EXAMINING LATERAL POSITIONS OF CARS AND HEAVY VEHICLES ON A TWO LANE, TWO WAY MOTORWAY

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KEYWORDS

Multi-combination vehicle, B-double, semi-trailer, road train, heavy vehicle, motorway, freeway, driver behaviour, road design, traffic operation

SUMMARY

While most motorways in Queensland are divided with at least two lanes in each direction, a few motorways have been constructed as two lane, two way roads. These “half motorways” have been designed and constructed with the intent of eventual duplication to divided carriageways. This type of roadway is similar to a two lane, two way highway constructed to a high standard. Motorways are critical elements of urban freight networks. There is a growing need from the freight industry to allow multi-combination vehicles to use a larger network of urban roads. This raises concerns regarding the psychological impacts on drivers of surrounding vehicles, and their behaviour around the MCVs.

Lennie and Bunker (2004) studied some behavioural characteristics of passenger car drivers surrounding MCVs on a four lane, divided motorway. However, drivers are expected to behave differently while opposing each other on an undivided two lane, two way motorway or highway. That study was extended here to examine driver behaviour on the Port of Brisbane Motorway, which is a “half motorway”. Specifically, the following were examined: Lateral position distribution for passenger cars, semi-trailers and B-doubles (23m or longer); and lateral separation distribution of passenger cars from heavy vehicles and other passenger cars.

The study showed that a maximum 7s time gap between opposing vehicles influenced drivers’ positioning of their vehicles. It was shown that the lateral positions of cars, utility vehicles, and semi-trailers are statistically different when opposed than when unopposed; whereas, the lateral positions of B-doubles were not. This indicates that B-double drivers did not tend to move laterally when opposed by oncoming traffic.

On average, passenger car drivers did not position their vehicles appreciably differently when opposed by semi-trailers and B-doubles than other passenger cars, and there was no appreciable difference in passenger car drivers’ positions when faced by oncoming semi-trailers than B-doubles.

Average and 95th percentile envelopes were provided to indicate position in the lane of unopposed and opposed vehicles on this type of roadway section. The off-side edge of the 95th percentile passenger car straddled the edge line, while both the 95th percentile semi-trailer and B-double occupied part of the wide, sealed shoulder. The semi-trailer wandered further onto the shoulder. The vehicle envelopes are useful to understand the impacts of heavy vehicles on driver behaviour, and can also inform road design and pavement asset management.

1.0 Background

The US Highway Capacity Manual[1] defines a freeway as '*a multilane, divided highway with a minimum of two lanes for the exclusive use of traffic in each direction and full control of access without traffic interruption.'*

The Queensland Road Planning and Design Manual[2] adopts the term "motorway" in lieu of the term "freeway"; defining it as a high speed, high volume road with full control of access with no property access allowed. While most motorways in Queensland are divided with at least two lanes in each direction, a few motorways have been constructed as two lane, two way roads. These "half motorways" have been designed and constructed with the intent of eventual duplication to divided carriageways. This type of roadway is similar in character to a two lane, two way highway constructed to a high standard.

As motorways are high standard roads that are generally accessible only to motorised traffic they are critical elements of urban freight networks. Multi-combination vehicles (MCVs) are road freight vehicles with a prime mover towing two or more trailers[3] and are used due to their payload efficiencies. These vehicles are common in regional Australia; however, there is a growing need from the freight industry to allow them to use a larger network of urban roads, where the surrounding motorists are becoming increasingly exposed to their presence[4]. Complaints about large trucks are often received from the public[2].

The presence of MCV on motorways raise concerns regarding the psychological impacts on drivers of surrounding vehicles, and their behaviour around the MCVs. Lennie and Bunker[3] studied some behavioural characteristics of passenger car drivers surrounding MCVs on a four lane, divided motorway in Brisbane, Australia. Lateral position characteristics were examined, and the suitability of the lane width determined for situations with vehicles travelling alongside MCVs.

However, drivers are expected to behave differently while opposing each other on an undivided two lane, two way motorway or highway. Lennie and Bunker's study[3] was extended to examine driver behaviour on the Port of Brisbane Motorway, which is a recently constructed "half motorway", also located in Brisbane. Specifically, the following were examined: Lateral position distribution for passenger cars, semi-trailers and B-doubles (23m or longer); and lateral separation distribution of passenger cars from heavy vehicles and other passenger cars. The results are reported herein.

2.0 Data Collection and Test Location

Lennie and Bunker[3] considered various data collecting options and selected a data collection process called screen superimposition. This process was adopted here. A video camera was placed on the pedestrian walkway of an overpass over a section of the Port of Brisbane Motorway as shown in Figure 1. Digital video footage was recorded and then analysed frame by frame. Vehicle position and passing time were measured by the operator using a scale transparent overlay on the computer screen. The scale was divided into eight divisions for each lane; each division representing 437.5 mm over the 3.5 m wide lane.

Figure 1 Hemmant & Tingalpa Road overpass, Port of Brisbane Motorway

The data collection process was trialled and refined in a pilot testing program. To minimize vertical and horizontal occlusion, the video camera was fixed on top of the overpass guardrail straddling the carriageway centreline.

The Hemmant test location shown in Figure 2 was chosen in context of the data collection procedure and the following criteria:

- MCV traffic: The presence of significant number of MCVs on the road, in this case B-doubles of up to 25m in length accessing the port;
- Half motorway cross section: The road needed to have two lanes, two way to study the behaviour of traffic due to presence of opposing MCVs;
- Relatively straight and level section of road: The section was chosen to reduce the effects of geometry;
- Away from the influence of ramp junctions: The ramp junctions of the nearest interchange are located approximately 1.0km to the west of the site.

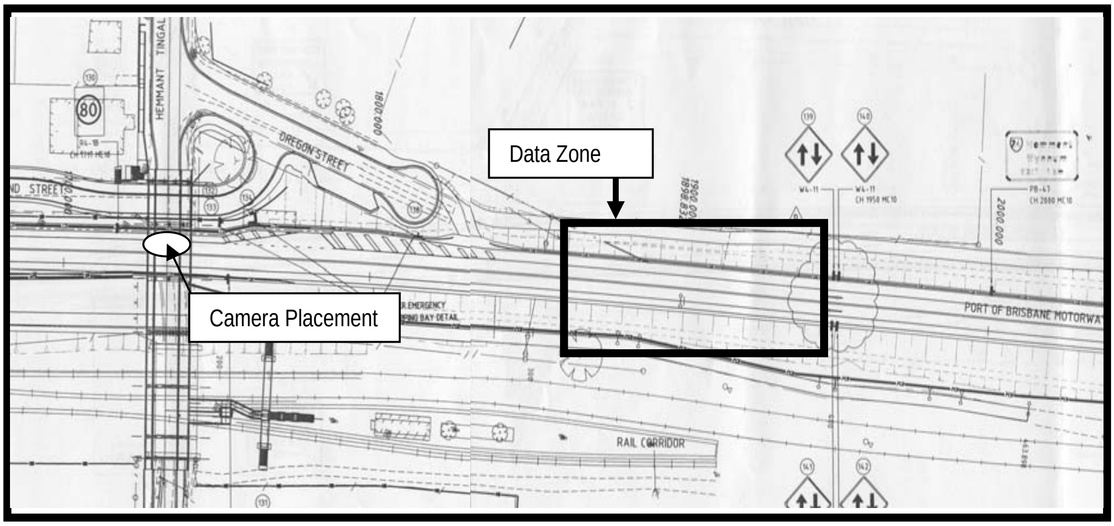

Figure 2 Site layout at Port of Brisbane Motorway, Hemmant

Table 1 lists the site specific geometry and traffic conditions, showing that the site has a high quality road alignment design and condition. In particular, the paved shoulders on this road are generous.

The peak hour to daily traffic ratio at this site was very low, indicating a broad traffic spread across the day. While traffic is not permitted to overtake on this section, the running speeds were high throughout the day including the peak hour, fairly close to the free flow speed, which is estimated to be at the posted speed limit of 80km/h. The traffic spectrum of this urban, two lane motorway section displays characteristics quite different from those on a two lane rural highway, even though the geometric characteristics may be similar. The Highway Capacity Manual Two Lane Highways methodology[1] does not properly reflect the conditions present and consequently was not used to evaluate the traffic level of service (LOS). The HCM Basic Freeway Sections methodology was instead adopted, yielding a peak hour level of service of E. While peak hour traffic conditions are currently uncongested, only marginal traffic growth on this corridor would result in congestion.

Table 1 Site conditions at Port of Brisbane Motorway, Hemmant

Criterion	**Condition**
Geometry	
Lane width	3.5m * 2
Shoulder width	2.8m * 2
Horizontal curvature	In excess of 2,900m
Crossfall	3 percent westbound (south lane) 5 percent eastbound (north lane)
Terrain	Level
Interchange spacing	3km
Pavement type and roughness condition	Flexible granular with asphaltic concrete wearing surface. Very good condition.
Posted speed limit	80km/h
Lane restrictions	Double continuous barrier line (no overtaking)
Traffic	
Annual Average Daily Traffic (AADT)	23,437 at 2003
Percentage heavy vehicles	27%
Peak Hour	6a.m. to 7a.m.
K ratio (peak hour: AADT)	7.8%
D ratio (peak direction: combined directions)	63%
Peak hour traffic level of service (LOS)	E

Vehicles were categorised and typical dimensions used[3,5,6] as listed in Table 2.

Table 2 Vehicle categorisation and typical dimensions used in Study

Vehicle Type	**Austroads Part 3 Classification**	**Width (m)**	**Length (m)**
Passenger car, 4 wheel drive	1	1.77	4.3
Utility vehicle, van	1	1.85	4.6
Rigid truck (small, medium, large)	3 to 5	2.5	12.5
Semi-trailer	6 to 9	2.5	19
B-double	10	2.5	25

<u>Lateral Position</u>

Lateral position of a vehicle is defined as the distance between the carriageway centreline and the nearest edge of the vehicle. In the case where the vehicle width varies, the lateral position is measured to the nearest part of the vehicle combination.

Figure 3 illustrates the data collected for each vehicle of interest. As the front of the vehicle passed over the reference line, the time (frame number in the video software) was noted, and similarly when the rear end of the vehicle passed over the reference line, the time was noted. The closest *lateral position* of the vehicle between these instances was recorded.

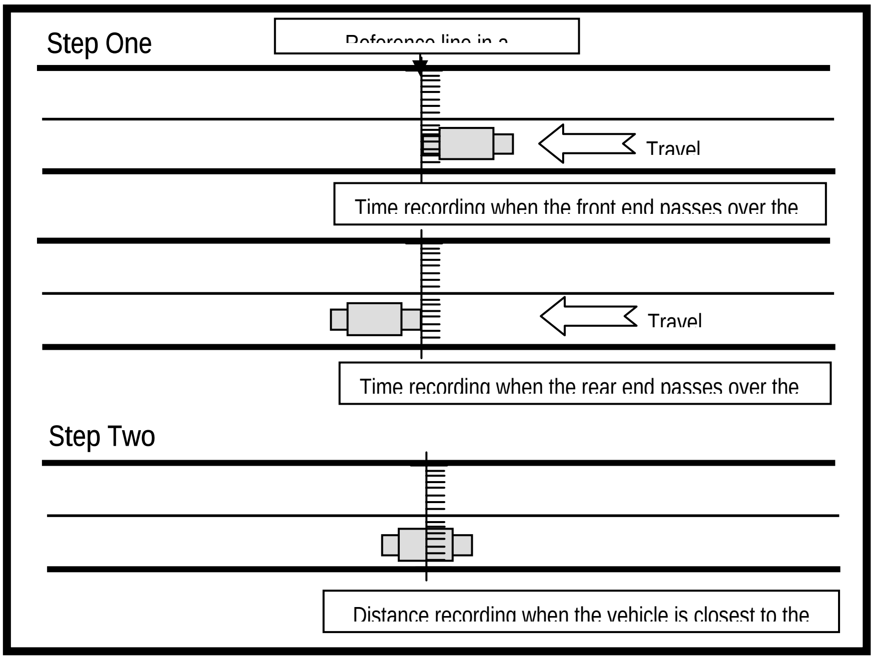

Figure 3 Vehicle position measurement using reference line

<u>Lateral Separation</u>

When two vehicles opposed each other at the reference line, or within a defined maximum opposing time gap, the sum of lateral positions of the two vehicles was recorded as the *lateral separation* as shown in Figure 4. In the case where more than one vehicle opposed a subject vehicle the minimum lateral separation governed. The maximum opposing time gap is discussed later. Table 3 illustrates an example data record for an event.

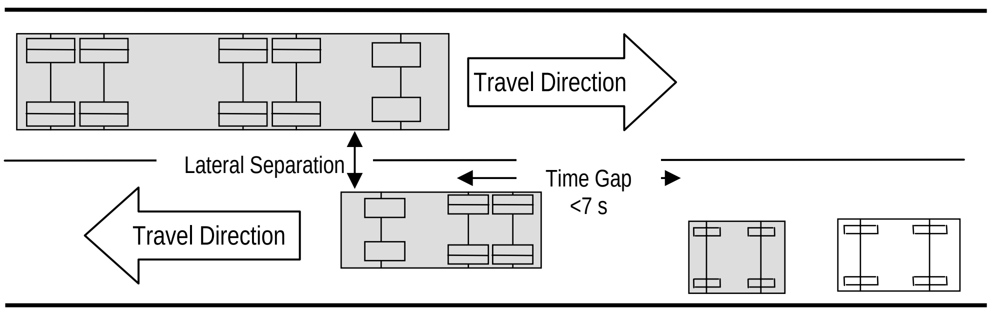

Figure 4 Lateral separation between opposed vehicles

Table 3 Example event data record

Lane One		**Lane Two**	
Vehicle Type	Car	Vehicle Type	B Double
		Arrival	
Min	0	Min	0
Sec	56	Sec	8
Frame*	11	Frame*	14
		Departure	
Min	0	Min	0
Sec	56	Sec	9
Frame*	15	Frame*	12

Lateral Position**	2.8	Lateral Position**	2.0

* frame = 0.04 sec **measured in division

Approximately four hours of video footage was recorded. Data was captured for each vehicle crossing over the reference line. The total number of vehicles was 3,151, some of which were opposed by oncoming vehicles while others were unopposed.

Sample sizes for some opposed vehicle pair categories were statistically insufficient. Consequently the study focused on events that involved passenger cars and heavy vehicles.

3.0 Influence of Opposed Time Gap

Even when two opposing vehicles are some time apart, they may be affected by each other's presence. Hence a maximum time gap of influence between the opposing vehicles is important. The effective sample sizes may change considerably with the change in definition of opposed and unopposed vehicles.

Armour[7] reported that vehicles opposed within 7s of each other on a two lane rural highway would behave as "meeting" or opposed vehicles. This equates to a distance of 155 m apart at 80 km/h. She tested this assumption with a lesser time gap of 3.5s which was reported to produce a similar result for the lateral position distribution of vehicles. This study has also considered minimum opposed time gap of 3.5s and 7s to evaluate the importance of this value.

Gunay[8] confirmed that it is reasonable to assume the lateral position of vehicles within a lane is distributed normally. Lateral separation has also been treated as normally distributed for this analysis, which is evident in Figure 5 for the sample distributions representing passenger cars opposing other passenger cars, and passenger cars opposing utility vehicles.

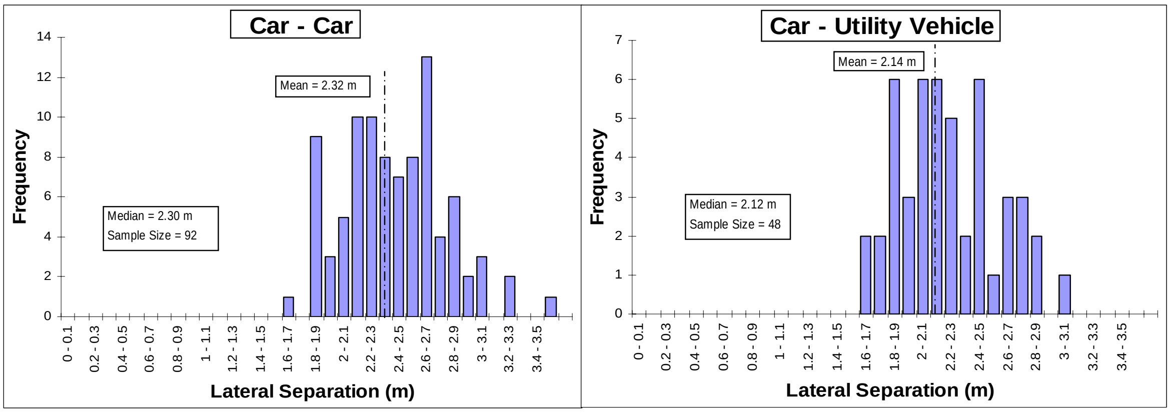

Figure 5 Lateral separation distributions for passenger cars opposing other passenger cars, and passenger cars opposing utility vehicles

Analysis of Variance (ANOVA) tests were performed on lateral separation samples for events when a car is opposed by another car, a utility vehicle, a semi-trailer, or a B-Double. These tests compared the lateral separation distribution assuming a maximum opposing time gap of 3.5s with that assuming a maximum of 7s. Table 4 shows that the distributions are mostly similar. In the case when semi-trailers opposed cars the result was not conclusive.

Table 4 ANOVA tests comparing maximum time gap influencing lateral separation

Distributions compared	Sample Size	Mean (m)	Variance	F	F critical
Car and car opposed within 3.5s against 7s					
Car/car <3.5s	74	2.37	0.109	0.796	3.90 @5%
Car/car <7s	92	2.32	0.141	Distributions are similar	

Utility and car opposed within 3.5s against 7s					
Ute/car <3.5s	50	2.26	0.129	2.946	3.93 @5%
Ute/car<7s	56	2.14	0.114	Distributions are similar	
Semi-trailer and car opposed within 3.5s against 7s					
Semi-trailer/car <3.5s	121	2.22	0.121	6.344	3.87 @5% 6.72 @1%
Semi-trailer/car <7s	179	2.12	0.122	Distributions may be different	
B-double and car opposed within 3.5s against 7s					
B-double/car <3.5s	19	2.30	0.093	2.695	4.11 @5%
B-double/car <7s	19	2.14	0.091	Distributions are similar	

Table 4 suggests that it is reasonable to assume that drivers choose their position in the lane at least 7s from when they meet the oncoming vehicle, which accords with Armour's study[7] results. A maximum time gap of 7s was consequently adopted in defining opposed vehicles for this study.

4.0 Lateral Separation Analysis

The summary statistics of the sample lateral separation distributions with cars opposed by other cars, utility vehicles, semi-trailers and B-doubles are presented in Table 5.

Table 5 Lateral separation distributions summary statistics

Opposed Vehicle Pair	Sample Size	Mean (m)	Variance (m)
Car/Car	92	2.32	0.141
Car/Utility	48	2.14	0.114
Car/Semi-trailer	179	2.12	0.122
Car/B-double	19	2.14	0.091

Table 5 indicates that lateral separations and their spread generally reduce as the size of the vehicle opposing the passenger car increases. This is to be expected, as there is less freedom for both vehicles to move laterally as the size of either vehicle increases.

The data does show a slightly larger mean separation lateral separation between passenger cars and B-doubles than between passenger cars and semi-trailers. An ANOVA test, reported in Table 6, was conducted to determine whether this is significant. The results show that the two distributions are not significantly different. Given that the frontal widths of both types of heavy vehicle are generally the same, it follows that drivers did not distinguish oncoming B-doubles from semi-trailers to the extent that their lateral separation was any different.

Table 6 ANOVA tests comparing opposed vehicle pairs' lateral separations

Distributions compared	Sample Size	Mean (m)	Variance	F	F critical
B-double and car opposed, against semi-trailer and car opposed					
B-double/car	19	2.14	0.091	0.050	3.89 @5%
Semi-trailer/car	179	2.12	0.122	Distributions are similar	
Car and car opposed, against utility vehicle and car opposed					
Car/car	92	2.32	0.141	8.394	6.81 @1%
Ute/car	56	2.14	0.114	Distributions are different	
Car and car opposed, against semi-trailer and car opposed					
Car/car	92	2.32	0.141	18.77	6.73 @1%
Car/semi-trailer	179	2.12	0.122	Distributions are different	

An ANOVA test was similarly conducted to determine whether the lateral separation is different between passenger cars and other passenger cars, than between passenger cars and utility vehicles, as reported in Table 6. The results indicate that the two distributions are statistically different at the 1% and 5% level of significance possibly due to utility vehicles being somewhat wider.

Further, an ANOVA test was conducted to determine whether the lateral separation is different between passenger cars and other passenger cars than between passenger cars and semi-trailers, as reported in Table 6. The results indicate that the two distributions are statistically different, which again is to be expected considering the additional width of the semi-trailer.

5.0 Lateral Position Analysis

Lateral separation alone provides limited information on passenger car behaviour around heavy vehicle. Driver behaviour was further examined by considering their lateral position with respect to the centreline of the road when opposed by another vehicle. Figures 6, 7, and 8 illustrate the distributions of lateral positions of opposed passenger cars, semi-trailers and B-doubles respectively.

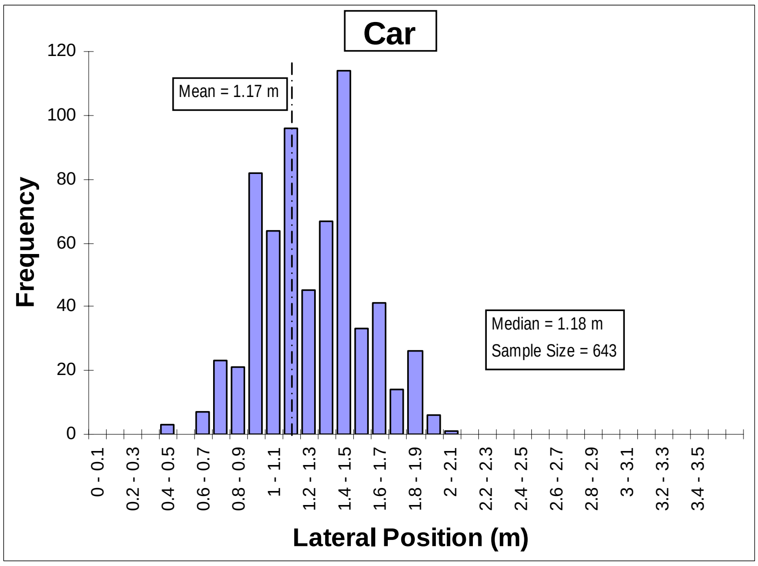

Figure 6 Distribution of car lateral positions when opposed by other vehicles

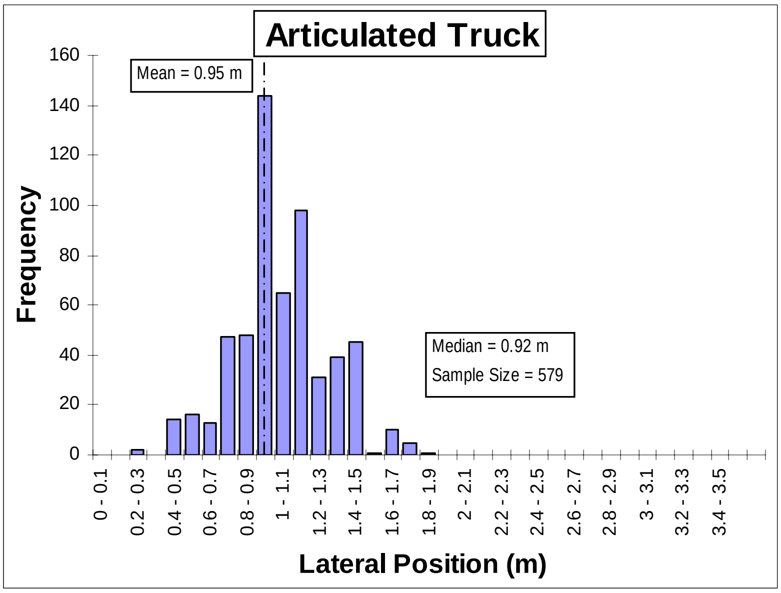

Figure 7 Distribution of semi-trailer lateral positions when opposed by other vehicles

It is apparent that the lateral positions of passenger cars are greater than those of the articulated heavy vehicles, which is expected due to their smaller size. Notably, the mean lateral positions of the semi-trailers and B-doubles were almost the same, however a little less spread is evident for the B-doubles.

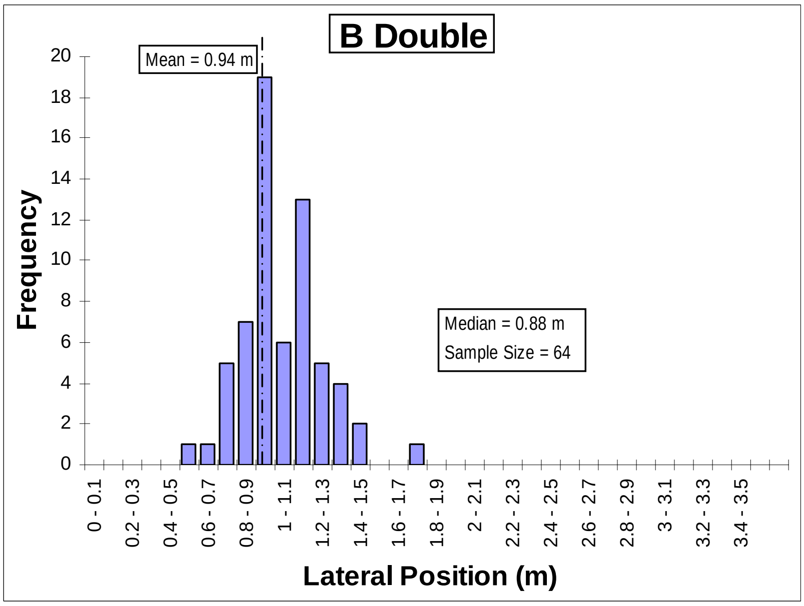

Figure 8 Distribution of B-double lateral positions when opposed by other vehicles

Table 7 presents the results of ANOVA tests examining, for cars and utilities respectively, whether lateral position was significantly different when they were opposed than when they were not opposed. The results indicate that, for each of these vehicle types, the two distributions are statistically different and therefore that drivers do adjust their lateral position when opposed. These results were to be expected.

Table 7 ANOVA tests comparing unopposed against opposed lateral positions by vehicle type

Distributions compared	Sample Size	Mean (m)	Variance	F	F critical

Car unopposed against opposed					
Car unopposed	209	1.05	0.084	25.9	6.66 @1%
Car opposed	643	1.17	0.083	Distributions are different	
Utility unopposed against opposed					
Utility unopposed	80	1.02	0.095	7.648	6.73 @1%
Utility opposed	196	1.13	0.077	Distributions are different	
Semi-trailer unopposed against opposed					
Semi-trailer unopposed	579	0.85	0.062	24.1	6.67 @1%
Semi-trailer opposed	201	0.95	0.066	Distributions are different	
B-double unopposed against opposed					
B-double unopposed	27	0.89	0.028	1.14	3.95 @5%
B-double opposed	64	0.94	0.042	Distributions are similar	

Also presented in Table 7 are the results of ANOVA tests examining, for semi-trailers and B-doubles respectively, whether lateral position was significantly different when they were opposed than when they were not opposed. For semi-trailers, the results indicate that the two distributions are statistically different and therefore that semi-trailer drivers do adjust their lateral position when opposed. However, this was not the case for B-double drivers, whose lateral positions do not vary significantly when opposed than when unopposed. This result could be attributable to better vehicle stability and/or driver training prescribed under the performance based standards for this vehicle type[5].

6.0 Vehicle Envelopes

Table 8 details the lateral envelopes of various combinations of unopposed vehicles on the motorway section under average lateral position conditions assuming the typical vehicle dimensions in Table 2. Passenger car drivers tended to leave about 60% of the unoccupied lane width towards the centreline and 40% towards the edge line.

Table 8 Unopposed vehicle envelopes under average (mean) lateral position

Vehicle Type	Distance from Edge Line (m)	Distance from Centreline (m)
Car	0.68	1.05
Semi-trailer	0.15	0.85
B-double	0.11	0.89

Unopposed semi-trailer and B-double drivers positioned their off-side edge close to the edge line, leaving 85% and 89% of the unoccupied lane space towards the centreline respectively.

Table 9 details the lateral envelopes of various combinations of opposed vehicles on the motorway section under average lateral separation conditions. It can be seen that passenger car drivers do not tend to move laterally due to opposing semi-trailers or B-doubles appreciably more than they do due to opposing passenger cars. When there is an opposing vehicle, regardless of size, passenger car drivers tend to leave about 67% of the unoccupied lane space towards the centreline and 33% towards the edge line. Opposed passenger car drivers tended to shy away from the centreline of the road more so than unopposed drivers.

Table 9 Opposed vehicle envelopes under average (mean) lateral separation

Lane 1		Lane 2	
Distance from Edge Line (m)	Distance from Centreline (m)	Distance from Centreline (m)	Distance from Edge Line (m)
Passenger Car		Passenger Car	
0.57	1.16	1.16	0.57
Passenger Car		Semi-trailer	
0.56	1.17	0.95	0.05
Passenger Car		B-double	

0.53	1.20	0.94	0.06
Semi-trailer		B-double	
0.05	0.95	0.94	0.06

Regardless of opposed vehicle type, under average lateral separation conditions, semi-trailer and B-double drivers positioned the off-side edge of their vehicle very close to the edge line, maintaining around 95% of the unoccupied lane space towards the centreline.

Table 10 details the 95th percentile opposed vehicle envelopes regardless of opposed vehicle type. The off-side edge of the passenger car straddled the edge line, while both the semi-trailer and B-double occupied part of the wide, sealed shoulder. The semi-trailer wandered further onto the shoulder at 18% of the vehicle's width than did the B-double at 14% of the vehicle's width. This again indicates that B-double drivers tend to move less across the lane than semi-trailer drivers.

Table 10 Opposed vehicle envelopes under 95%ile lateral separation

Vehicle Type	Distance from Edge Line (m)	Distance from Centreline (m)
Car	-0.07	1.80
Semi-trailer	-0.45	1.45
B-double	-0.35	1.35

7.0 Conclusions

This study investigated the influence of heavy vehicles on driver behaviour, specifically their influence on lateral movement characteristics due to oncoming vehicles. Testing was undertaken on the Port of Brisbane Motorway in Australia, which is a two lane, two way, half-motorway segment that is relatively straight, level and away from the influence zones of ramp junctions. Two driver movement measures were considered; lateral separation between the nearest edges of two opposing vehicles, and lateral position of the nearest edge of individual vehicles from the road centreline.

The study showed that a maximum 7s time gap between opposing vehicles influenced drivers' positioning of their vehicles.

It was shown that the lateral positions of cars, utility vehicles, and semi-trailers are statistically different when opposed than when unopposed; whereas, the lateral positions of B-doubles were not. This indicates that B-double drivers did not tend to move laterally when opposed by oncoming traffic.

The study showed that, on average, passenger car drivers did not position their vehicles appreciably differently when opposed by semi-trailers and B-doubles than other passenger cars, and there was no appreciable difference in passenger car drivers' positions when faced by oncoming semi-trailers than B-doubles.

Average and 95th percentile envelopes were provided to indicate position in the lane of unopposed and opposed vehicles on this type of roadway section. The off-side edge of the 95th percentile passenger car straddled the edge line, while both the 95th percentile semi-trailer and B-double occupied part of the wide, sealed shoulder. The semi-trailer wandered further onto the shoulder. The vehicle envelopes are useful to understand the impacts of heavy vehicles on driver behaviour, and can also inform road design and pavement asset management.

8.0 References

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