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Factors Affecting Overtaking Behaviour On Single Carriageway Road: Case Study at Jalan Kluang-Kulai

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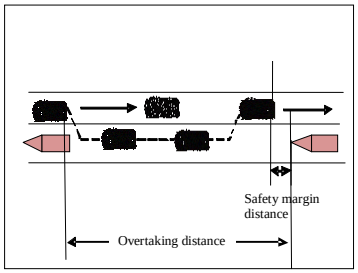
Graphical abstract



Abstract

Overtaking is one of many important behaviour considered in the analysis of road traffic accidents and performance of single carriageway road. This paper seeks to determine factors affecting the speed of an overtaking vehicle. The study was conducted for a single carriageway road section which is flat and straight so that there is no effect of sight distance on overtaking. Overtaking behaviour data were recorded using a video camera. The data extracted from the video recordings were the decision times, overtaking times, overtaking distances, safety margins, accepted and rejected gaps, headways at the start of the overtaking manoeuvres, headways at the end of the overtaking manoeuvres, speed of the overtaken vehicle, speed of the overtaking vehicle at the end of the overtaking and acceleration of the overtaking vehicle during the overtaking. The data were analysed statistically to establish relationships between the various overtaking parameters. This study found that the speed of overtaking vehicle was affected by the speed of overtaken vehicle, drivers' decision times, safety margin, overtaking times and acceleration.

Keywords: driver behaviour; overtaking

1.0 INTRODUCTION

Driving a motor vehicle is a complex task involving the driver, the vehicle and the road environment [1]. The success of an overtaking manoeuvre is affected by many factors including the performance of the overtaking vehicle, driving style, volume of traffic flow in the opposing direction and characteristics of the leading vehicle. Therefore, the overtaking manoeuvre requires the driver to visualise in advance every detail of what might happen during the operation [2]. If passing is to be accomplished with safety, the driver should be able to see a sufficient distance ahead, clear of traffic, to complete the overtaking manoeuvre without cutting off the passed vehicle in advance of meeting an opposing vehicle appearing during the manoeuvre. The overtaking action has a large number of variable components including the judgement of the overtaking driver and the risks which the driver is prepared to take, the speed and size of the vehicles involved, the actions of the driver being overtaken, and the actions of the other drivers in the vicinity. Inappropriate driver's behaviour especially in overtaking manoeuvre is commonly seen as the major contributing factor to road crashes [3, 4, 5, 6]. These behaviour problems include lack of driver attention, poor observation skills, excessive speed, failing to obey the road rules, fatigue and sleepiness. Therefore, this paper seeks to explore the impact of each of the overtaking parameters on the speed of overtaking vehicle among Malaysian drivers on single carriageway roads.

In the design and operational analysis of single carriageway roads, provision of overtaking sections requires overtaking behaviour data such as decision times, impeder vehicle speed, oncoming vehicle speed, decision time of overtaking vehicle, headway between the overtaking vehicle and the overtaken vehicle at the start of manoeuvre, safety margin between the overtaking and conflicting vehicles at the completion of manoeuvre, vehicle acceleration, accepted and rejected gaps, headways at the end of the overtaking manoeuvres [7, 8, 9].

2.0 LITERATURE REVIEW

Overtaking situation and manoeuvres has been classified according to five basic descriptors as below [3, 10]:

(i) Type of overtaken vehicle
Overtaking vehicles may have different response towards the different classes of overtaken vehicle. A high performance car may see a small and slow car as a block or delay on the road and the way the high performance car overtakes the smaller vehicle may be different from the way the high performance car overtakes another different types of high performance car.

(ii) Type of overtaking vehicle
The performance of the overtaking vehicle may vary according to the classes of vehicles. For example, heavy trucks and saloon cars will perform the overtaking manoeuvre differently due to the difference performance in engine capacity of these two types of vehicles.

(iii) Speed of overtaken vehicle
Speed of overtaken car may indicate how far the distance for overtaking vehicle should go in order to pass the overtaken vehicle.

(iv) Flying or Accelerative
Several overtaking strategies had been identified such as *flying overtaking* (no braking beforehand to follow the leading vehicle), *multiple overtakes* (passing more than one vehicle), *accelerative overtakes* (increasing speed throughout the manoeuvre, *piggy-back overtakes* (following another overtaker)[3, 13]. An overtaking vehicle should analyse whether it can overtake as soon as it catches up with the overtaken vehicle (*flying*) or slow down first and adjusted its speed to match the speed of overtaken vehicle before overtake (*accelerative*).

(v) Form of overtaking opportunity
Overtaking opportunity can be observed through the distance of oncoming vehicle which is visible to the driver. The visibility of the oncoming vehicle may be restricted because of the sight distance[13].

Under the conditions of low conflicting traffic, the number of *flying-type overtaking* will increase (those in which the overtaking vehicle needs not decelerate when approaching the leading vehicle). On the other hand, as conflicting traffic flow increases, the number of *accelerative-type overtaking* will increase (overtaking vehicle needs to decelerate and queue behind the leading vehicle). It was found that the speed differential decreases (the difference between the speeds of the following vehicle and the leading vehicle) as the conflicting traffic flow increases [11]. The speed differential decreases due to a queue forming up behind the leading vehicle before an acceptable gap appears in the conflicting traffic flow. As speed differential decreases, the overtaking vehicle needs a longer time on the adjacent lane during the overtaking manoeuvre hence increasing the risk of an overtaking failure. It was found by Chandra and Shukla that as the speed differential between the following vehicle and the leading vehicle increases, the overtaking vehicle for all vehicle types require shorter time to overtake [13]. However, in the study, they excluded the effect of the conflicting traffic has on the overtaking manoeuvre as the study was conducted on multilane divided highways.

In general, it would be expected that the longer the vehicle length, the higher the speed required to complete the overtaking manoeuvre within similar gaps in conflicting traffic flow. If the speed of overtaking vehicle does not increase, the driver will either queue behind the leading vehicle or he will accept an effectively smaller gap. Queuing for a longer time to wait for a larger gap in the conflicting traffic will induce congestion on a two-lane road. However, if the driver accepts a smaller gap in the conflicting traffic, the overtaking manoeuvre will be made with a reduced safety margin hence increasing the risk of a crash. Besides that, as the speed of the leading vehicle increases so does the required passing sight distance for completing or aborting the overtaking manoeuvre [12].

In the design and operational analysis of single carriageway roads, provision of overtaking sections requires data of overtaking behaviour [7-9].

3.0 METHODOLOGY

The study investigated the overtaking behaviour on rural single carriageway road section. The overtaking road section considered is flat and straight such that the overtaking manoeuvre is not restricted by the sight distance. Field studies were carried out to collect and analyse all traffic data for the analysis on overtaking behaviour. In general, the observation sites selected should be representative of rural single carriageway roads and road layout and traffic would provide a high proportion of impeded vehicles. Therefore, the selection of the observation site, Jalan Kluang-Kulai was based on the following criteria:

(a) A straight and level overtaking section.
(b) An overtaking section of considerable length
(c) The absence of major intersections or roadside development
(d) Flow rates which in conjunction with the geometry would motivate frequent overtaking attempts in the section
(e) Vehicle population containing a significant proportion of Heavy Goods Vehicles (HGVs)
(f) Good overhead vantage points suitable for video recording.

Motorcycles were excluded in the study because it is not fully diverted from original lane. Field data collections were carried out using video camera. The video camera was positioned at a vantage point to allow for the coverage of the whole overtaking section at a distance that invisible to driver's attention. The study was conducted under good weather condition. Figure 1 shows the arrangement of recording equipment on the site.

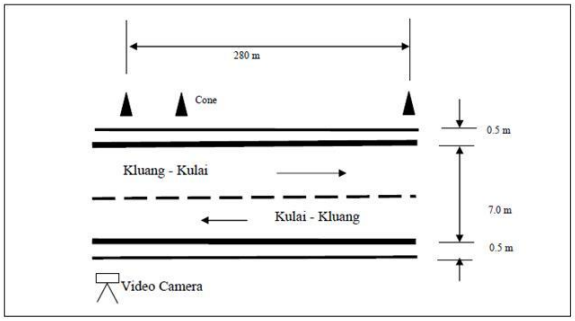


Figure 1 Arrangement of video camera for video recording process

As shown in Figure 1 above, a 280 meters distance was observed for the overtaking provision on the road section. Cones were used as an indicator of distance measurement on the site. Trumeter was used to measure the distance between the cones and the length of

the overtaking section. Character generator was attached to the video camera to provide a permanent record of stopwatch timings. Traffic data were recorded for each two hours recording session which covering 8.00 am to 10.00 am, 11.00 am to 1.00 noon, and 2.00 pm to 4.00 pm. The recording periods were considered appropriate for evaluating the required traffic parameters under a range of traffic flows. The observations were carried out during weekdays and under good weather conditions.

Each of the videotapes containing the recorded scenes was played back to retrieve the relevant data. The data extracted from the videotapes were stored in Excel spreadsheet file and then transferred to SPSS 16, a statistical analysis tool.

The data that are required are listed below [8, 9]:

- Driver's decision time
- Overtaking times
- Overtaking distances
- Safety margins
- Accepted and rejected gaps
- Headways at the start and at the end of the overtaking manoeuvres
- Speed of overtaken vehicle
- Speed of overtaking vehicle at the end of overtaking
- Acceleration of the overtaking vehicle during the overtaking

The definitions of some of these parameters are shown in Figure 2 below.

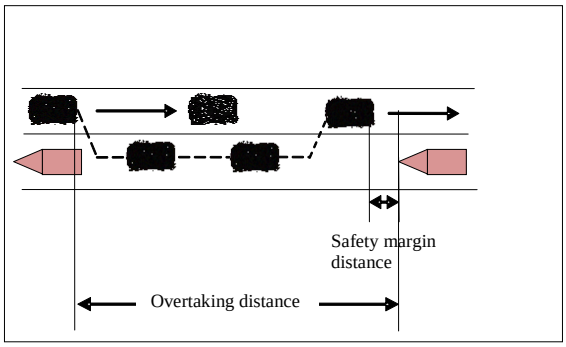


Figure 2 Definitions of some overtaking parameters

As shown in Figure 2 above, overtaking manoeuvre commences when the overtaking vehicle first crossed the centreline and completes when the vehicle returning to its original lane [8]. Accordingly, the distance covered during this manoeuvre was considered as overtaking distance. Then, the speed of overtaking vehicle was measured based on the distance covered and the time taken by the vehicle during the manoeuvre. Similarly, the speed of overtaken vehicle was measured as the distance divide by time travelled by the overtaken vehicle on the road section.

Headway distance was measured as the distance between two successive vehicles passing a same reference point on a roadway before the overtaking manoeuvre started. The reference points at which the headway data were measured, were marked using road cones. The decision times of overtaking was measured when the driver (observed in the video) slightly incline to the right of the road and move close to the centreline. Finally, the speed of overtaking vehicle divided by time travelled during overtaking to indicate the vehicle's acceleration during overtaking.

The data were analysed using statistical software SPSS16. Analysis of the data began by examining the dependent variables and independent variables. The speed of overtaking vehicle was chosen as a dependent variable as it represents the intention of overtaking behaviours on the road. The driver's action is also dependent on other variables before committing overtaking manoeuvre such as the speed of the vehicle, headway distance and acceleration capability of the vehicle.

3.0 RESULTS

In total there were 101 overtaking manoeuvre observed on the road section. Table 1 below shows a descriptive statistics for all overtaking parameters used in this study.

It was observed that the drivers tend to overtake in a situation where the leading vehicle moves at a slower rate compared to the following vehicle and sufficient space is available between the leading vehicle and the oncoming vehicle from the opposing direction. There was greater variability in overtaking distances, safety margin and accepted gap (shown in Table 1) caused by different circumstances and judgement by individual during the overtaking manoeuvre.

Table 1 Descriptive statistics of overtaking parameters

Number of sample for each of the parameter = 101				
Parameters	Minimum	Maximum	Mean	Standard Deviation
Decision Times (seconds)	2.00	6.50	2.47	0.71
Overtaking Times (seconds)	1.40	15.00	3.33	1.85
Speed of Overtaken Vehicle (km/h)	55.00	90.00	69.95	8.73
Speed of Overtaking Vehicle (km/h)	66.86	169.71	102.63	21.13
Start Headway (meters)	13.00	70.00	28.13	13.76
End Headway (meters)	13.00	90.00	24.12	13.35
Overtaking Distance (meters)	40.00	330.00	93.38	52.77
Acceleration of Overtaking Vehicle (m/s^2)	1.33	45.87	10.71	6.14
Safety Margin (meters)	60.00	500.00	464.26	91.96
Accepted Gap (meters)	121.00	800.00	555.16	95.26

Figure 3 and Figure 4 show speed distribution for both overtaking vehicle and overtaken vehicle.

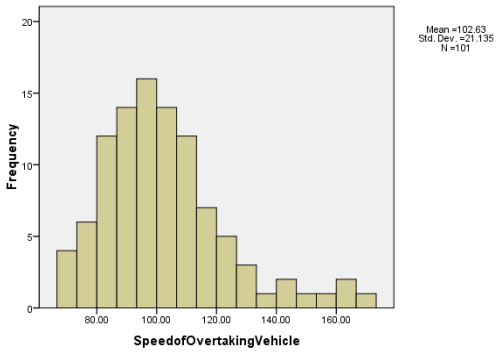


Figure 3 Speed distribution for overtaking vehicle

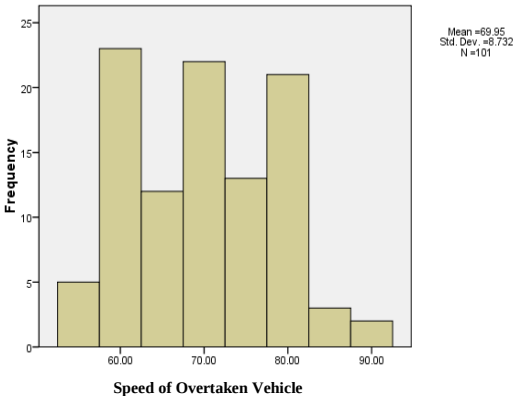


Figure 4 Speed distribution for overtaken vehicle

As expected, from Figure 3 and 4 above, it can be seen that the mean speed of overtaking behaviour is higher than the mean speed of overtaken vehicle.

The Spearman Correlation was conducted to explore the strength of relationship among the parameters involved in overtaking behaviour. Preliminary analyses were performed to ensure no violation of the assumptions of normality and linearity of the data. The results are shown in Table 2 below.

As shown in Table 2 below, five parameters have a statistically significant correlation with the speed of overtaking vehicle i.e the speed of overtaken vehicle, decision times, overtaking times, acceleration of the overtaking vehicle and safety margin. The speed of the overtaken vehicle has a strong positive correlation to the speed of the overtaking vehicle ($r = 0.718$, $p < 0.01$). It is inferred that the increase in the speed of the overtaken vehicle caused an increase in the speed of overtaking vehicle. The acceleration of the overtaking vehicle also shows a strong correlation to the speed of the overtaking vehicle ($r = 0.602$, $p < 0.01$). Thus higher speed of the overtaking vehicle is associated with the higher acceleration of the overtaking vehicle. Chandra and Shukla had observed in their study that overtaking vehicle starts to accelerate as the overtaking manoeuvre begins, however, the study did not investigate the correlation of this acceleration to the speed of overtaking vehicle [13].

Furthermore, it was found in this study that there is a weak negative correlation between the speed of overtaking vehicle and these three parameters; decision times ($r = -0.252$, $p < 0.05$), overtaking times ($r = -0.306$, $p < 0.01$) and safety margin ($r = -0.205$, $p < 0.05$). It was observed that higher overtaking speed is associated with the aggressive behaviour in overtaking manoeuvres, therefore, the overtaking driver perceived a shorter gap with the oncoming traffic hence a shorter decision time, overtaking time and safety margin. This trend justifies the negative correlation between the speed of overtaking vehicle and each of these three parameters (decision times, overtaking times and safety margin).

Table 2 Spearman Correlation results

			Speed of overtaken vehicle	Decision Times	Overtaking Times	Start Headway	End Headway	Overtaking Distances	Overtaking Acceleration	Safety Margin	Accepted Gap
Spearman's rho	Speed of Overtaking Vehicle	Correlation Coefficient	0.718**	0.252*	-0.306**	0.132	0.187	0.151	0.602**	0.205*	0.003
		Sig. (2-tailed)	0.000	0.011	0.002	0.190	0.061	0.131	0.000	0.039	0.974
		N	101	101	101	101	101	101	101	101	101

** Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)

Overall, based on results in Table 2, there are five parameters that can be used to predict the outcome of speed of overtaking behaviour in single carriageway roads: speed of overtaken vehicle, decision times, overtaking times, vehicles' acceleration and safety margin. Statistical test using SPSS (shown in Table 3) was conducted to test the ability of the parameters to predict the outcome of speed of overtaking vehicle.

Table 3 Summary of the test

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.697[a]	.486	.458	15.55338	.486	17.930	5	95	.000

a. Predictors: (Constant), SafetyMargin, OvertakingAcceleration, DecisionTimes, SpeedofOvertakenVehicle, OvertakingTimes

b. Dependent Variable: SpeedofOvertakingVehicle

As shown in Table 3 above, all these 5 parameters have a medium correlation with the speed of overtaking behaviour (R = 0.697). Speed of overtaken vehicle, decision times, overtaking times, vehicles' acceleration and safety margin account for 48.6% of the variation in the speed of overtaking vehicles and the R square change in this model is statistically significant ($p < 0.05$). This is expected as that the sample size used in the study was not big enough hence the medium correlation in this model. Therefore it is suggested that more samples should be collected for further analysis on the behaviour of each of overtaking parameters.

■4.0 CONCLUSIONS

It is best to note that the study was conducted on only one road section i.e. the Jalan Kluang-Kulai, therefore the finding in this study does not necessarily represent the behaviours of Malaysian drivers. However, the analysis has provided an insight on the behaviours of each overtaking parameters in predicting the overtaking behaviour among Malaysian drivers. The relationship found in this study is useful to understand the overtaking behaviour of vehicle on rural single carriageway roads.

In this study, it was found that five parameters have a correlation with the speed of overtaking vehicle which include the speed of overtaken vehicle, driver's decision times, overtaking time, acceleration of overtaking vehicle and safety margin.

Based on the statistical analysis conducted, larger amount of data is suggested for more reliable results and to support the finding in this preliminary analysis. This is crucial in exploring in depth the relationship of all the parameters involved in predicting the overtaking behaviour on rural single carriageway road. These are important parameters when developing simulation models for traffic movements.

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References

[1] Wadhwa, L.C. 1995. *Vision Zero Requires Five Star Road Safety System.* James Cook University, Townsville, Queensland, Australia.
[2] Vlahogianni, E.I. 2013. Modeling duration of overtaking in two lane highways. *Transportation Research Part F*. 20: 135–146.
[3] Clarke, D.D., Ward, P.J. and Jones, J. 1998. Overtaking Road-Accidents: Differences in Manoeuvre as a Function of Driver Age. *Accident Analysisi And Prevention*. 30(4): 455–467.
[4] Lamm, R., Psarianos, B. and Mailender, T. 1999. *Highway Design and Traffic Safety Engineering Handbook*. 1st edition. McGraw Hill: New York.
[5] Wigmore, B.J. and Alley, B.D. 2001. Human factors of Overtaking Lane Design. *Traffic Management Workshop Conference*. Auckland.
[6] Hegeman, G. 2004. Overtaking Frequency and Advanced Driver Assistance Systems. *IEEE Intelligent Vehicle Symposium*. 14–17 June 2004. University of Parma, Italy.
[7] Farber, E. and Silver, C.A. 1969. Conceptualisation of Overtaking and Passing on Two Lane Rural Roads. *Vol II: Drivers Judgement and Decision Making*. Franklin Institute Research Laboratories.
[8] Mahdi, T.A. 1991. *The Effect of Overtaking Provision on the IOperating Characteristics of Single Carriageway Roads*. PhD Thesis. University of Wales, College of Cardiff.
[9] Roozenburg, A. and Nicholson, A. 2000. *Required Passing Sight Distance for Rural Roads: A Risk Analysis*. Institution of Professional Engineers New Zeland (IPENZ) Transportation Group. Technical Conference Paper 2003. 17 September 2003. University of Cantebury.
[10] Mclean, J.R. 1944. Two-lane highway traffic operations (TWOPAS). In: Ashford, N., Bell, W. (Eds). *Transportation Studies*. Vol 11. Gordon and Breach Science Publishers, Amsterdam.
[11] Romana, M.G. 1999. Passing activity on two-lane highways in Spain. *Transportation Research Record*. 1678: 90–95.
[12] Hanley, P.F. and Forkenbrock, D.J. 2005. Safety of passing longer combination vehicles on two-lane highways. *Journal of Transportation Engineering. Transportation Research Part A: Policy and Practice*. 39.
[13] Chandra, S. and Shukla, S. 2012. Overtaking Behaviour on Divided Highways Under Mixed Traffic Conditions. *Procedia Social and Behavioural Sciences*. 43: 312–322.