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A Study on Commercial Vehicle Speeds and Its Operational Characteristics

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Abstract – *A commercial vehicle is the backbone of the logistics industry which drives a vibrant economy of a country. Nevertheless, commercial or heavy vehicle-related accident is drawing serious attention. The height, weight and width dimension of the commercial vehicles reduce the visibility of other drivers and thereby increase the risk of an accident. Furthermore, due to the evolution of technology, larger trucks are now equipped with higher horsepower where a lot of speeding-related accidents were reported. This study is set to evaluate the speed profile for different types of commercial vehicles at different road hierarchy. The results indicate that in general most of the heavy vehicles (4.39%-98.61%) travelled fast and did not comply with the speed limits posted on different types of road hierarchy. The lower the posted speed limit the higher the percentage of non-compliance rates which means that the compliance increase as the speed limit increase. The majority of the commercial vehicles (28%-57%) occupied the middle lanes and those smaller sizes of vehicles (as compared to other sizes of commercial vehicles) had more tendencies to travel on the fast lane.*

Keywords: Commercial vehicles, speed, risk of accident

1.0 INTRODUCTION

Commercial vehicle is the backbone of the logistics industry, which drives the vibrant economy of a country. Nevertheless, commercial or heavy vehicle-related accident is drawing serious attention. In 2014 alone, a total of 57,430 road accidents involving lorry, bus, and taxi was recorded (Ministry of Transport Malaysia, 2014). Figure 1 shows the commercial vehicle road accidents from 2005 to 2014 where a decreasing trend was detected since the year 2012**.** However, commercial and heavy vehicle-related accident is still challenging looking by the fact that the numbers of accidents are more than 10,000 vehicles per year and yearly new registered commercial vehicles are constantly on the rise.

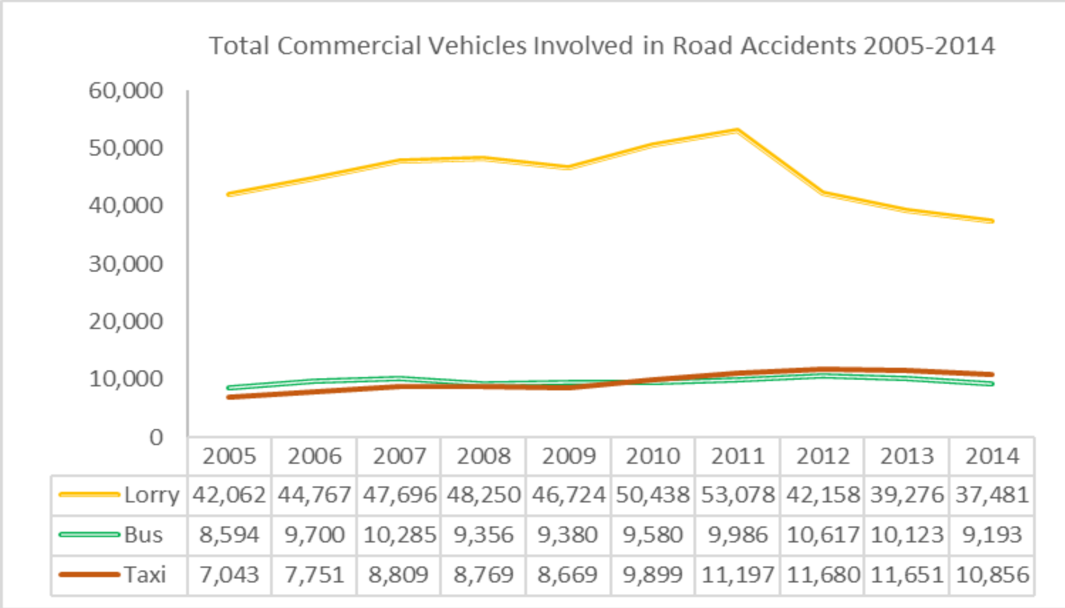

Figure 1: Road accidents involving commercial vehicles from 2005 to 2014

In Malaysia, "commercial vehicle" is the term used for all the public service vehicles and goods vehicles according to the Commercial Vehicles Licensing Board Act 1987. Goods vehicles are then divided into two categories according to their permissible laden weight: light goods lorry (*lori ringan*) below 5,999 kg and heavy lorry (*lori berat*) more than 6,000 kg (PUSPAKOM, 2018). Goods vehicles include also rigid lorry, rigid trailer lorry, tipper/dumper, prime mover, semi-trailer, and container prime mover (Ministry of Transport Malaysia, 2014). The goods vehicle definition may have some differences according to the country policy. In European Nation (EU), Heavy Goods Vehicles are referred to vehicles over 3.5 tons/3,500 kg maximum permissible gross weight (Evgenikos et al., 2016).

Commercial vehicle poses threats on other road users due to its physical size and traffic operational characteristics. The height, weight and width dimension reduces the visibility of other drivers and limiting the manoeuvre ability other road users (Mussa & Price, 2004). On rolling and mountainous terrain, larger trucks can hinder the traffic flow (Mussa & Price, 2004). However, due to the evolution of technology, larger trucks are now equipped with higher horsepower. This is true as we can frequently see commercial/heavy vehicles speeding on the roads.

While the presence of a commercial vehicle is unavoidable, its coexistence with other types of vehicles on the road is worrying. Many countermeasures such as truck restriction strategies have been implemented. For instance, commercial vehicles are restricted by speed, time, lane, and route. In addition, numerous researches were also conducted to explore the impact of various attributes such as vehicle and driver characteristics, environmental factors, restraint usage, alcohol impairment, roadway geometrics and other related factors on injury severities in accidents involving large trucks (Alassar, 1988; Campbell et al., 1988; Joshua & Garber, 1992; Brown & Baass, 1997; Chang & Mannering, 1999; Khorashadi et al., 2005; Chen & Chen, 2011). Works are also carried out to understand the difference between truck-related accidents in urban and rural areas (Khorashadi et al., 2005).

In Malaysia, all the commercial vehicles are limited to maximum 90 km/h on the expressway and 60 km/h to 80 km/h on the federal and state roads. A preliminary study on bus speeding on North-South Expressway was conducted during festive season found that 45% of 1041 buses exceeded the speed limit (90 km/h) and 67% of the buses travelled in the middle lane (MIROS, 2010). Another unpublished work by MIROS at Port Klang revealed that most of the trucks or heavy vehicles were driving above 90 km/h (MIROS, 2011). The speeding issues not only expose other road users to the risk of accident but also to the passengers in the vehicles. A study pointed out that speeding contributed 22.6% of the total crashes (Oluwole et al., 2015).

Little was known about the speeding problems of the other commercial vehicles particularly trucks and trailers. Its operational characteristics such as the preference travel lane by each type of commercial vehicle, the speed profile in the traffic stream as well as in the different road environments. Thus, this study is set to evaluate the speed profile for different types of commercial vehicles at different road hierarchy. The speed profiles are very useful in assisting the authority in road and infrastructure design. For instance, appropriate traffic calming measures can be deployed based on the speed profiles on the specific roads.

2.0 DATA DESCRIPTION

2.1 Data Collection

The data can be categorised into two types: characteristics of commercial vehicles on normal road and road with non-exclusive motorcycle lane. Therefore, two sets of data are needed in this study. The former data set was obtained from the video data from the other project (which was able to maximise the time, human and monetary resources) and the latter was collected on-site for this study.

The selection of data collection site was based on the following criteria:

i. The observation section of the road shall be on a straight section. This is to ensure that the observed heavy vehicle maintains its speed on a straight road section. It is because theoretically a vehicle would reduce speed at a horizontal or vertical alignment.
ii. Each section of the road shall have at least 5% of heavy vehicles from the total traffic volume. This is to ensure the validity of the results.
iii. Each section of the road shall have a vantage point to set up the equipment.
iv. Data collection shall be during off-peak hours and during clear weather for good visibility. This is also to ensure the consistency of the operational characteristics.

Similar criteria were applied to the study of commercial vehicles on non-exclusive motorcycle lanes.

2.2 Data Reduction

The software was developed to assist the data reduction of commercial vehicles. The software was named as Commercial Vehicles Speed Operational Characteristics Software (CVSOC). Figure 2 shows the snapshot of the software where the information such as characteristics of the roads, types of commercial vehicles and lane travelled. The videos (after selection) are in sync with the data logger interface in terms of the time (up to milliseconds) in order to calculate the speed of the observed commercial vehicles.

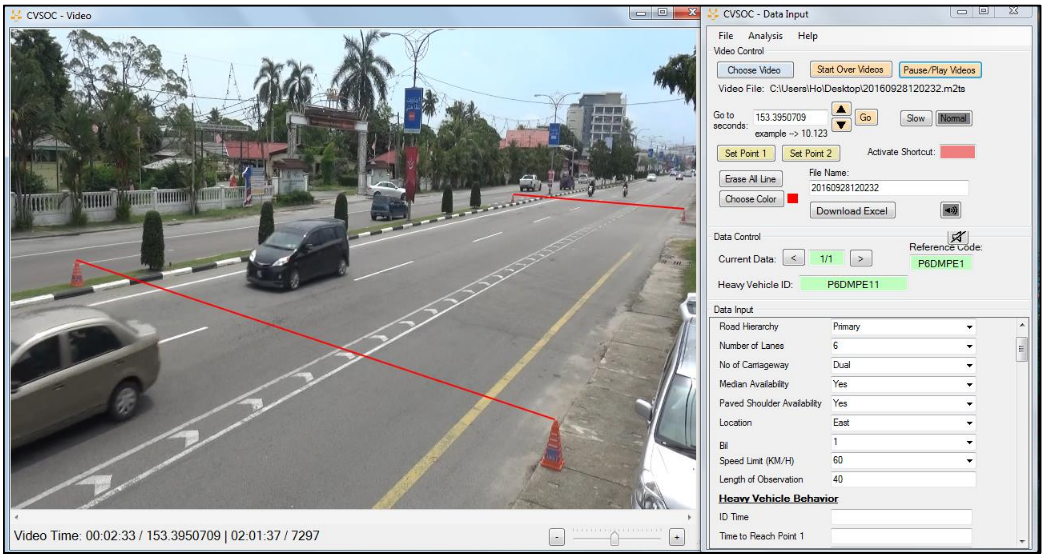

Figure 2: Screen shot of the CVSOC software

2.3 Data Analysis

Since the data were collected from roadside observations where the underlying factors to behaviour of the commercial vehicle driver cannot be determined (e.g. commercial drivers' inherent attitude to the road environment or to safety), additional heterogeneity across observations could be presence (Jones & Jørgensen, 2003). In light of the inherent deficiencies of current observation data, statistical and econometric methods have been developed to address this issue as unobserved heterogeneity (variations in the effect of variables across the sample population that are unknown to the analyst, see Revelt and Train (1998), Jones and Jørgensen (2003), Dupont et al. (2013) and Manan (2014)). Bias from unobserved heterogeneity is particularly important to take into account because estimates of the effect of independent variables will be biased even if the unobserved heterogeneity is not correlated with the observed independent variables (Washington et al., 2003). Unobserved heterogeneity is typically dealt with either by conditioning through random effects, or by transforming the data to eliminate individual-specific fixed effects (Revelt & Train, 1998). A three-level multilevel model for binary data with a single explanatory variable that has both fixed effect and random effect was proposed. It was observed that *yijk*, a binary response for commercial vehicle driver (*i*) in a commercial vehicle (*j*) and *xij*, an explanatory variable at the Level 1. Then, it defines the probability of the response equal to one as *pijk = Pr (yijk = 1)* and let pijk be modelled using a logit link function.

The standard assumption is that *yijk* has a Bernoulli distribution. Then the three-level model can be written as:

$$yijk = \log [pijk / (1 - pijk)] = \beta 0 + \beta 1xijk + u1jk\, xijk + v0k + u0jk \qquad (1)$$

where *i*, *j*, and *k* are index, respectively, Level 1, 2, and 3, *v0k* and *u0jk* are the random intercepts for Level 3 and Level 2, respectively, and *uljk* is the random coefficient for the explanatory variables *xijk*.

3.0 RESULTS AND DISCUSSION

A total of 42 sites (inclusive of six roads with non-exclusive motorcycle lane) has been selected for the purpose of this study. This study had observed a total of 7,168 commercial vehicles that include van, bus, different axles of lorries, taxi and prime mover. Figure 6 shows the distribution of commercial vehicles in this study samples. The highest sample sizes (46.42%) obtained from primary roads and two-axles light lorry accounted for the biggest proportion of the commercial vehicles.

Table 1 presents the speed data for all sites. The average speeds of commercial vehicles ranged between 47.60 km/h to 69.94 km/h on the four types of road hierarchy. It also exhibits that 85% of the commercial vehicles on these roads travelled above the minimum speed limits for the respective road hierarchy. On the other hand, the compliance rates for various posted speed limits configuration were also shown in Table 5. The results indicate that in general most of the heavy vehicles (4.39% to 98.61%) travelled fast and did not comply with the speed limits posted on different types of road hierarchy. The lower the posted speed limit the higher the percentage of non-compliance rates which means that the compliance increase as the speed limit increase.

Table 1: Distribution of speeds by road hierarchy

Road hierarchy	N	Mean speed	85th percentile	Speed limit	% Above speed limit	% above 85th traffic speed
Expressway	459	69.94	86.51	80	30.28	15.03
	2084			90	9.07	15.02
Primary	72	67.74	84.37	50	98.61	16.67
	482			60	43.94	15.20
	545			70	17.25	15.05
	1242			80	36.65	15.00
	1013			90	7.01	15.20
Secondary	154	62.29	75.10	60	60.37	15.24
	113			70	26.55	15.04
	570			80	4.39	9.82
	41			90	7.32	14.63
Collector	393	47.60	60.76	60	15.78	15.52

Table 2 shows the results of two model estimations. The mixed effect logistic regression result is divided into three sections: Fixed effects parameters, Random effects parameters or Hierarchical effects and Goodness-of-fit. After exhaustive attempts, there are only two models that are statistically significant to be considered; Model 1 and 2 are both statistically significant at the fixed and random parameters ($p<0.05$). In order to evaluate these models, each section of the table has to be examined.

Model 2 is better in explaining the factors and their variations in association with the occurrence of commercial vehicles moving with excessive speed. From Table 2, both models hold the same fixed parameters except for the commercial vehicle driving behaviour parameters (i.e. moving with the presence of other moving vehicles, overtaking behaviour and lane occupancy) in Model 2. Since both models hold similar parameters, they also have almost similar odds ratios but different in statistical significant level. However, in testing the Goodness of fit of both models, it seems that Model 2 has a better fit than Model 1 based on the AIC, i.e. $AIC_{Model\ 2} < AIC_{Model\ 1}$. Moreover, Model 2 has more explanatory variables that are statistically significant ($p<0.05$) compared to Model 1.

The fixed effects parameters can be interpreted as a normal logistic regression. Thus, focusing on Model 2, we can see that Expressway roads ($OR_{Model\ 2}$ = 6.193, 95% CI = 3.24–11.85) have the probability of nine times more likely than Primary roads to have commercial vehicle moving over the 85th speed of other vehicles. The analysis also shows that having a road without paved shoulder (or kerbed roads) and a road with Median has also the probability of 6 to 12 times likely to have commercial vehicle moving at excessive speed (Without paved shoulder: $OR_{Model\ 2}$ = 2.241, 95% CI = 1.45–3.46, With median: $OR_{Model\ 2}$ = 11.808, 95% CI = 6.30–22.13) than road with paved shoulder and roads without road median. Moreover, roads with 60 km/h have the highest likelihood probability (16 times) of commercial vehicles moving with excessive speed compared to roads with a speed limit of 70 km/h, 80 km/h, and 90 km/h.

In terms of commercial vehicle characteristics, the two-axle light-vehicle type ($OR_{Model\ 2}$ = 2.342, 95% CI = 1.07–5.13), 4-axle ($OR_{Model\ 2}$ = 3.662, 95% CI = 1.28–10.46) and the 5-axle or more vehicle type ($OR_{Model\ 2}$ = 4.123, 95% CI = 1.54–11.01) have two to four times likely to have commercial vehicle moving at excessive speed compared to a van. Surprisingly, commercial vehicle that is loaded with goods ($OR_{Model\ 2}$ = 1.333, 95% CI = 0.97–1.83) are more likely to move with excessive speed compared to an empty commercial vehicle.

In terms of the driving behaviour that were displayed by commercial vehicle drivers, the model predicts that commercial vehicles that are tailing a vehicle ($OR_{Model\ 2}$ = 2.994, 95% CI = 1.94–4.63) and moving in between two vehicles ($OR_{Model\ 2}$ = 3.782, 95% CI = 1.73–8.25) are three to four times likely to move beyond the 85th percentile speed, compared to those commercial vehicles that are moving without any other vehicle passing (see Table 17). The model also predicts that commercial vehicles that are being overtaken by other vehicles ($OR_{Model\ 2}$ = 2.912, 95% CI = 1.70–4.99) are three times likely to move with excessive speed compared to those commercial vehicles that are not overtaking other vehicles. Moreover, those commercial vehicles that moving on the second lane (i.e. middle lane out of three or more lane roads) ($OR_{Model\ 2}$ = 9.686, 95% CI = 6.62–14.17) and the slow lane ($OR_{Model\ 2}$ = 25.359, 95% CI = 17.05–37.72) are 10 to 25 times likely to move with excessive speed compared to commercial vehicles occupying the fast lane.

Table 2: Distribution of speeds by road hierarchy

Variables	Model 1				Model 2			
	OR	**SE**	**95% C.I.**		**OR**	**SE**	**95% C.I.**	
Fixed effects								
Intercept	1.352	0.94	0.35	5.30	1.201	0.70	0.38	3.76
Road hierarchy								
Expressway	6.193**	2.05	3.24	11.85	9.630**	3.58	4.64	19.97
Secondary	0.190**	0.05	0.11	0.32	0.109**	0.03	0.06	0.19
Collector	0.440*	0.22	0.17	1.15	0.232**	0.12	0.08	0.64
Road median								
With median	10.836**	3.32	5.94	19.76	11.808**	3.78	6.30	22.13
Number of lanes								
4 lanes	0.749	0.24	0.40	1.40	6.051**	2.34	2.84	12.91
6 lanes	0.014**	0.01	0.01	0.04	0.029**	0.01	0.01	0.08
8 lanes	0.026**	0.02	0.01	0.11	0.035**	0.03	0.01	0.16
Paved road shoulder								
Without paved shoulder	1.323	0.26	0.90	1.94	2.241**	0.50	1.45	3.46
Speed limit category								
60 km/h	7.486**	4.31	2.42	23.13	15.693**	10.18	4.40	55.98
70 km/h	4.910**	2.59	1.75	13.81	7.324**	4.29	2.33	23.07
80 km/h	2.336*	1.14	0.89	6.10	2.796*	1.52	0.96	8.11
90 km/h	3.930**	2.02	1.44	10.75	4.658**	2.57	1.58	13.72
Commercial vehicle type								
2 axle light vehicle	2.998**	1.03	1.52	5.90	2.342**	0.94	1.07	5.13
2 axle heavy vehicle	2.657**	0.98	1.29	5.48	2.010	0.87	0.86	4.68
3 axle vehicle	2.535**	1.01	1.16	5.53	1.969	0.90	0.80	4.82
4 axle vehicle	4.450**	2.08	1.78	11.14	3.662**	1.96	1.28	10.46
>5 axle vehicle	4.170**	1.81	1.78	9.76	4.123**	2.07	1.54	11.01
Bus	1.460	0.58	0.67	3.19	1.116	0.52	0.45	2.78
Taxi	0.880	0.32	0.43	1.80	0.875	0.38	0.38	2.03
Prime mover	7.309*	8.29	0.79	67.43	6.190	7.46	0.58	65.65
Loading								
Loaded	1.380**	0.20	1.04	1.83	1.333*	0.21	0.97	1.83
Overloaded	1.576	1.66	0.20	12.47	0.736	0.81	0.08	6.42
Presence of other moving vehicles								
In between two vehicle					3.782**	1.51	1.73	8.25
Beside a vehicle					1.843**	0.41	1.19	2.85
In front of a vehicle					1.706*	0.55	0.90	3.22
Tailing a vehicle					2.994**	0.66	1.94	4.63
Overtaking								
Being overtake					2.912**	0.80	1.70	4.99
Overtaking					0.686	0.17	0.42	1.12
Lane occupancy								
Second lane					9.686**	1.88	6.62	14.17
Slow lane					25.359**	5.14	17.05	37.72
Random effects/Hierarchical								
Level 1 (CV above 85^{th} % speed)								
Intercept variance, σ^2_{e0}	1				1			
Level 2 (CV type), Num. of groups								
Intercept variance, σ^2_{u0}	0.32	0.26	0.06	1.56	0.60	0.48	0.13	2.86
Level 3 (Zone) , Num. of groups = 4								
Intercept variance, σ^2_{v0}	0.17	0.11	0.05	0.59	0.23	0.15	0.06	0.83
Goodness-of-fit								
Number of observation	7191				7191			
Ll (model)	-1403.371				-1118.047			
df	25				33			
AIC	2856.741				2302.093			
BIC	3028.756				2529.153			
Integration method: mvaghermite								
Integration points	7				7			
Wald chi2	360.5				600.02			

P-value	0.000	0.000
LR test vs. logistic regression:		
chibar2(01)	58.88	67.76
Prob>=chibar2	0.000	0.000
Intra-unit correlation:		
ICC Level 1, ρ1	0.872	0.799
ICC Level 2, ρ2	0.084	0.145
ICC Level 3, ρ3	0.044	0.056

OR: Odds ratio, SE: Standard Error, C.I.: Confidence Interval
CV: Commercial Vehicle
* p < 0.1, ** p < 0.05, ***= significant at p<0.05 level based on the likelihood ratio test versus ordinary logistic regression (fixed effect parameters)
mvaghermite: Mean-variance adaptive Gauss–Hermite quadrature
AIC: Akaike's information criterion, BIC: Bayesian information criterion

One of the key interests of fitting a multilevel model here is to determine if, after controlling for the variables in the fixed part of the model, there is any statistically significant variation in the commercial vehicle moving with excessive speed outcomes within a certain zone or commercial vehicle type attributes. The variance between the three levels of each model may be neatly summarised by the three parameters σ^2_{e0}, σ^2_{u0} and σ^2_{v0} (see Table 2: Intra-unit correlation). They are known as variance parameters, as they measure the variance in the parameters at Level 1, 2 and 3. In other words, they show the relative variability in the model residuals that may be attributed to the effects of each Commercial vehicle (at Level 1) and the variation of Type of commercial vehicle (at Level 2) and Zone (at Level 3), as seen in Figure 3. In this case, the Level 1 variance parameter is constrained to the value 1 to correspond to a binomially distributed response, as stipulated by Jones and Jørgensen (2003), and this value is multiplied by $\pi^2/3$, which is extensively described in Jones and Jørgensen (2003)**.**

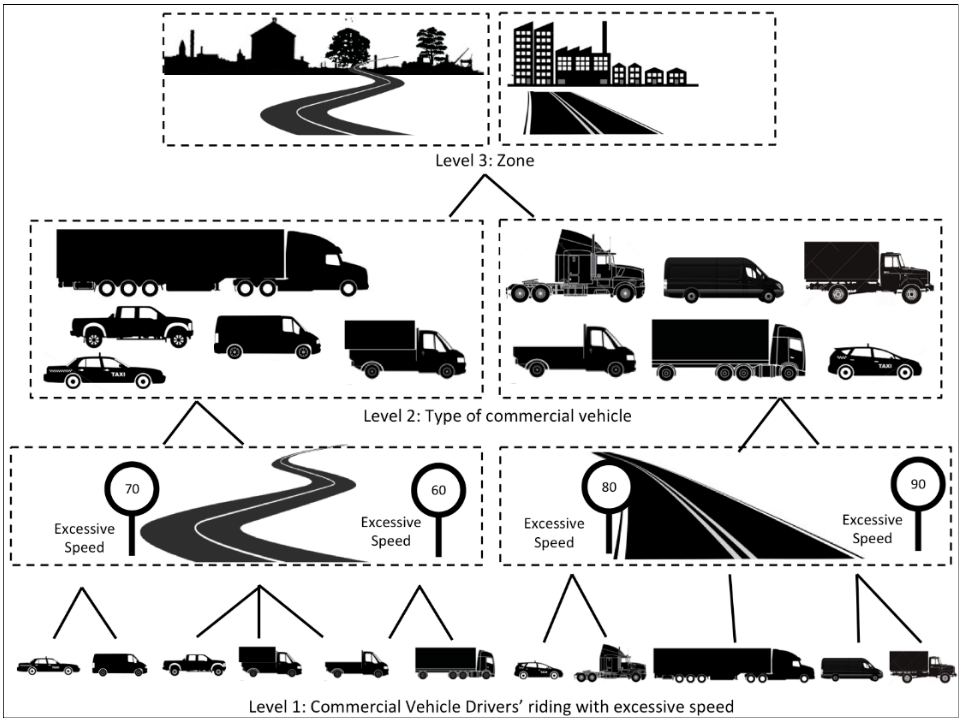

Figure 3: The diagram of the Mixed Effect Logistic Regression Based on Model 2

To estimate the proportion of overall residual variability, which is associated with each level, equations 3, 4 and 5 are used (see Table 2: Intra-unit correlation). Model 2 shows that 79.9% of the variations come from Level 1, i.e. each commercial vehicle, while the type of commercial vehicle (Level 2) and different types of Zone (Level 3) only constitute up to 14.5% and 5.6% respectively. Comparing the two models, Model 2's variations for Level 1 (14.5%) and Level 2 (5.6%) are higher than the variations in Model 1 due to the increasing number of explanatory variables (commercial vehicle driver's driving behaviour) into the model that reduces the variation at Level 1.

The high variation connected to each commercial vehicle may indicate that there can be additional commercial vehicle drivers' characteristics and riding behaviour associated with driving at excessive speed, that are yet to be identified. Furthermore, these variations also show that commercial vehicle driver's characteristics and riding behaviour are still the main factors compared to Zone and type of commercial vehicle. On the other hand, the level of variation for Zone associated with excessive speeding is lower than the other factors clearly indicate that the different types of zone may not be associated with excessive speeding. In other words, commercial vehicles may move with excessive speed regardless of the type of zones.

4.0 CONCLUSION

The data used in this study was collected from an observational study on various road hierarchies such as expressway, primary road, secondary road, collector road as well as non-exclusive motorcycle lane in Malaysia. This is to examine the effects of road characteristics on the occurrence of driving above the speed limit and excessive speeding. To ease the data reduction, a software known as CVSOC was specifically developed. The characteristics of commercial vehicles such as the type of vehicle, speed, lane occupancy, and moving manoeuvre were recorded.

A total of 7,168 commercial vehicles were observed on the four types of roads. Nearly 50% of them were collected on primary roads. About one-third of the samples were light lorry with two axles while two axles heavy lorry constituted 16%. Evidence from the results shows that most of the commercial vehicles travelled above the speed limits of the respective roads. When comparing with other vehicles in the traffic stream, the differential speeds were found statistically significant. The wide gap of speeds in the same traffic stream may elevate the risk of accidents. Johnson and Pawar (2005) proved that there will be more interactions with other vehicles when a vehicle's speed differs from the mean speed, thereby increase the risk of accidents.

While the divided road can reduce the potential head-on accidents, it was found that probability of speeding is increasing on the dual carriageway. The results were further reinforced by the model developed in this study where it shows that commercial vehicles were 12 times more likely to speed on the dual carriageway. It was also noted that the lower the speed limit, the higher the speed violation rates. This finding coupled with the high differential speeds among the traffic stream informs us that the risk of an accident is very high. To worsen the situation, lower speed limits are usually applied at the area where most of the human activities (i.e. pedestrian crossing or cycling activities) are anticipated.

The higher proportion of commercial vehicles travelled on the middle lane of the expressway and most of the commercial vehicles occupying the fast lanes were smaller in size. The 85th percentile speed on the fast lane reached 103 km/h and was significantly different from other commercial speeds on the middle and slow lanes. Nevertheless, it should be highlighted that 10% of the commercial vehicles with higher horsepower or high-performance trucks were observed travelling in the fast lane. It is quite alarming as it contributes to the overall risk of an accident.

On the other hand, it is interesting to see the opposite trend on a non-exclusive motorcycle lane. Speeds of the commercial vehicles were relatively slower on the dual carriageway as compared to their counterparts on the single carriageway. Significant different in speeds between the two carriageway were observed among van, two-axle light lorry, two-axle heavy lorry and lorry with 4 axles and above. The high travel speeds on single carriageway may trigger another problem such as excessive overtaking that results in head-on accident.

Based on the findings, it is suggested to segregate fast and slow-moving vehicles as well as the vehicles and the vulnerable pedestrians. The mix of fast and slow road users creates serious problems and it increases the risk of head-on and rear-end accidents. In most accidents, the vulnerable road users are always being the victims. Nevertheless, segregation by non-physical painting (non-exclusive motorcycle lane) observed some illegal occupying of commercial vehicles particularly buses on the lanes. Proper design of bus stop locations, as well as side parking, are essential, especially in urban areas. Lane restriction on trucks as implemented in other countries may be considered to be applied to the local expressways. Apart from this, enforcement by the relevant authority is indeed equally important in managing the speeds as well as overloading issues.

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