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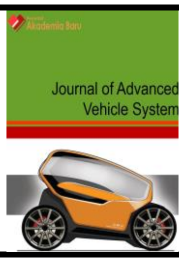

A Case Study: The 85th Percentile Operational Speed of a Two-Lane Rural Highway at Different Road Segments for Different Speed Limit Signage Colours

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ABSTRACT

A study has been conducted to evaluate the safe operational speed at the 85th percentile. It was aimed to provide the best signage colour that is visible to alert road users. It is very important to facilitate the road with a clear signage to allow road users to be more aware of the necessity to obey to the speed limit. This can avoid unwanted incidents from happening at the most crucial part of the case study which is at the mid-curve. The speed data was collected from a two-lane rural highway along the horizontal curve of Jalan Bukit Palong Lukut, Port Dickson, Negeri Sembilan. The road is classified as Federal Route 5 (FR5) and Rural 5 (R5) at a flat terrain with 90km/h design speed. The 85th percentile was obtained based on four (4) conditions starting with the absence of any signage followed by the installation of yellow signage, red signage and white signage. The varying-coloured speed limit signage is posted before approaching the tangent line in a staggered manner for a safe and smooth manoeuvring before entering the curve section. The traffic volume was gathered simultaneously using the tally counter for the northbound direction and southbound direction. Two sets of data were collected during the day and nighttime respectively for both traffic counts and spot speed data. Road configurations were measured using the measuring wheel. Several analyses have been carried out using the Minitab® Statistical Software to generate results like the regression analysis and paired t-test. It was observed that during the day, the data was more significant since traffic was heavier, and vehicles could not drive at a higher speed than the speed limit whereas vehicles tended to speed up during night time due to the lesser number of vehicles causing the results to be insignificant. The findings obtained from this study should be beneficial for practitioners in deciding the best colour selection for a speed limit signage and its effectiveness.

Keywords:
85th percentile; operating speed model; horizontal curve; traffic volume; speed limit; coloured signage

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1. Introduction

In Malaysia, there are a few design standards that are currently being used by the government for designing roads which are the Arahan Teknik Jalan (ATJ 8/86) and Malaysian Highway Capacity Manual (HCM) [5]. These standards are developed based on the context of Malaysian road users. Some specifications were adopted from guidelines of other countries like America that suit the

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situations, geography, and climates in Malaysia. A good design ensures a smooth manoeuvring and rideability for the road users. The road section that was used as a site study in this paper started from the tangent line to the start of curve and finally ends at the tail of a curve. Assessing a horizontal curve was the core of this study as it focused on the change of speed and the ability of drivers to control their speed when approaching a curve ahead.

This study focuses on the 85th percentile which is the operating speed that is gained from spot speed studies. It should comply with road specifications stated in the standard even when the result obtained from the data collection is different [9]. This is because standards are made based on researches and experiments that are carried out in Malaysia to set specifications that suit the country's road conditions. The operational speed that is collected in-situ on a different road segments is the result of varying speed accumulation when speeding and non-speeding. It is highly correlated with the geometric of the design [9]. Spot speed study and traffic volume are the end-products that can be generated from the data gathered.

Design speed is a not a representation of operational speed but the minimum speed for the design [2]. It helps in determining the geometric design of a road based on the road categorisation. Accidents are very common in Malaysia and safety measures have to be taken in order to minimise the traffic problems that are faced by highways in this country through the proper traffic signs being put up on the road. As we all know, the horizontal curve on a road section is a very popular crash location, with high density and often underestimated by drivers and motorcyclists. Characteristics of curves have to be taken seriously in designing the section as it gives a very crucial impact to driving performance, users' safety and riding quality. Apart from operating speed, the topography and neighbouring land uses are the common factors that affect a road design.

1.1 Problem Statement

The issues related to road safety have always been a serious concern by the Malaysian government and other related authorities. Malaysia has been experiencing rapid increase in road accidents ever since the beginning of the 21st century. Fatalities are growing as well as death tolls on daily basis. The trends of traffic accident caused by motorized vehicles or even non-motorized vehicles are both worrisome. Due to this worrying trend, the relevant road authorities have been working harder to come out with better solutions to minimize road accidents and fatalities.

Quoting the news reported by New Straits Times [8], the official number of deaths caused by road accidents in Malaysia is 23 for every 100,000 people. The Malaysian government projected the death cases to happen roughly around 7,000 to 8,000 for a population of 30 million. This is a huge concern to everyone and one of the lead causes is said to be speeding. We can see that the automotive industry keeps on enhancing their technologies by putting higher specifications and horsepower to buy the interests of car enthusiasts. Development is necessary for every sector but the downside of it is, it is agonizing road practitioners at controlling the safety of road users.

Providing a safer ride for all road users are important to avoid any unwanted events from happening. Mid-curves have very frequent road accidents and this requires a very good safety measure. Hence, working on reducing the vehicle speed is a good first action to create awareness among drivers to obey to the designated speed limit. Nevertheless, the present speed limit signage does not seem to affect drivers' attention and the problem is may be due to the unattractive colour used. Humans have very short time to react to the posted speed limit and choosing the best colour is very crucial in attracting their attention when driving. Selecting the best choice of colour for the signage may help to manage vehicles to move under the speed limit because previously, wrong colour usage might have affected the obeyance of drivers towards the warning. Therefore, this study is carried out to choose the best colour that can attract the attention of end users to drive prudently and minimise road accidents.

1.2 Literature Review

The 85th percentile is the speed that is extracted from the plotted graph of cumulative frequency against average speed obtained from the spot speed study. The geometric design of a road depends on the operational speed to determine whether it is satisfactory, moderate or below par. Tangent line has the free flow speed readings recorded as it is for the determination of the 85th percentile operating speed of that particular road [3]. The presence of speed limit signage globally is crucial for managing the speed of vehicles on the road as it helps to lower down the variance between vehicles by surging the safety during the ride [11]. Hence, this study emphasises on the choice of signage colours to capture the attention of road users on the hazards that waits ahead of them. The hazard that is referred to in this case study is the mid-curve.

In Malaysia, it is not stated in any standards on how long is the tangent line should be. This is a challenge for designers to decide on the optimum tangent line length that should not compromise with safety. Setting a certain specification for the length has to consider the stretch of the tangent line as the longer the tangent line is, the higher the operating speed will be and this will jeopardise the safety of road users since they are required to lower their vehicle speed when approaching a sharp or non-sharp curve after running through a segment of direct and lengthy road section [2]. Radius length is also a contributing factor to vehicle speed as shown in Figure 1 [2].

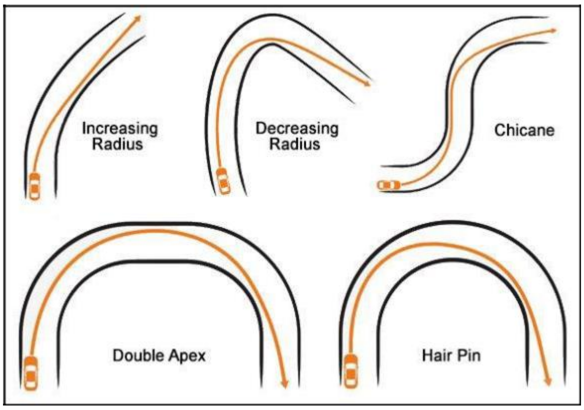

Fig.1. Vehicle speed condition at different curve sections [2]

Signage should be exhibited at the tangent line before approaching the start of the curve as it gives a head start to drivers that the speed has to be decreased because there is an incoming obstacle ahead. The location of the traffic signs is accountable for, not only the keys of selecting the colours and shapes considering the visibility and accessibility of the posted signage [4]. Therefore, the posted speed limit plays a vital role in assisting vehicles to slow down whenever they have to. Choosing the mid-day is the best time for a data collection for this test as traffic volume is very much lower for optimising the most reliable free flow readings [7].

It is now a question on which type of signage is the best to capture the attention of drivers. The principal of a road signage is always the choice of colours and patterns to give the best captivation and adherence to the message when driving [4]. The colours and configurations that give the best attention to human visuals are very important characteristics of a road sign [4]. Gathered data are to be sorted out to omit the uncommon finding. This situation can arise in times where some data are absent due to inattention of the data collector on site [2]. For data analysation, plotting visual graphical result presentations are very helpful as it is clearer to tell which variation of colour gives the best impact towards the results [7].

2. Study Objective

There were a few objectives that have been set for this study. The first objective was to perform an empirical field data collection under different configuration of signage colours during daytime and night time using the regression analysis and paired t-test methods. The data collected were then used to tackle the second objective which was to compare the efficiency of various coloured speed limit signage during day and night time as a speed controller. This was to observe the role of disparate colours in managing the velocity of vehicles on the road through the presence of a speed limit signage. Lastly, the objective was to evaluate the impact of vehicle speed in the presence and in the absence of the speed limit coloured signage at different road sections. Every part of the road segment in analysed to observe how coloured road signage affects the alertness of road users.

3. Methodology

3.1 Research Flow

This study was guided by a series of flowchart that consist of all steps and procedures involved in the data collection process. The flow of process is illustrated in Figure 2.

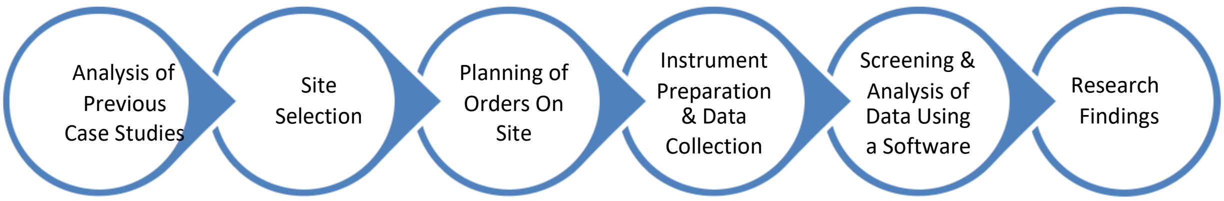

Fig.2. Flow of the study procedures

3.2 Site Selection and Planning of Orders on Site

This study has been carried out on Jalan Bukit Palong Lukut, Port Dickson, Negeri Sembilan. Previously, the area used to be a mine and as time went by, it is now has developed as an industrial centre with one operating solar farm known as Bukit Palong Solar Power Plant (Cypark). The road condition is quite for a tough use since heavy vehicles are on this highway all day long. This two-lane rural highway is gazetted as a Federal Route 5 (FR5) and categorised as Rural 5 (R5) that links Port Dickson, Negeri Sembilan to Sepang, Selangor. The terrain is classified as flat with a design speed of

90km/h. Figure 3 shows the study area for this research which highlights the tangent line, start of curve section and the end of curve.

Fig.3. Site location of the study area

3.3 Instrument Preparation and Data Collection

Data collection process was carried out at the three sections which are tangent line, beginning of curve and ending of curve on 25th of December 2020. The data were collected from 4.30p.m. to 6.30p.m. for the day-session and from 8.55p.m. to 10.55p.m. for the night-session. It was a Christmas holiday for the whole of Malaysia and hence, the traffic was assumed to be less crowded as it was a public holiday. Good free-flow data was expected on that day since the road was bound to experience a light traffic. On the 26th December 2020, road measurements were taken for recording the actual geometric layout of the study area. Figure 4 shows the Google Map image of the location and the actual photo of the study area, as well as Figure 5 and Figure 6 that represent different segments of the road. The data were collected by a few enumerators at the same time and day. This was to increase the reliability of results as the occurrences were continuous and could be interrelated as the same vehicles passed through the stretch of the road at the section. The results were considered as the primary results since the authors were on site to take part and observe the data collection at the mentioned area.

Fig. 4. Tangent line of the road section on site (left) and from aerial view (right)

Fig. 5. Start of curve of the road section on site (left) and from aerial view (right)

Fig. 6. End of curve of the road section on site (left) and from aerial view (right)

Several instruments have been used in the data collection. For the traffic count, a tally counter as shown in Figure 7 was used where each counter was labelled with different types of vehicles in the order as per Table 1. The process was more efficient since all tally counters were aligned according to vehicles and attached together for an easy handling. In addition, spot speed data was collected by speed capturing with the use of Pro Laser III Laser Gun as shown in Figure 8, simultaneously. To minimize the factor of human error and inconsistencies, the process was carried out hidden from the sight of the drivers so that vehicles were at their actual speed and not influenced by the fear of thinking that the data collectors might be trapping their speed. This has eventually increased the dependability of the results gained. Every single vehicle that passed by the road section was counted and the speed was documented. Figure 9 shows the measuring wheel which was the apparatus used to measure the actual dimensions of the road configurations on site.

Table 1
Passenger car equivalents for two lane highways [5]

Vehicle Class	Vehicle Type	Passenger Car Equivalents
Class 1	Cars / Small Vans / Utilities	1.00
Class 2	Lorries (with 2 axles) / Large Vans	4.11
Class 3	Large Lorry / Trailers / Heavy Vehicles (with 3 axles and more)	1.83
Class 4	Buses	1.93
Class 5	Motorcycle	0.96

Fig. 7. Tally counter

Fig. 8. Laser gun

Fig. 9. Measuring wheel

The posted signages were installed at the tangent line starting with without signage, followed by the installation of yellow signage, red signage and lastly white signage as shown in Figure 10. Northbound is the direction from Sepang to Port Dickson and Southbound is the direction from Port Dickson to Sepang.

Fig.10. Site location without signage (left), with yellow signage (second from left), red signage (second from right) and white signage (right)

The speed data collection using the laser gun was executed with the help of infrared radiation laser light. The infrared light that detects vehicle movements is sent back to the laser gun to be transferred into a speed reading. The reading is accurate because it is not affected by the waves produced by vehicles on the opposite direction. This instrument is very suitable for two-directional highways. The speed was recorded for traffic volume and also for the spot speed study with respect to different instruments for all vehicles that have passed by the road section.

4. Results and Discussion
4.1 Result Presentation

During data collection, all measurements were tabulated in Table 2 which shows the dimensions for every road segment at Northbound and Southbound. Each direction was observed to have quite inconsistent dimensions despite being of the same road sections. In Figure 11, the sample of graph for cumulative frequency against average speed was plotted for the start of curve during the white signage installation at nighttime. The 85th percentile was highlighted to show the operational speed of the road section.

Table 2
Geometric design of the actual layout

Segment	Measurement	Length (m)	
		Northbound	Southbound
Tangent Line	Lane width	5.0	5.0
	Shoulder width	1.6	1.5
	Merging lane width	2.5	-
Start of Curve	Lane width	4.9	4.8
	Shoulder width	1.4	1.5
	Radius of curve	150	
sEnd of Curve	Lane width	3.7	3.7
	Shoulder width	0.5	0.5
	Diverging lane width	1.2	-
	Length of end of curve	50	

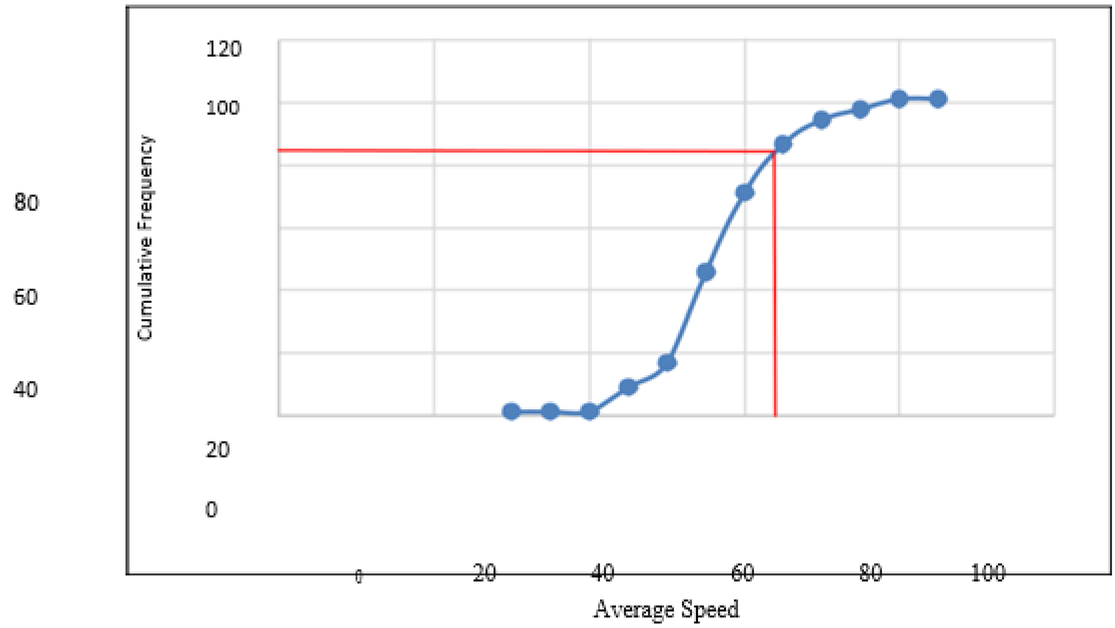

Fig.11. The graph of cumulative frequency against average speed at mid-curve during night time with a posted white speed limit signage

4.2 Regression Analysis

Using the Minitab® Statistical Software, all the operating speeds were generated through histogram for all segments and for both time sessions. The regression equation below shows the correlation between the 85th percentile and the northbound flowrate linearly. The study was done to develop the speed prediction for horizontal curve, by considering the middle of the curve (Syed et al., 2010). The mean recorded was 66.79 km/h which produced an approximate operating speed of the 85th percentile at 70 km/h. The detail statistics of the 85th percentile and both-way flowrate is shown in Table 3.

Regression Equation

85th Percentile = 63.9 + 0.00316 Both-way Flowrate

Table 3
Descriptive statistics of 85th percentile and both-way flowrate

Variable	N	Mean	SE Mean	Standard Deviation	Minimum	Median	Maximum	Skewness	Kurtosis
85th Percentile	24	66.792	0.662	3.243	60.000	67.500	72.000	-0.53	-0.31
Both-way Flowrate	24	914.0	71.6	350.9	281.2	967.4.1	1276.9	-0.52	-1.03

From Table 4, it can be seen that the P-Value was 0.102 which was more than 0.05. This means that the data was insignificant to the 85th percentile. The null hypothesis of mean difference equal to zero was accepted and H1 was rejected.

Table 4
Coefficients of a constant and both-way flowrate

Term	Coefficient	SE Coefficient	T-Value	P-Value	VIF
Constant	63.90	1.81	35.34	0.000	
Both-way Flowrate	0.00316	0.00185	1.71	0.102	1.00

In the analysis of variance (ANOVA) in Table 5, another P-Value was found which gave out the same value as in Table 4 with the same analysis of data. There was an involvement of H_0 and H1 which could be determined based on the hypothesis below:

H_0 : The mean difference between 85th percentile and both-way flowrate is equal to zero
H_1 : The mean difference between 85th percentile and both-way flowrate is not equal to zero

Table 5
Analysis of Variance (ANOVA)

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	1	28.35	28.348	2.92	0.102
Northbound Flowrate	1	28.35	28.348	2.92	0.102

Table 6 is the traffic volume for directions heading northbound and northbound for the day session. The highest traffic was from 5.30p.m. to 6.00p.m. which was 1277 pcu/h.

Table 6
Traffic volume for both directions during day session

TIME	Northbound (pcu/h)	Southbound (pcu/h)	Total Bothways (pcu/h)
4.30p.m. – 5.00p.m.	625	500	1125
5.00p.m. – 5.30p.m.	699	568	1267

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5.30p.m. – 6.00p.m.	658	619	1277
6.00p.m. – 6.30p.m.	548	680	1228

Table 7 is the traffic volume for directions heading northbound and southbound for the night session. The highest traffic was from 8.55p.m. to 9.25p.m. which was 810 pcu/h. Daytime has a higher pcu/h as compared to night time. This means that more people travel during day time and it was observed that there were more commercial vehicles at night.

Table 7
Traffic volume for both directions during night session

Time	Northbound (pcu/h)	Southbound (pcu/h)	Total Bothways (pcu/h)
8.55p.m. – 9.25p.m.	387	423	810
9.25p.m. – 9.55p.m.	380	340	719
9.55p.m. – 10.25p.m.	270	335	605
10.25p.m. – 10.55p.m.	190	91	281

4.3 Paired T-Test Analysis

This analysis was to compare the correlation between the absence of signage and with the installation of the coloured signage and they were the fixed variable and the manipulated variable respectively. The results are tabulated in Table 8 segregating daytime and nighttime results for tangent line segment.

Table 8
Result for tangent line section during day time and night time

Session	Signage		P-Value	Percentage of Mean Difference	Speed Difference
Day Time	Without	Yellow	0.006	5.47%	Significant
	Without	Red	0.012	4.48%	Significant
	Without	White	0	10.0%	Significant

Night Time	Without	Yellow	0.448	1.61%	Not Significant
	Without	Red	0.613	1.10%	Not Significant
	Without	White	0.045	4.03%	Significant

The percentage difference for the day session at tangent line was the highest during white signage installation with 10.0% and 4.03% during night time. This showed that the signage colour plays an important role in affecting the illusions of drivers.

Table 9
Result for start of curve section during day time and night time

Session	Signage		P-Value	Percentage of Mean Difference	Speed Difference
Day Time	Without	Yellow	0.068	4.43%	Not Significant
	Without	Red	0.151	3.70%	Not Significant
	Without	White	0.686	0.87%	Not Significant
Night Time	Without	Yellow	0.041	4.23%	Significant
	Without	Red	0.003	5.57%	Significant
	Without	White	0.022	4.69%	Significant

The highest percentage difference for day time in Table 9 is 4.43% for yellow signage and night time is 5.57% for red sign at the start of curve. This difference may be due to lighting from sunlight at that angle that brings out the brightest and clearest image for drivers and riders differently.

Table 10
Result for end of curve section during day time and night time

Session	Signage	P-Value	Percentage of Mean Difference	Speed Difference

Day Time	Without	Yellow	0.163	3.27%	Not Significant
	Without	Red	0.805	0.50%	Not Significant
	Without	White	0.041	4.47%	Significant
Night Time	Without	Yellow	0.009	6.10%	Significant
	Without	Red	0.234	2.53%	Not Significant
	Without	White	0.003	6.48%	Significant

The percentage difference for both day and night time at end of curve in Table 10 is the highest during white signage with 4.47% and 6.48% respectively. This shows that road users are more aware of that colour and obeyed the posted message. From all these three tables, all coloured speed limit signage can be correlated since all values has a P-value that is not equal to 0. Thus, H null is rejected while H1 is accepted.

5. Conclusions

Consequently, drivers were proven to be affected by the road signage colours, shapes and locations. These kinds of enhancements are very vital to ensure that all road users are aware of all the instructions and warnings that are presented in the form of road signs with the utilisation of all those characteristics and features [4]. Based on the objectives, all hypotheses were accepted.

Each colour produced different speed results in which it was observed that the white signage was the most obvious colour for daytime and white for night time as vehicles moved below the posted speed limit. This demonstrated that signage colours significantly affect the visions of road users and creates awareness for them to follow it. The traffic volume was also obtained from the data collected directly through the use of tally counters.

As for the recommendation for this study area, the posted speed limit should be 70 km/h as that is the mean speed obtained from the data analysis. Secondly, choosing white as the colour for speed limit signage is a good choice as it is clearer and more visible during both daytime and night time. Drivers tended to be more aware and seemed to be slowing down when approaching the curve. Thirdly, the road design is substandard since it does not comply with the specifications set out for that particular road class. Therefore, the road requires improvements on site. Lastly, the radius of curve is 150 meters in which the road is supposed to be classified as R3 based on the design speed with a supposedly radius of 160 meters based on ATJ 8/86 (2015). Hence, this design is a substandard and requires design improvements.

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