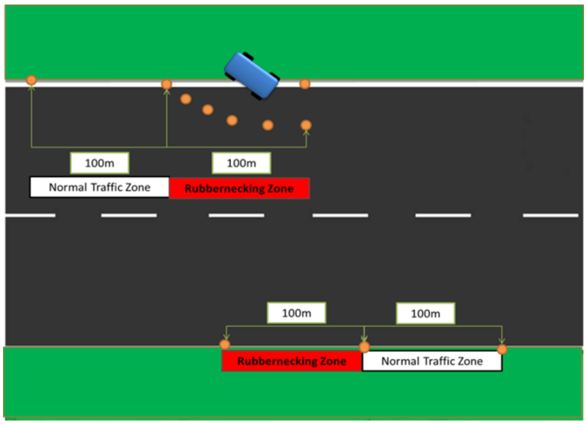
Figure 2: Two-second rule of driving as illustrated by (Murphy, 2017)

Table 1: The total number of speed profiles

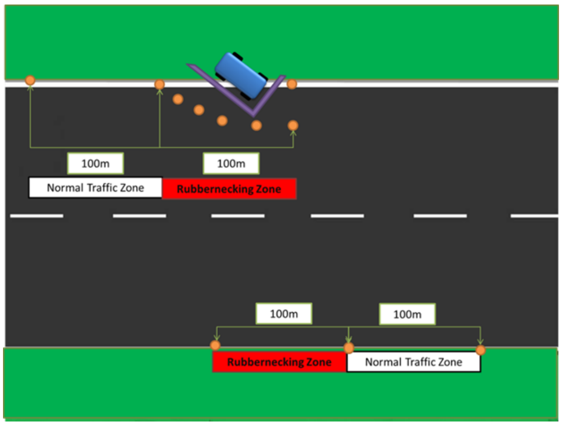
Routes	No. of directions	No. of case studies	No. of samples	No. of speed profiles
Route 1	2	3	2	12
Route 2	2	3	2	12
		Total no. of speed profiles		24



Case Study 1: Free flow traffic without accident



Case Study 2: Accident on road shoulder without scene barrier



Case Study 3: Accident on road shoulder with scene barrier

Figure 3: Case studies conducted in the suburban area through simulation of an accident

The accident set-up for data collection is illustrated in Figure 4, and it consists of normal traffic zone and rubbernecking zone. In the normal traffic zone, drivers shall experience normal driving without being distracted by the accident scene. For the rubbernecking zone, drivers shall be distracted by the accident scene and they are expected to slow down to see what is happening. Based on consideration of road distance, road type and literature as stated by Chen et al. (2012), the length for normal traffic zone and rubbernecking zone are set to be 100 m respectively. The distance is enough for collecting the speed-time data to determine the vehicle deceleration rate in the suburban area.

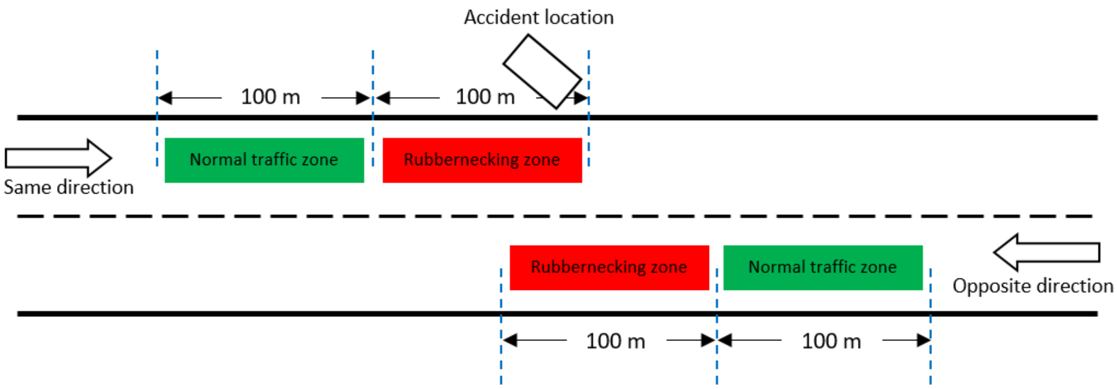


Figure 4: Accident set-up for data collection

2.2 Data Analysis

Raw speed-time data were extracted from OBDII. All the speed-time data were filtered according to the normal traffic zone and rubbernecking zone by referring to the GPS coordinates. The unified speed and acceleration database were then generated from the raw data. Vehicle acceleration rate (km/h/s) was calculated from consecutive vehicle speed (km/h) samples according to the following equation (Tutuianu et al., 2014).

$$a_i = (v_{i+1} - v_{i-1}) / 2 \quad (1)$$

Next, the raw data were grouped according to normal traffic zone database and rubbernecking zone database for each direction and each case study. Finally, the vehicle deceleration rate could be determined by calculating the average deceleration for each case study and each direction. Based on Table 2, the deceleration mode of the vehicle is defined by acceleration value lower or equal to - 0.5 km/h/s. The results of vehicle deceleration rate will be presented and discussed in the next section.

Table 2: Definition of driving modes based on the technical report by Tutuianu et al.(2015)

Driving modes	Notation	Definition
Idle	(I)	Speed < 5 km/h and - 0.5 km/h/s < Acceleration < 0.5 km/h/s
Cruise	(C)	Speed ≥ 5 km/h and - 0.5 km/h/s < Acceleration < 0.5 km/h/s
Acceleration	(A)	Acceleration ≥ 0.5 km/h/s
Deceleration	(D)	Acceleration ≤ - 0.5 km/h/s

3.0 RESULTS AND DISCUSSION

Results of the average vehicle deceleration rate (km/h/s) in each case study are tabulated in Table ***3***. Negative values (-) indicate that the vehicle is in deceleration mode (D). For normal traffic zone, the vehicles were found to be in a cruise mode (C) in all cases of study. Since there was no accident simulated in case study 1, the driving mode of vehicles was also found to be in cruise mode (C) for rubbernecking zone. Conversely, another 2 cases of study in the rubbernecking zone were found to be in deceleration mode (D) when an accident was simulated on the road.

Table 3: Summary of average vehicle deceleration rate (km/h/s) for each case study

Case Study	Normal Traffic Zone		Rubbernecking Zone	
	Same Direction	Opposite Direction	Same Direction	Opposite Direction
1 (Free flow traffic without accident)	- 0.40 km/h/s (C)	- 0.44 km/h/s (C)	- 0.42 km/h/s (C)	- 0.40 km/h/s (C)
2 (Accident on road shoulder without scene barrier	- 0.44 km/h/s (C)	- 0.45 km/h/s (C)	- 1.93 km/h/s (D)	- 1.21 km/h/s (D)
3 (Accident on road shoulder with scene barrier	- 0.45 km/h/s (C)	- 0.49 km/h/s (C)	- 1.10 km/h/s (D)	- 0.73 km/h/s (D)

Bar charts for average vehicle deceleration rate in normal traffic zone (Figure 5) and average vehicle deceleration rate in rubbernecking zone (Figure 6) are constructed to illustrate the differences between each case study for each direction. Based on Figure 5, it can be observed that a very low deceleration rate occurred for both directions in all cases of studies in the normal traffic zone (- 0.5 km/h/s < Acceleration < 0.5 km/h/s). So, it can be considered that the vehicles were in cruise mode (C) according to the technical report by Tutuianu et al. (2015). When a primary accident was simulated without a scene barrier (case study 2), the average vehicle deceleration rate reached - 1.93 km/h/s in the same direction and - 1.21 km/h/s in the opposite direction. After setting up the scene barrier at the accident scene (case study 3), the average vehicle deceleration rate was reduced to - 1.10 km/h/s and - 0.73 km/h/s in the same direction and opposite direction respectively.

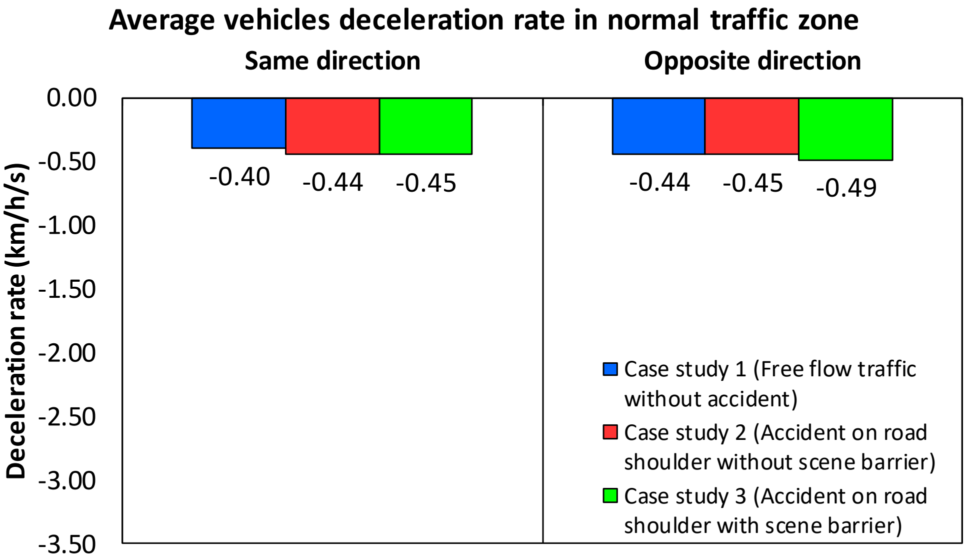


Figure 5: Average vehicles deceleration rate in normal traffic zone

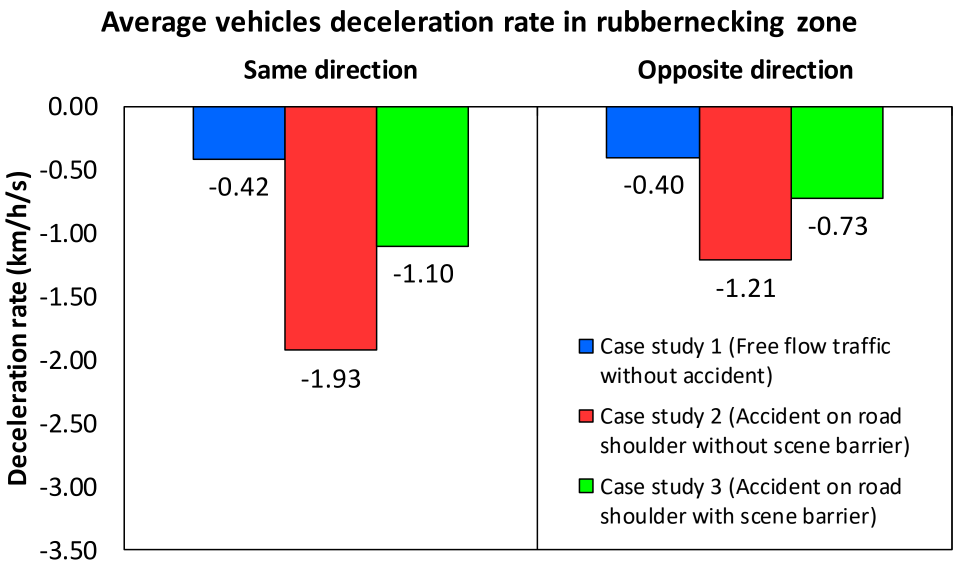


Figure 6: Average vehicle deceleration rate in rubbernecking zone

In general, case study 2 (accident on road shoulder without scene barrier) showed the vehicles shifting into deceleration mode in the rubbernecking zone for both directions as the drivers were distracted by the accident scene. The simulated accident led to the rubbernecking phenomenon and caused the drivers to slow down. For case study 3, by covering the accident scene with the scene barrier, the average vehicle deceleration rate improved by 43.0 % (same direction) and 39.7 % (opposite direction) respectively. The improvement of average vehicle deceleration rate in the rubbernecking zone proves that both traffic congestion and rubbernecking can be reduced by the scene barrier. Nevertheless, the vehicles were still in deceleration mode as the source of distraction was not totally prevented.

4.0 CONCLUSION

Traffic congestion due to the primary accident and leading to the rubbernecking phenomenon can be minimized by introducing a scene barrier to block the drivers' vision of the accident scene. In order to study to the capability of the scene barrier in reducing rubbernecking and traffic congestion, an experimental validation has been conducted in the selected suburban area by simulating a primary accident with different case studies, comprising free flow traffic without an accident, an accident on road shoulder without scene barrier and an accident on road shoulder with scene barrier.

The average vehicle deceleration was investigated in a set of distance, which was divided into normal traffic zone and rubbernecking zone. Drivers were found to slow down their vehicles up to – 1.93 km/h/s when entering the rubbernecking zone possibly to see what was happening at the simulated accident scene. After setting up a scene barrier, the vehicle deceleration rate at the accident scene improved by 43.0 % (same direction) and 39.7 % (opposite direction) respectively. Narrowing the gap of vehicle deceleration rate between normal traffic zone and rubbernecking zone by cutting down unnecessary slowdown especially during the primary accident could improve traffic flow and indirectly reduce the occurrence of secondary or tertiary accident.

Although the presence of the scene barrier manages to reduce the rubbernecking phenomenon and traffic congestion, the sudden deceleration cannot be totally eliminated during the simulated accident. This might be due to drivers' ability in estimating the safest distance to start braking when they were distracted by the primary accident. To avoid rear-end collision, a study of the optimization of braking time during a primary accident with Autonomous Emergency Braking (AEB) system is necessary.

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