

Car Driving Behaviour on Road Curves : A study Case in Universiti Tun Hussein Onn Malaysia

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Abstract. The World Health Organization (WHO) predicted that in 2020, road accidents will become the third cause of deaths in the world. Several factors contribute to road accidents, among them are human error, speeding, irregularities in road design and period of driving (either nighttime or daytime). In road design, horizontal curves are of particular interest to the designer, given that accidents are very likely to occur at such locations if drivers lose control of their vehicles due to inappropriate speed choices. This study was conducted to investigate the variation of driving behaviour on horizontal curves. The test car was fitted with a Global Positioning System (GPS) device and driven by 30 participants. The research findings show that drivers' choice of speed varies while approaching horizontal curve, on the curve and just after leaving the curve. Apart from this, although drivers were found to have driven at a slightly higher speed during daytime compare to evening driving, however the difference was not significant. A comparison between genders also revealed that female and male drivers drive at similar speed behaviour.

Introduction

Human error, traffic, vehicle and road conditions, and the surrounding environment have been determined as key factors that influence driving behaviour. Previous studies emphasize that these factors also contribute to road accidents [1]. Several earlier studies have dealt with drivers' behaviour on horizontal curves. Horizontal curves, which provide the link between two or more tangents have been identified as an important cause of vehicle crashes [2]. There are several reasons that horizontal curves become an integral part of the roadway as highlighted by Diew [3]. The first main reason is because of constraints imposed on road layout by topography and land use. In certain road projects, the horizontal curve is compulsory due to limitation of budget especially when straightening the road incurs enormous cost. However, it should be noted that the insertion of a curve along long tangential sections will be beneficial to the road user, particularly in reducing the monotony while driving. Apart from this, horizontal curves can also reduce glare from opposing vehicles during night hours.

Variation in speed strategy on horizontal curves has been captured from previous studies. One of the examples is from a research by Abele and Molter [4] using a driving simulator. From driver behaviour observed, researchers concluded that:

- (i) The mean speed on curves was lower than on straight sections
- (ii) Drivers drove closer to the center line on curves
- (iii) Drivers reduced speeds on curves with the presence of trees along the curve roadside

Other researchers, Nie [5] suggested that the effect of highway geometry on speed behavior on horizontal curves varies depending on road class. On freeways, the impact of road alignment on speed behavior is minor. However, on two-lane rural highway, the tangent length can influence the operating speed.

Rohani [6] studied about human effect on driving behavior by grouping individual differences, attitudes and demographic as a human factor that influences driver behavior. Moreover, it was explained that these factors can have an impact on the level of aggressive driving. This is supported by other researchers such as Olteidal and Rundmo [7] who related gender with risky driving. From the study Olteidal and Rundmo suggested that gender affects 37% of risk driving behavior variance.

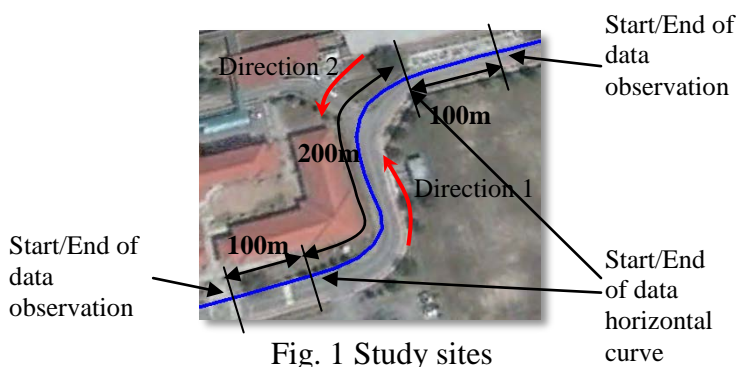
Rohani and Buhari [8] in other paper also reviewed that, in urban environment driving, the behavior of the driver will be influenced by traffic control, street environments, and road condition. Other urban traffic characteristics such as the number of stop along the road have an impact on average acceleration and deceleration rate of the driver for the entire trip. Besides, factor such as day time and night time driving can also become additional factors that affect how drivers manage their driving strategy. This is highlighted by Edquist et. al. [9] that less visual information at night can lower drivers' perception of how fast they are traveling.

Research Setting and Approach

Research aim. This research aims to study the variation of driving behavior on horizontal curves. It also investigates the impact of different periods of driving and gender on speed control of cars driven on curves.

Research approach. Researchers conducted a closed-course study at Universiti Tun Hussein Onn Malaysia (UTHM) campus. To minimize the impact from traffic on driver behaviour, a curve which had the lowest traffic was selected for the study. This site is a horizontal curve that has extreme elevation changes. Within this curve, drivers endured a combination of left and right curves. The curvature of the road alignment for both curves are about the same. For analytical purposes, the data used was based on a 309 meter distance. This includes a 100 meter distance before entering the curve and another 100 meters leaving the curves (refer Fig. 1).

Research participants were recruited from UTHM. Thirty university students aged between 20 to 25 years participated in this study and were each required to have a current valid license. Of the 30 students, 15 were female and 15 male. During data collection they were asked to drive in both directions of the road during the day and at night. The data collection was measured in-vehicle. Speeds were observed every second using a portable GPS device (DG200) (Fig. 2).



Result and discussion

Speed distribution at study areas. Fig. 3 presents the distribution of speed at the curves for both directions of travel. It can be seen that, the speed does not show very good distribution of data. Data collected in Direction 1, obviously showed that the speed distribution exhibits a non-symmetric, bimodal distribution. Speed was found to be maximum at two distinct peaks of 28km/h and 43km/h. In Direction 2, although the speed distribution seems to be better than Direction 1, but detailed investigation has found that speed peaked at 29 km/h and 34km/h. This result can be explained by the fact that the drivers were dealing with speed differently at three different position (when approaching the curve, on the horizontal curve and when leaving the curve). This is shown in the speed profile presented in Fig. 4 that the speed control strategy of drivers were related to the change in road alignment. Speed was significantly reduced when drivers approach and enter the horizontal curve. Drivers accelerated just before they left the curve until they reached and maintained a reasonable speed. Table 1 presents the results from a descriptive analysis of speed differences on the horizontal curve. The mean speeds along the horizontal curve in both directions were significantly lower than the mean speeds when approaching and leaving the curve.

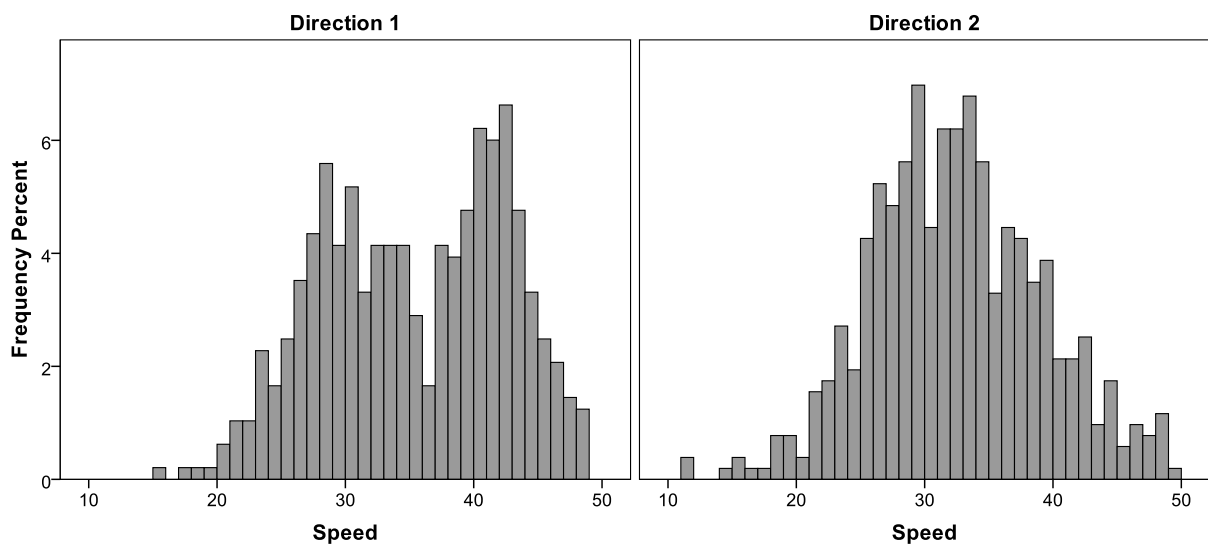
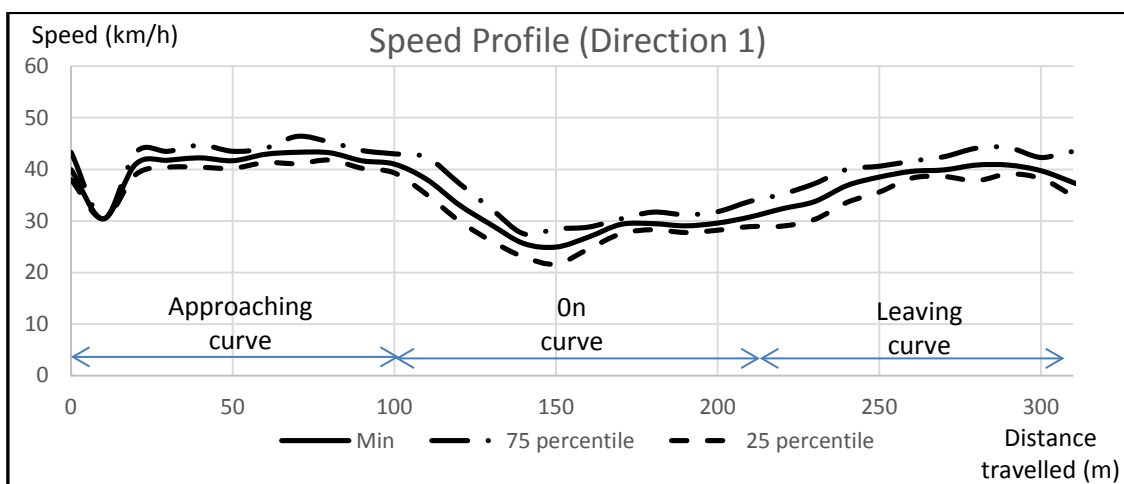


Fig. 3 Distribution of speed on horizontal curve at (a) road Direction 1 and (b) road Direction 2



(a) Speed Profile on Curve (Direction 1)

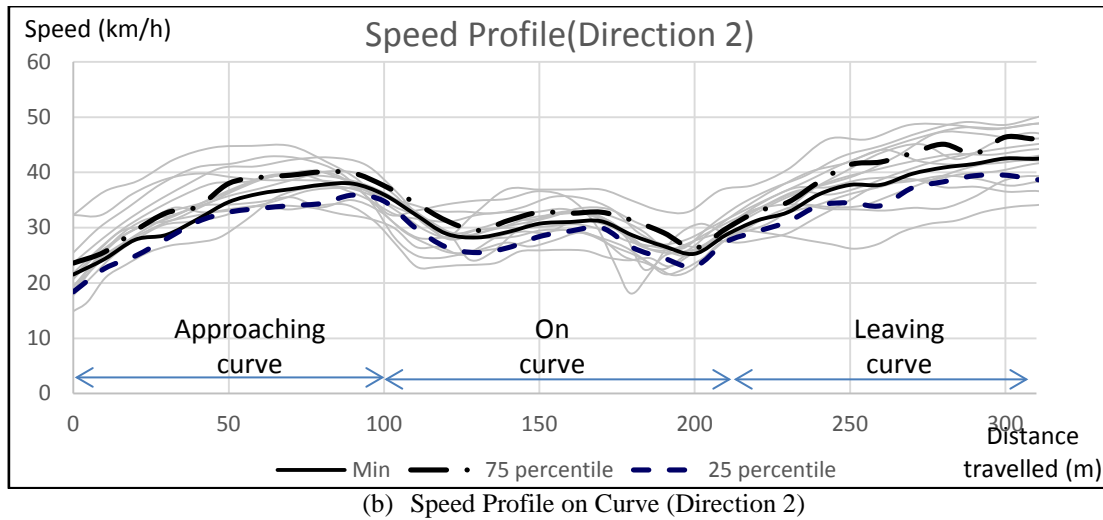


Fig. 4 Speed Profile Data Observed at(a) Direction 1 and (b) Direction 2

Table 1 Descriptive analysis of speed at different position on study road

Direction	Position on study road	Speed			
		Minimum	Maximum	Mean	Median
1.00	Approaching curve	28	48	42	42
	On Horizontal curve	16	44	29	29
	Leaving curve	18	48	38	38
2.00	Approaching curve	12	45	32	34
	On Horizontal curve	18	37	29	29
	Leaving curve	26	49	38	38

Gender effect on speed. Comparison of speed data for male and female drivers was performed to determine any differences in speed along the horizontal curve that was studied. The analysis aimed to investigate whether gender has an impact on driving behaviour on horizontal curves. The results obtained from comparison test are summarized in Table 2. The overall results indicate that, male and female driver drove with similar average speed on the studied road ($p > 0.05$), except in Direction 1. This occurred when the drivers were approaching the curve. Female drivers were found to drive about 11% faster than male drivers.

Table 2 Comparison of speed control on curve between male and female drivers

Road Direction	Position on study road	Sig. (2-tailed)	Mean of speed		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
			Male	Female			Lower	Upper
1.00	Approaching curve	.000	39.75	44.24	-4.486	.525	-5.524	-3.448
	On Horizontal curve	.290	28.98	29.72	-.739	.697	-2.113	.635
	Leaving curve	.155	36.98	38.26	-1.279	.894	-3.046	.488
2.00	Approaching curve	.728	31.84	32.23	-.392	1.123	-2.609	1.825
	On Horizontal curve	.641	29.03	28.80	.236	.505	-.759	1.231
	Leaving curve	.669	38.03	37.61	.427	.996	-1.545	2.398

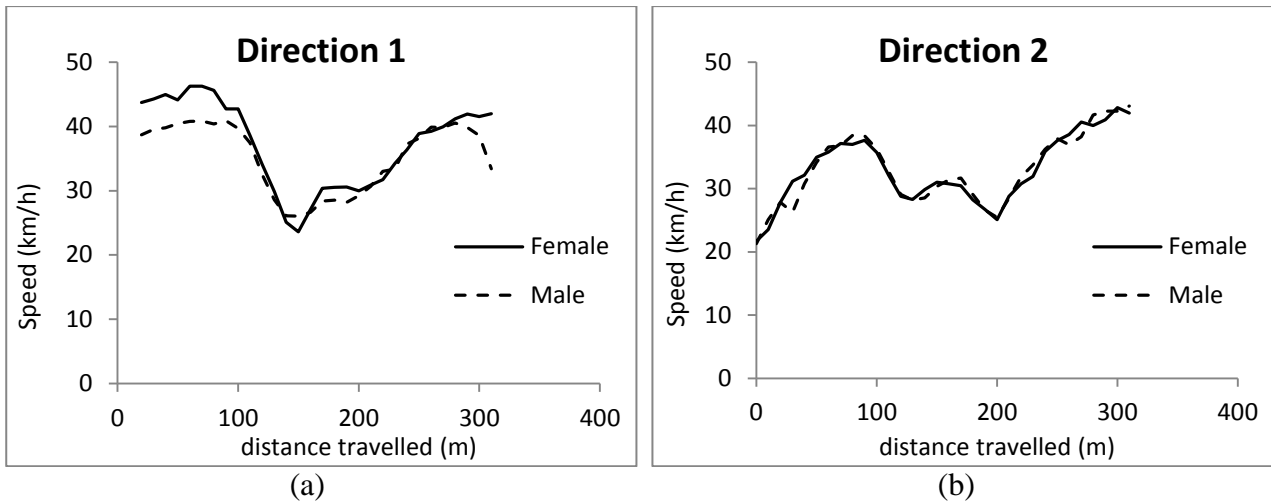


Fig. 5 Speed Profile for female and male drivers from (a) Direction 1 (b) Direction 2

Daytime versus Nighttime driving. The impact of daytime and night-time driving on horizontal curves was assessed in this study. From the T-test analyses conducted, it was found that speed control by the drivers during the night was not significantly different from speed control during the day (Table 3). However the graphical comparison as presented in Fig. 6 shows that although the difference was not statistically significant, mean speed during night-time driving was slightly lower (averaging 3% and 4% for Direction 1 and Direction 2 respectively) than daytime at majority of the distance travelled.

Table 3 Comparison of speed control between night-time and daytime driving

Road Direction	Position on study road	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
1.00	Approaching curve	.278	.577	.529	-.471	1.624
	On Horizontal curve	.224	.987	.805	-.614	2.587
	Leaving curve	.063	1.875	.882	.124	3.626
2.00	Approaching curve	.288	1.247	1.165	-1.077	3.571
	On Horizontal curve	.060	1.061	.557	-.048	2.169
	Leaving curve	.802	.232	.920	-1.602	2.065

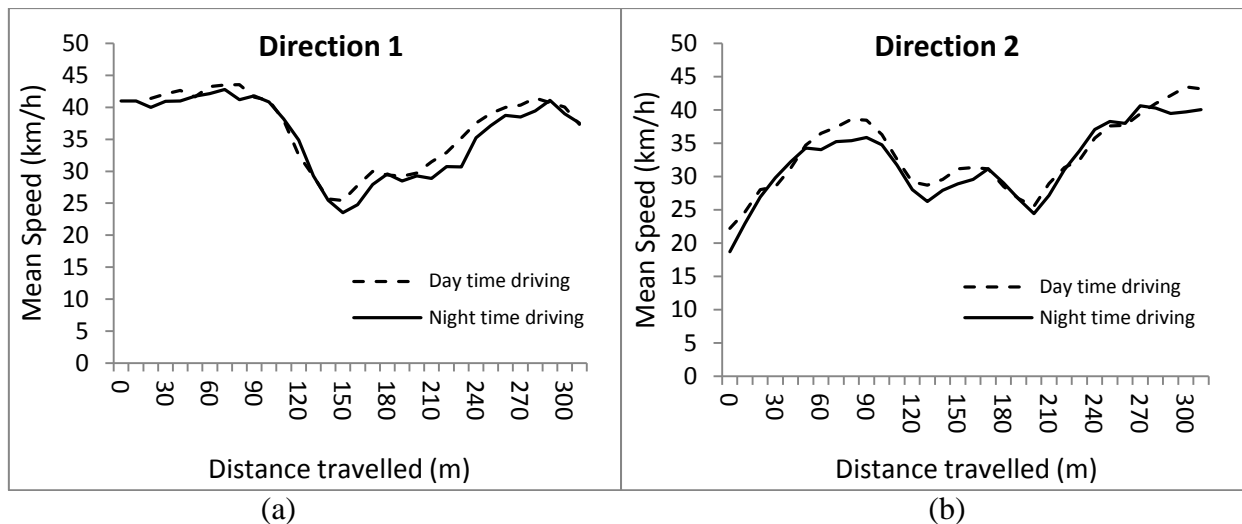


Fig. 6 Speed Profile during daytime and night-time driving from (a) Direction 1 (b) Direction 2

Discussion and Conclusion

Findings of this study showed that drivers reduce speed when entering the horizontal curve. This was demonstrated in the Direction 1 and Direction 2, where the average speed reductions were 30% and 10% respectively. However, speed increased by 31% for both directions as they left the curve. Based on these findings, the speed variation among drivers completing the drive-through on the studied horizontal curve, might reflect the ability of drivers to maintain higher speeds as they drove on different road alignments. Therefore, speed variation observed within the limit of the curved section, supports previous study by Abele and Molter [4] that suggested drivers do not maintain a constant speed on horizontal curve. This is because the drivers tend to improve driving stability along road curvature.

This study was also carried out to investigate differences in speed behavior between male and female drivers on horizontal curves. The T-tests explained that female and male drivers demonstrated similar driving behavior on the studied road curve. This finding opposes the notion that gender has an effect on driving behaviour as suggested by Oltedal and Rundmo [7]. In this study, male and female drivers were likely to have equal self-confidence when driving on studied road curve. These findings may help us understand that gender is not the main factor that affects driving skills on horizontal curves.

The capacity of drivers to correctly negotiate their speed when driving along horizontal curves can be influenced by the time of travel. Driving at night is commonly associated with problems such as vision deterioration that reduces driving performance [9]. However, there was no evidence to support the aforementioned driving differences in this study. While the graphical comparison showed a 3% - 4% of speed reduction during the night, however this difference was found to be not statistically significant. One possible explanation for this result is that the lighting system at the study area was sufficient for night-time visibility. This allows the driver to control their speed confidently, as they would while driving during daytime.

This research was undertaken to assess driving behaviour on horizontal curves and compare speed differences between gender and driving time. The results suggest that in general, gender and driving time have no impact on driving behaviour on horizontal curve in study. However, the speed variation observed might inspire the conclusion that road alignment can influence driving behaviour. This research has raised many questions that require further investigation, such as how

the road curvature influences driving stability. Therefore an expansion of this research in the future can provide a better insight of driving behaviour on horizontal curves.

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