

# Motorist Understanding of Pavement Centre Lines and their Effect on Driving Behaviour

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## ABSTRACT

Human factors and more generally driver errors account for the largest number of road accidents. Driver errors are external human factors that can contribute to specific error types selected from slip, lapse, mistake and violation. Action and information retrieval errors are both examples of driver errors. The failure to interpret correctly an intended road marking's message causes driver misunderstanding and lead to a driver error. Centre lines are examples of such markings and if misread or unrecognised may cause unintentional driver violations and unsafe driving. This study focused on the examining of driver understanding of road markings, and the influence of centre lines on their driving behaviour. This study determined that drivers had a much better understanding of the overtaking messages intended by road markings, than the directional flow message. Drivers demonstrated that they relied more on signs and other drivers to determine whether the road is a two-way or not. This study demonstrated that the presence of both centre lines and edge lines have a positive effect on a driver in handling and controlling of their vehicles' position. It was postulated from this study that the absence of the edge lines has a more significant effect on a vehicle's position than the absence of centre lines.

**Keywords--** Centre Lines, Driver Error, Human Factor, Lateral Vehicle Position

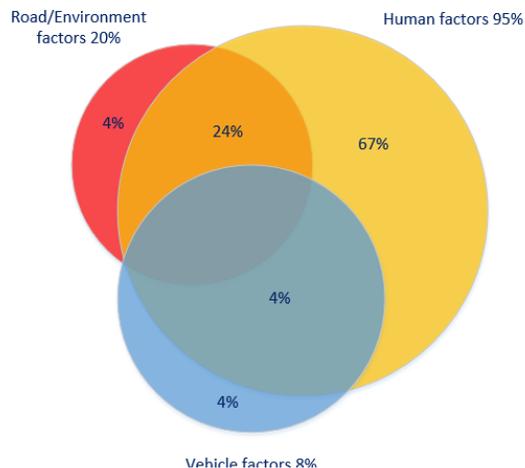
## I. INTRODUCTION

Human factors, and more generally human errors, account for the largest number of road accidents [1], [2]. A study carried out in the Western Cape of South Africa to investigate the relationship between accident types and causes determined that the human factor contributed about 75.4% to the occurrence of accidents [3]. Human factors, particularly of drivers, include factors such as error, impairment, fatigue, traffic violations, alcohol, negligence, age, speed choice and distraction. These factors are all external factors that may lead to a specific error type ranging from slips, lapses to, mistakes and violations [4].

Road markings are traffic control devices intended to relay messages on the road [5]. Sometimes they may either be interpreted wrongly or fail to be recognised by motorists. The general contributing conditions to such driver misunderstandings may include their level of training, driving experience and knowledge [6]. Traffic control device affect a motorist's control of their vehicle [4]. Depending on the implemented traffic control device and road characteristics, the lateral vehicle position control may be such that the motorist drives the vehicle too close to the edge of the opposing travelling lane [7], [8].

## II. LITERATURE REVIEW

Risk factors for road fatalities include human, vehicle and environment factors [1]. Human factors followed by road/environment factors are the dominant risk factors in most countries such as USA and Australia. However, the South African Department of Transport found that vehicle factors play a larger role than road/environment factors, probably reflecting in the lower quality of vehicles and vehicle maintenance in developing countries such as South Africa [3], [9].



**Figure 1:** Contributing factors to road accidents from studies in Australia [3].

Studies done in South Africa have demonstrated that driver-related factors are present in almost 75.4%. Figure 1 shows the contributing factors to road accidents from studies conducted in Australia. This figure illustrates that driver-related factors are as high as 95%, and the same figure indicates that this factor is the main contributing factor to accidents in Australia. Driver-related factors are considered as human factors and include the following driver related characteristics among others: driver error, age, drug/alcohol influence, emotional agitation, traffic violations, aggressive driving/speeding and negligence [3].

Human errors are generally failures of planned cognitive or physical actions to achieve their intended outcome. These errors are the major causal factor in high proportion of accidents and incidents [10]–[12]. An example is research within the Australian road transport system which indicates that driver error contributes to 75% all road accidents [13]. Figure 2 shows a road user error classification scheme developed in Australia. It divides road user error into error types and external error modes that these road user errors take.

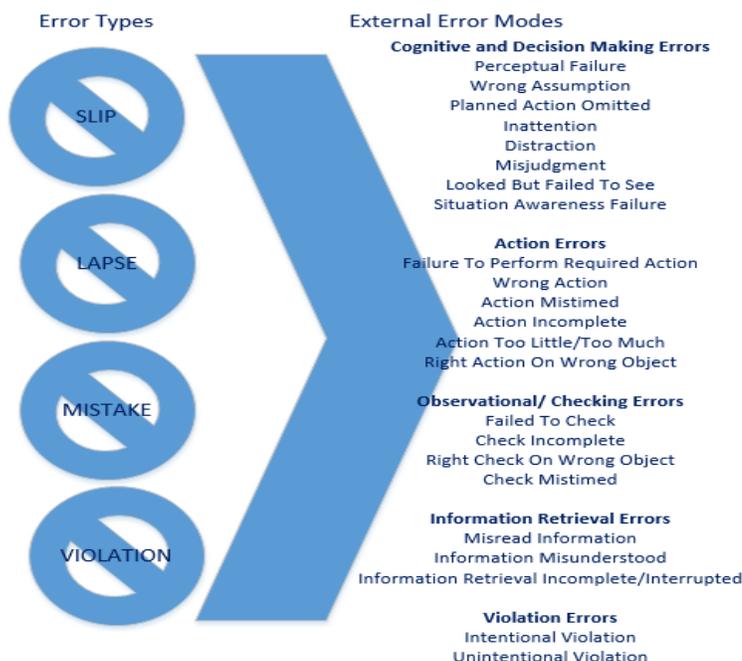


Figure 2: Road user error classification [14]

Cognitive work load is an important concept when talking about cognitive and decision making errors in that it refers to the information processing demands imposed by the performance of a task, and in that high cognitive work load leads to degradation in performance [10], [15], [16]. Any degradation in driver performance restricts the driver in the interaction with their environment, and thus cognitive and perceptual errors are principally involved in accident causation and not violations [17], [18].

Cognitive failures are defined as failures in which the executed action does not match the intention, and thus also defined as failures in memory, perception, and motor functioning [2], [19]. Motor function slips, lapses in attention and lapses in memory are examples of such failures [20]. Lapses in attention are failures in perception. On the other hand, memory lapses are failures in information retrieval, and motor function slips are action

slips defined as the slips in performance of unintended actions [14].

Decisional failures occur at the stage of deciding on the execution of a specific vehicle manoeuvre. It is these failures that lead to violations and errors [21], [22]. These decisions depend on the interpretations of the perceived information processed at a stage referred to as the diagnostic stage. For a correctly performed detection stage, the problems of evaluating physical parameters and misunderstandings of information acquired concerning confronted situation characterise failures at this stage [2], [23].

Information retrieval errors are classified as detection and diagnosis failures [14]. Driver misunderstanding of information is an example of such an error. Drivers depending on their knowledge may wrongly interpret the message a road marking intends to

communicate. However, experienced drivers may not tend to make this error as much as beginners [5], [21].

Action errors are failures that occur at the psychomotor stage of the action being executed [4], [21]. In the case of vehicle control, drivers positioning their vehicles too close to either edge of the travelling lane demonstrate action errors [11], [17].

Violations are failures in the decision-making function, and can be either intentional or unintentional [4], [6]. Deliberate violations of a safety rule are examples of intentional violations [21]. An unintentional violation on the other hand refers to situations where the infringement is not deliberate but an error such as drivers' failure to remain in control of their vehicle. Another example is drivers overtaking in a prohibited area and unaware of violation [2], [6], [21].

The South African Road Traffic Signs Manual documents the standards for road signs, road markings and other traffic control devices such as traffic signals. It is in this manual that the guidelines and standards for road marking symbols and patterns used in South Africa are presented [24]. Yellow and white colour codes are used for centre line markings in the United States of America. This yellow-white pavement marking system is different from the centreline marking system adopted by South Africa, which is an all-white system [5]. However, both countries have a colour coding of white, yellow or red for edge line marking depending on regular occurrence of mist, fog and rain. Zambia, like South Africa, uses an all-white colour coding system, for centre line markings. However, unlike South Africa, only white or yellow markings are used in Zambia for edge lines. Zambia does not have an original manual developed for the design, implementation and maintenance of traffic control devices. It relies on the regulations provided in the Roads and Road Traffic Act, Chapter 364 of the Laws of Zambia [25]. The predominantly used centre line markings in both South Africa and Zambia are single broken lines, single solid lines and double lines (broken and solid). In both countries, continuous road marking lines indicate prohibition of crossing or overtaking, and passing zones are indicated by broken lines [24]. In Zambia, in place of white centre lines, road studs with a colour code of white, silver or light grey are used as substitutes in locations where the road markings are subject to conditions of poor or limited visibility [25]. In South Africa, road studs are used for the same purposes. However, the three colour codes used are red, yellow and white. According to South African standards, red represents prohibition, yellow represents warning, and white offers vehicle guidance [24].

A study carried out by [26] in Virginia, investigating the impacts on safety of edge and centre lines on narrow, low-volume roads. The data analysed was 5-years of accident data (2004-2008 road accident data) from

Virginia Department of Transportation (VDOT). This was based on pavement width, Average Annual Daily Traffic (AADT) and the presence of edge and centre lines. The methods of Analysis of Variance (ANOVA) modelling and Negative Binominal modelling were the two approaches taken in measuring safety in this study.

Individual ANOVA models were developed for the pavement widths 4.9 m, 5.5 m and 6.1 m, so as to account for the difference in pavement widths. The presence of centre lines and edge lines were taken as the independent variables and predictors of these models, whereas the safety measures adopted for these models were taken as dependent variables. The safety measures used in the ANOVA modelling approach included 5-year road accident frequency, density and rate. These safety measures were calculated as follows:

**i.** Road accident frequency was calculated from the number of recorded road accidents in the 5-year period (number of road accidents/5 years)

**ii.** Road accident density was calculated from the road accident frequency divided by the total length based on pavement width (number of road accidents/kilometre/5 years)

**iii.** Road accident rate was calculated from the road accident density divided by the AADT data based on pavement width (number of road accidents/kilometre/vehicle/5 years)

This study indicated strong correlations among AADT, the presence of both centre lines and edge lines, and the pavement width. These results show reduced mean road accident predictions for segments with both centre lines and edge lines. This suggests a positive effect when both markings are present.

[27] conducted a study in USA on driver understanding of road marking colours and patterns, and this was carried out using a driver survey. This survey was administered to 851 drivers in five different states of USA, which included Texas, Illinois, California, Minnesota, and Georgia. This survey contained five questions demographic information;

**i.** Three-open ended questions based on determining drivers' dependence on road markings for directional cues when found in unfamiliar situations;

**ii.** Multiple choice questions structured to determine driver understanding of colour by basing these questions on four image-based scenarios with yellow and white road markings; and

**iii.** Multiple choice questions structured to determine driver understanding of patterns by basing these questions on four image-based scenarios with road markings shown in black on a grey road.

The four graphics used for questions on centre line marking patterns and colour included images of a single broken line, double solid lines, passing prohibited

double lines (broken and solid lines), and passing permitted double lines (broken and solid lines).

Results from this study indicated that drivers rely on signage and other traffic as the primary indication of whether a road is one-way or two-way. The survey results also suggest that at least 75% drivers understand both directional separation and passing control purpose of both yellow and white centre lines. This study shows that drivers have a better understanding of whether a centre line prohibits (95%) or allows passing (90%), than they do of whether it separated opposing traffic (75%).

### III. METHODOLOGY

One of the purposes of this study was to evaluate motorist understanding and recognition of centre line and road markings based on patterns. This assessment was carried out through a driver survey distributed to 100 drivers in Zambia and South Africa. This was to explore inter-cultural-comparisons, between a Zambian and South African cultural context. This survey focuses on determining the level of motorists' understanding of highway standards regarding patterns of centre line markings.

The other purpose of this study was to observe driving behaviour based on a vehicle's distance from the centre line of the roadway. This was carried out by making field observations of lateral position for various vehicle types on selected roads with centre and edge line markings. These observations were carried out only in South Africa, in the township of Stellenbosch, and a minimum of 100 test vehicles was selected. Only single broken centre lines were included in this part of the study. This was because this study focuses on data collected for narrow, two lane, urban streets, and this is the centre line marking predominantly used for such roads. These observations were made manually from video footage recorded on level and straight stretches of road. This was attainable by selecting vantage points at intersections that allowed videotaping of approaching and departing vehicles. This video footage was analysed using screen superimposition and a frame-by-frame analysis. This analysis was done by placing a transparent sheet on a computer screen as the video footage played. This horizontal scale was used to measure the lateral position of

vehicles as they passed the horizontal reference line of this scale. These lateral positions were observed for eight vehicle classes. Table 1 tabulates these classes and the class designation used for the purpose of this study. The predominantly targeted classes in this study are classes C1, C2, C4 and C7 because this study focuses on urban streets.

**Table 1:** Vehicle classes selected for this study

Class Designation	Description
C1	Motorcycle/scooter
C2	Passenger car
C3	Microbus/minibus taxi (9-16 seats)
C4	Light Delivery Vehicle (bakkie, minivan, SUV)
C5	Minibus (24-40 seats)
C6	Big bus (50-70 seats)
C7	Medium Delivery Vehicle/ rigid trucks (2-axle)
C8	3 or more axle rigid trucks

### IV. RESULTS AND DISCUSSION

This research was carried out in two-study area countries that are both located in Southern Africa, South Africa and Zambia. The two studies in this research include the survey and field study:

i. The survey is administered in Lusaka, a city located in Zambia, and Stellenbosch, a town located in the Western Cape in South Africa.

ii. The field study is conducted in Stellenbosch. It is in this location that three test sites were selected based on road characteristics required for investigating three different test conditions. Table 2 shows the road characteristics for each of these selected test sections. Test site 1 has both a larger pave width of closer to 4.5 m (greater than the minimum lane width of about 3.5 m desired for low volume roads) and a bicycle lane on both sides of the road. Test sites 2 and 3 have a much narrower lane width (less than 3.5 m) than site 1.

**Table 2:** Road characteristics for test sections

Characteristic	Site		
	Site 1	Site 2	Site 3
Location	Martinson Rd.	Merriman Ave.	Victoria St.
Road Type	Urban Street	Urban Street	Urban Street
Pavement Type	Bituminous	Bituminous	Bituminous
Number of Lanes	2	2	2

<b>Lane Width</b>	>3.5m (about 4.5m)	<3.5m	<3.5m
<b>Usable Shoulder for Vehicle (&gt;1.2m)</b>	No	No	No
<b>Bicycle Lane(s)</b>	Yes (both sides of the road)	No	No
<b>Parking</b>	No	No	Yes
<b>Single Broken Centre Line</b>	Yes	Yes	No
<b>Edge Line</b>	Yes	No	Yes
<b>Curved or Straight Road</b>	Straight Road	Straight Road	Straight Road

In this research, the three comparison scenarios or test conditions for distinct vehicle classes included the following:

- i. Site 1: Both centre line and edge line markings present
- ii. Site 2: Centre line markings present and edge line markings absent
- iii. Site 3: Centre line markings absent and edge line markings present

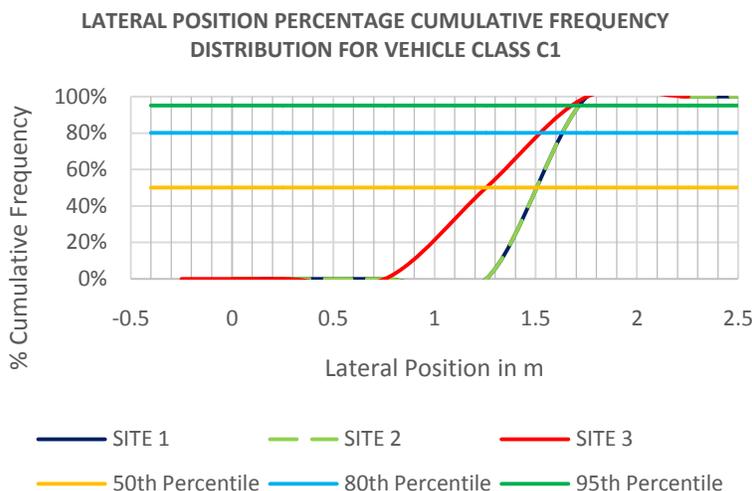
The measurement of performance used for vehicles observed at these sites was lateral position from the centre of the carriageway.

The frequency of vehicles at each site were transformed to corresponding percentage frequencies, so as to eliminate the effects of different vehicle class volumes when analysing and comparing the lateral position distribution for each site. The lateral position of vehicles was determined by measuring the perpendicular distance or deviation of the right front wheel from the centre of the road. Deviations falling within the travelling lane represented a positive deviation. No deviation observed at any of these sites exceeded +2.0m. This study postulates that minibus taxis (C3) are the only vehicle class without lateral wandering more than +1.51m regardless of the

presence and/or absence of centre and edge lines. The table shows that for each of the classes C2, C3, C4 and C7, the lateral deviation from the centre line reduced as the pavement width reduced. This shows that a reduction in pavement width had a much greater influence in the change in deviation than the absence of centre lines but presence of edge lines (site 3) test conditions.

A negative value for the lateral position represented wheel wandering to the right side of the centre line of the carriageway. No deviation observed at any of these sites exceeded -0.5m and only one site (site 3) had negative lateral positions for the vehicle classes observed. The absence of centre lines however, did influence drivers of class C2, C4 and C7 vehicles to have negative lateral positions. Lane width seems to have attributed less to such wheel wandering as both site 2 and site 3 test conditions had almost the same narrow lane widths of less than 3.5m.

Figures 3 to 7 show the effect of centre and edge line markings on the lateral position distribution of distinct vehicle classes. To study this effect, the scenario with both markings present (test site 1) is used as the reference scenario in the comparison analysis of the other test conditions.

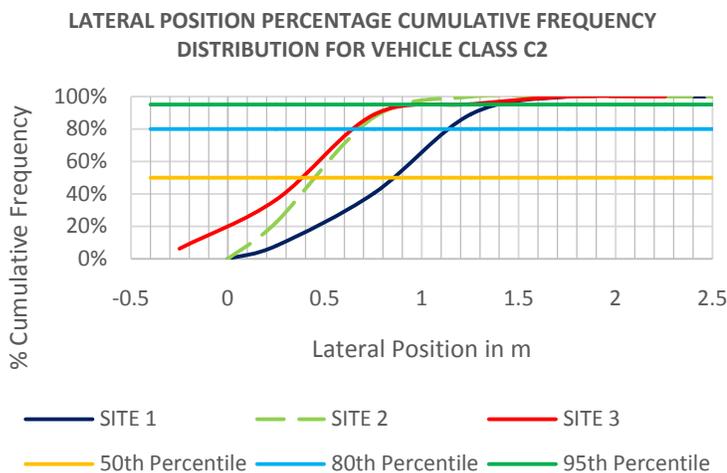


**Figure 3:** Lateral Position PCF Distribution for motorcycles/scooters

Figure 3 shows that up to 95% of motorcycles/scooters shift towards the right-side edge of the travelling lane when a centre line is absent but edge line is present (site 3/test three conditions). However, this graph indicates that the absence of the edge lines but presence of centre lines (site 2/test two conditions) has no notable effect on the shift in lateral position distribution. Therefore, the effect of the presence and absence of these

line markings on motorcycles/scooters can be stated as follows:

- i. Centre lines present but edge lines absent- motorcycles/scooters maintain their lateral positioning.
- ii. Centre lines absent but edge lines present- motorcycles/scooters travelling on such a carriageway shift closer to the centre of the carriageway.

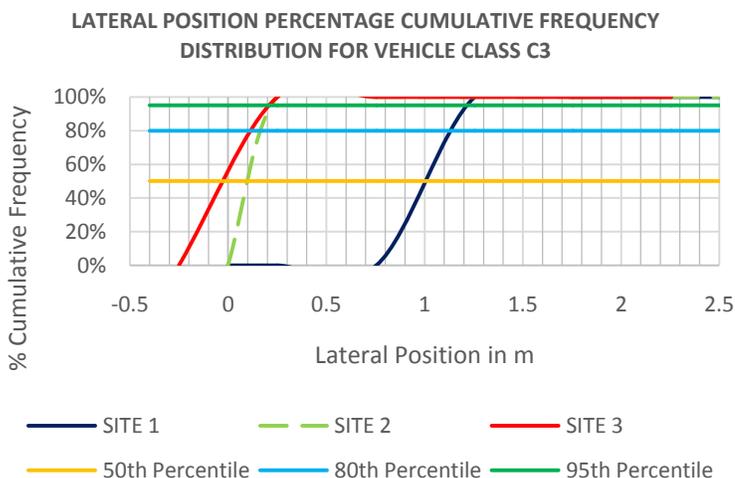


**Figure 4:** Lateral Position PCF Distribution for passenger cars

Figure 4 shows that up to 95% of passenger cars shift towards the right-side edge of the travelling lane when a centre line is present but edge line is absent (site 2/test two conditions). This graph indicates that 80% of passenger cars shift even further towards the right-side edge of the travelling lane when a centre line is absent but edge line is present (site 3/test three conditions). About 20% of passenger cars cross the centre of the carriageway into the opposing traffic lane under test three conditions.

Therefore, the effect of the presence and absence of these line markings on passenger cars can be stated as follows:

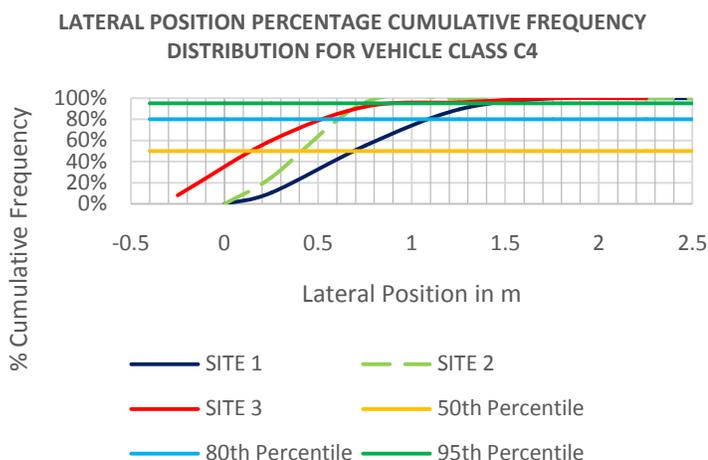
- i. Centre lines present but edge lines absent- passenger cars travelling on such a carriageway shift closer to the centre of the carriageway.
- ii. Centre lines absent but edge lines present- passenger cars travelling on such a carriageway shift even much closer to the centre of the carriageway than the former test condition.



**Figure 5:** Lateral Position PCF Distribution for mini bus taxis

Figure 5 shows that more than 95% of minibus taxis shift towards the right-side edge of the travelling lane when a centre line is present but edge line is absent (site2/test two conditions). This graph indicates that 95% of minibus taxis shift even further towards the right-side edge of the travelling lane when a centre line is absent but edge line is present (site 3/test three conditions). About 50% of minibus taxis cross the centre of the carriageway into the opposing traffic lane under test three conditions. Therefore, the effect of the presence and absence of these line markings on minibus taxis can be stated as follows:

- i. Centre lines present but edge lines absent- minibus taxis travelling on such a carriageway shift closer to the centre of the carriageway.
- ii. Centre lines absent but edge lines present- minibus taxis travelling on such a carriageway shift even much closer to the centre of the carriageway than the former test condition. In addition, negative deviations are observed for minibus taxis in such test conditions.

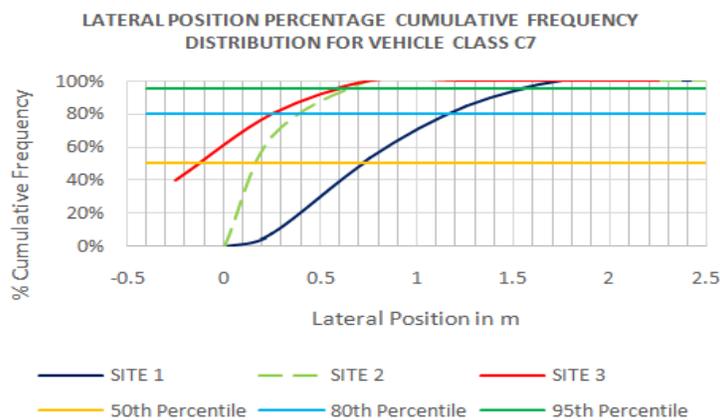


**Figure 6:** Lateral Position PCF Distribution for LDVs

Figure 6 shows that up to 95% of LDVs shift towards the right-side edge of the travelling lane when a centre line is present but edge line is absent (site2/test two conditions). This graph indicates that 90% of LDVs shift even further towards the right-side edge of the travelling lane when a centre line is absent but edge line is present (site 3/test three conditions). About 35% of LDVs cross the centre of the carriageway into the opposing traffic lane under test three conditions. Therefore, the effect of the

presence and absence of these line markings on LDVs can be stated as follows:

- i. Centre lines present but edge lines absent- LDVs travelling on such a carriageway shift closer to the centre of the carriageway.
- ii. Centre lines absent but edge lines present-LDVs travelling on such a carriageway shift even much closer to the centre of the carriageway than the former test condition. In addition, negative deviations are observed for LDVs in such test conditions.



**Figure 7:** Lateral Position PCF Distribution for MDVs

Figure 7 shows that more than 95% of MDVs shift towards the right-side edge of the travelling lane when a centre line is present but edge line is absent (site2/test two conditions). This graph indicates that 95% of MDVs shift even further towards the right-side edge of the travelling lane when a centre line is absent but edge line is present (site 3/test three conditions). About 60% of MDVs cross the centre of the carriageway into the opposing traffic lane under test three conditions. Therefore, the effect of the

presence and absence of these line markings on MDVs can be stated as follows:

i. Centre lines present but edge lines absent- MDVs travelling on such a carriageway shift closer to the centre of the carriageway.

ii. Centre lines absent but edge lines present-MDVs travelling on such a carriageway shift even much closer to the centre of the carriageway than the former test condition. In addition, negative deviations are observed for MDVs in such test conditions.

**Table 3: Hypothesis Test Statements**

	Site 1 and Site 2	Site 1 and Site 3	Site 2 and Site 3
<b>Null Hypothesis: <math>H_0</math></b>	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
<b>Alternative Hypothesis: <math>H_a</math></b>	$\mu_1 \neq \mu_2$	$\mu_1 \neq \mu_3$	$\mu_2 \neq \mu_3$
<b>Significance Level: <math>\alpha</math></b>	0.05	0.05	0.05
<b>Test: Z or t-test (two tail)</b>	Z-test; because sample size $n > 30$ and standard deviation is known	Z-test; because sample size $n > 30$ and standard deviation is known	Z-test; because sample size $n > 30$ and standard deviation is known
<b>Decision Rule: Critical Value</b>	$Z_{crit} = \pm 1.96$ If $Z < -1.96$ or $Z > 1.96$ , Reject $H_0$	$Z_{crit} = \pm 1.96$ If $Z < -1.96$ or $Z > 1.96$ , Reject $H_0$	$Z_{crit} = \pm 1.96$ If $Z < -1.96$ or $Z > 1.96$ , Reject $H_0$

Table 3 presents the hypothesis statements used to verify whether the differences of the means of the lateral position data ( $\mu_1$ : mean of lateral position data for test condition 1, and  $\mu_2$  or  $\mu_3$ : mean of lateral position data used as reference for comparisons), under two different situations exist or not. To determine whether the reduction in pavement width had a more effect on lateral position than test 3 road marking conditions, the researcher also

tested the difference in means between site 2 and site 3 lateral positions. Consequently, the researcher tested the effect of swapping from a scenario with the presence of centre lines to edge lines (surely also a swap in which of the two is absent), but with a minimal reduction in pavement width.

**Table 4: Hypothesis Test Results for Vehicle Class C2**

	Site 1	Site 2 Vs Site 1 :Test 2 conditions	Site 3 Vs Site 1 :Test 3 conditions	Site 3 Vs Site 2 :Test 3 conditions
<b>Vehicle Class C2</b>				
<b>Sample Size: <math>N</math></b>	4	54	66	66
<b>Mean: <math>\mu</math></b>	0.85	0.45	0.40	0.40
<b>Standard Deviation: <math>\sigma</math></b>	0.40	0.30	0.43	0.43
<b>Variance: <math>\sigma^2</math></b>	0.16	0.09	0.18	0.18
<b>Degrees of Freedom: <math>d</math></b>	4	53	65	65
<b>Z-value: <math>Z</math></b>	-	6.44	5.26	0.63

<b>P-Value: p</b>	-	<0.00001	<0.00001	0.53
<b>Conclusion Z-test:</b>	-	Reject $H_0$ Significant at $p<0.05$	Reject $H_0$ Significant at $p<0.05$	Accept $H_0$ Not significant at $p<0.05$

Table 4 shows that the effects of the absence of centre lines but presence of edge lines (test 3 conditions), for the vehicle class C2 were not significant because their P-values are greater than 0.05. This table shows that a reduction in pavement width has more effect (lower p-value) on lateral position (site 2 Vs site 1 and site 3 Vs site 1) than absence of centre lines. This is deduced from the test results when the presence of centre lines was swapped with edge lines but a minimal change in pavement width (site 3 Vs Site 2). The effect on difference in means of

lateral position observed between sites 1 and 3 is thus attributed to a reduction in pavement width when considering changes observed from this tested hypothesis and that of site 3 Vs site 2. This table also shows that the effects of the absence of edge lines but presence of centre lines (test 2 conditions), for this vehicle class, was statistically significant because of a P-value less than 0.05. Therefore, a reduction in pavement width coupled with the absence of edge lines has a significant effect on the lateral positioning of class C2 vehicle drivers.

**Table 5:** Hypothesis Test Results for Vehicle Class C4

	Site 1	Site 2 Vs Site 1 :Test 2 conditions	Site 3 Vs Site 1 :Test 3 conditions	Site 3 Vs Site 2 :Test 3 conditions
<b>Vehicle Class C4</b>				
<b>Sample Size: N</b>	42	38	27	27
<b>Mean: <math>\mu</math></b>	0.70	0.42	0.15	0.15
<b>Standard Deviation: <math>\sigma</math></b>	0.40	0.26	0.43	0.43
<b>Variance : <math>\sigma^2</math></b>	0.16	0.07	0.18	0.18
<b>Degrees of Freedom: d</b>	41	37	25	25
<b>Z-value: Z</b>	-	4.81	5.19	2.49
<b>P-Value: p</b>	-	<0.00001	<0.00001	0.0112774
<b>Conclusion Z-test:</b>	-	Reject $H_0$ Significant at $p<0.05$	Reject $H_0$ Significant at $p<0.05$	Reject $H_0$ Significant at $p<0.05$

Table 5 shows that the effects of the absence of centre lines but presence of edge lines (test 3 conditions), for the vehicle class C4 were significant because their P-values are less than 0.05. However, this table shows that a reduction in pavement width has a significantly more effect (lower p-value) on lateral position (site 2 Vs site 1 and site 3 Vs site 1) than absence of centre lines. This is deduced from the test results when the presence of centre lines was swapped with edge lines but a minimal change in pavement width (site 3 Vs Site 2). The effect on difference in means of lateral position observed between sites 1 and 3

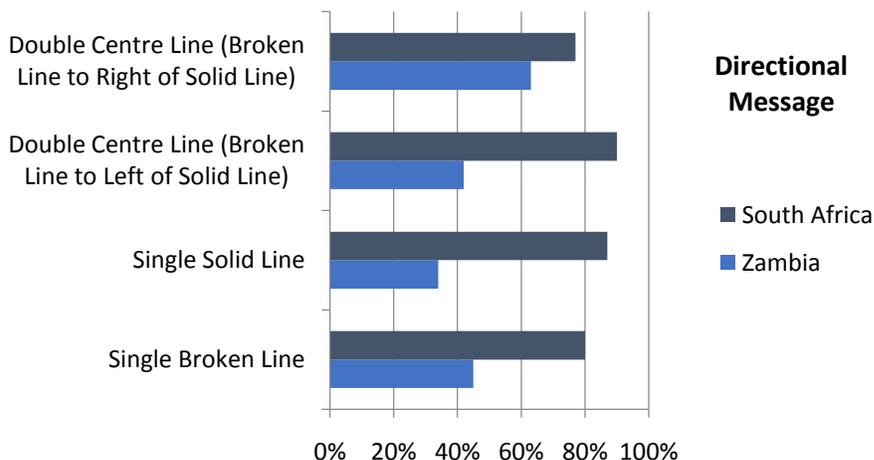
is thus attributed to larger extent to reduction in pavement width when considering changes observed from this tested hypothesis and that of site 3 Vs site 2. This table also shows that the effects of the absence of edge lines but presence of centre lines (test 2 conditions), for this vehicle class, was statistically significant because of a P-value less than 0.05. Therefore, a reduction in pavement width coupled with the absence of edge lines has a significant effect on the lateral positioning of class C4 vehicle drivers.

**Table 6:** Hypothesis Test Results for Vehicle Class C7

	Site 1	Site 2 Vs Site 1 : Test 2 conditions	Site 3 Vs Site 1 : Test 3 conditions	Site 3Vs Site 2 : Test 3 conditions
<b>Vehicle Class C7</b>				
Sample Size: $N$	15	4	5	5
Mean: $\mu$	0.70	0.15	-0.12	-0.12
Standard Deviation: $\sigma$	0.42	0.26	0.42	0.42
Variance : $\sigma^2$	0.18	0.07	0.18	0.18
Degrees of Freedom: $d$	14	3	4	4
Z-value: $Z$	-	3.76	3.78	0.96
P-Value: $p$	-	0.00017	0.000157	0.337055
Conclusion Z-test:	-	Reject $H_0$ Significant at $p < 0.05$	Reject $H_0$ Significant at $p < 0.05$	Accept $H_0$ Not significant at $p < 0.05$

Table 6 shows that the effects of the absence of centre lines but presence of edge lines (test 3 conditions), for the vehicle class C7 were not significant because their P-values are greater than 0.05. This table shows that a reduction in pavement width has more effect (lower p-value) on lateral position (site 2 Vs site 1 and site 3 Vs site 1) than absence of centre lines. This is deduced from the test results when the presence of centre lines was swapped with edge lines but a minimal change in pavement width (site 3 Vs Site 2). The effect on difference in means of lateral position observed between sites 1 and 3 is thus

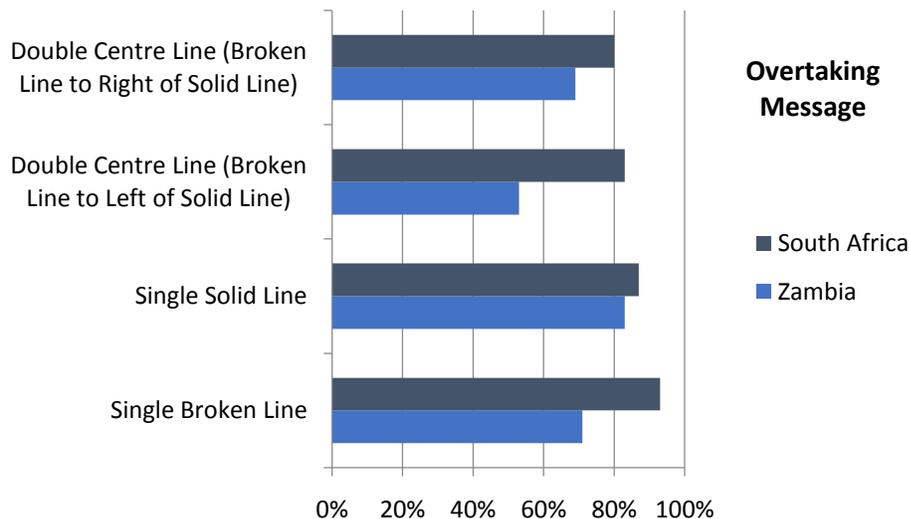
attributed to a reduction in pavement width when considering changes observed from this tested hypothesis and that of site 3 Vs site 2. This table also shows that the effects of the absence of edge lines but presence of centre lines (test 2 conditions), for this vehicle class, was statistically significant because of a P-value less than 0.05. Therefore, a reduction in pavement width coupled with the absence of edge lines has a significant effect on the lateral positioning of class C7 vehicle drivers.



**Figure 8:** Percentage of Respondents with Correct Response to the Directional Message Questions: Comparison between Zambian and South African Drivers

Figure 8 presents the different percentages of the respondents that gave a correct response to the directional message questions. This figure illustrates that for any of the surveyed road markings; at least 75% of South African drivers were able to interpret the intended directional messages for all of these road markings. Compared to

South African drivers, Zambian drivers had a lower level of understanding of these road markings, and had as high as 66% of drivers failing to interpret the intended directional message of a single solid line marking.



**Figure 9:** Percentage of Respondents with Correct Response to the Overtaking Message Questions: Comparison between Zambian and South African Drivers

Figure 9 presents the different percentages of the respondents that gave a correct response to the overtaking message questions. This figure illustrates that for any of the surveyed road markings; at least 80% of South African drivers were able to interpret the intended overtaking messages for all of these road markings. Compared to South African drivers, Zambian drivers had a lower level

of understanding of these road markings, and had at most 83% of drivers managing to interpret the intended overtaking message of a single solid line marking.

Figures 8 and 9 show that South African drivers have a better understanding of the directional and overtaking messages intended to be relayed by these road markings, than Zambian drivers.

## V. CONCLUSION AND RECOMMENDATION

The survey study indicated that the centre line that respondents had the most problem of understanding the directional message is the solid line marking. This is apparent from the percent respondents that correctly identified this marking’s intended directional message been as low as 34%. However, the level of understanding of the intended directional message by the other road markings is not as much as when compared to that of the overtaking message. This is discernible from the generally higher percentage of correct responses, for all the questioned type of centre lines. Results from this study also show that South African drivers have a better understanding of the directional and overtaking messages intended to be relayed by these road markings, than Zambian drivers do.

The classes with representative observed vehicles in the field study included motorcycles/scooters, passenger cars, Light Delivery Vehicles (LDVs), Medium Delivery Vehicles (MDVs) and minibus taxis. This study showed no deviation exceeding -0.5m and +2.0m at any of the test sites. Minibus taxis have the smallest wheel wander measured from the centre of the carriageway up to the 80<sup>th</sup> percentile of vehicles. MDVs and LDVs have subsequently larger wheel wanders for this same percentile for any given particular test condition. Therefore, for the 80<sup>th</sup> percentile of vehicles, Minibus taxis followed by MDVs then LDVs have the least control in travelling further from the centre of the carriageway. Even for the 95<sup>th</sup> percentile, minibus taxis followed by MDVs travel closer to the travelling lane at test sites 2 and 3. However, only minibus taxis maintain their position of having the least control in travelling further from the centre of the roadway at test site 1. At 95%, all observed vehicles cluster at almost the same lateral position of about +1.5 m,

except minibus taxis and motorcycles/scooters. Therefore, there is more lateral position control with centre line and edge line markings both present for a variety of the vehicle classes included in this study.

The effects of the presence and absence of these line markings on a particular vehicle class was also investigated in this study. Test site 1, where both centre and edge lines are present, is taken as the reference scenario and the others as comparison scenarios. Using the 95<sup>th</sup> percentile, there is an observed shift closer to the centre of the carriageway for up to 95 % of passenger cars, minibus taxis, LDVs, MDVs under test 2 conditions. However, there was no notable shift at any percentile of motorcycles/scooters under test 2 conditions. Test 3 conditions had the most shifting effect towards the centre on all vehicle classes with observed traffic volumes, and this was concluded to be attributed to reduction in pavement width since had even much lower width than site 2. Even motorcycles/scooters had a notable shift towards the centre of the carriageway. Only test site 3 exhibited negative deviations for the vehicle classes observed. All observed vehicles, except motorcycles/scooters, had representative vehicles with negative deviations Minibus taxis and MDVs are the only vehicle classes that had 50<sup>th</sup> percentile of vehicles with a lateral position in the opposing traffic lane under test 3 conditions.

It was concluded that the narrower the pavement width, the more the effect on lateral positioning and the absence of edge lines had a significant effect on vehicle lateral positioning.

There is inherent importance in the outcomes of this study's assessment of behavioural changes as influenced by the type of road markings present. The comparisons of these effects are made using the shift in lateral placement as a performance measurement. These lateral position distributions help in making decisions on lane width and road marking guidelines for similar urban streets. These guidelines will be able to have a general premise on deciding allowances for lateral drift and vehicle width for different expected vehicle. This study helps identify which combination of centre and edge lines present influences unsafe driving behaviour. An extended study on roads with expected significant numbers of heavy vehicles would be also of great value to the industry. This is, as it would contribute to the justification of decisions related to wheel paths and Pavement Management Systems (PMS)

From this study, even with all respondents having attended driving school, Zambian drivers demonstrated poor understanding of the meaning of such markings. South African drivers on the other hand showed that they have a much better understanding of the intended directional and overtaking message of these markings, than Zambian drivers do. This motivates the need for a more

revamped education system in Zambia on such road markings, to eliminate the problem of traffic violation as result of ignorance.

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