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An Analysis of Rear-End Impact Crash Characteristics and Injury Pattern in Malaysia

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Abstract – *Rear-end crashes are one of the most common types of accidents. The characteristics of rear impact crash (based on accident data in Malaysia) have not been well studied. The objective of this study is to investigate the rear impact crash characteristics in Malaysia between 2016 and 2018 using data obtained from Bukit Aman Traffic Investigation and Enforcement (JSPT), Royal Malaysia Police (RMP) Pol 27. The analysis revealed that motorcycles (40.3%) were the largest contributor to rear-end crashes, followed by occupant car (36.3%), lorry (16.3%), four-wheel (3.8%), bus (1.6%) and other vehicles (1.6%). The majority did not suffer any injury (60.8%), while there were fatalities (16.8%), injuries (14.3%), and severe injuries (8.1%). The highest percentage of fatal crashes occurred at the speed limit area 110 km/h (23.6%). The chi-square test showed that speed limit and type of crash were significantly associated (p<0.01). The result also showed a significant association between main vehicle part damage and injury level (p<0.01). The study shows a thorough examination and analysis of rear impact crash characteristics can provide important and useful information to guide transport policy, vehicle design, and driver education. Further research is needed to fully understand the key factors that contribute to rear-end impact crashes in Malaysia.*

Keywords: Rear-end impact crash, vehicle characteristics, speed limit, injury level

1.0 INTRODUCTION

Increased motorization has resulted in an unfortunate rise in road crashes. Motorization here refers to 'the process of adopting and using motor vehicles as a core part of economic and daily life'. It is estimated that annually over 1.2 million people died as a result of road crashes and up to 50 million people were injured and incapacitated (WHO, 2015). Most ASEAN countries record very high road fatality rates and they are rising exponentially. In fact, Malaysia's fatality rate is the third highest in ASEAN countries after Thailand and Vietnam.

Impact direction is categorized as frontal, left side, right side, rear, rollover, and others. Crash-type statistics reveal that rear-end collision is the fourth most common type of collision in single-vehicle crashes in the United States (NHTSA, 2016). The third-highest number of fatalities occur as a result of rear-end collisions in multiple-vehicle crashes.

Rear-end impact crash is considered important research focus due to its frequency and its severity. Rear-end crashes are defined as a type of crash where the rear side of a vehicle is hit by the front side of the following vehicle (Figure 1) (Butala, 2004; Chen et al., 2016). An increasing number of vehicles travel on freeways in many countries, resulting in congestions and accidents. Thus, identifying contributing factors to rear-end crashes, such as human behavior, road characteristics or environmental conditions, and vehicle characteristics is of practical importance to develop effective countermeasures for improving safety levels (Dimitriou et al., 2018).

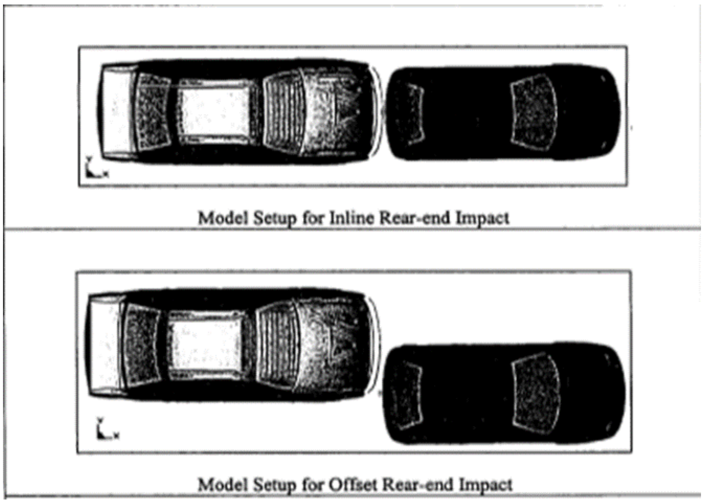

Figure 1: Rear-end crash configuration (Butala, 2004)

The National Highway Safety Administration (NHTSA) has reported that approximately 2.1 million rear-end crashes occurred in the US in 2015. It stated that although rear-end collisions account for only 6% of fatal automobile crashes, they account for 28% of all automobile accidents, making them one of the most frequent types of automobile accidents in the US. Despite this, rear-impact crashes are generally viewed as a benign crash mode with only damage to the vehicle and the passengers suffering at most minor injuries. However, in 2015, there were nearly 1,000 fatalities in rear-struck passenger vehicles, and 757 (63%) of these involved vehicles or light trucks manufactured in 2000 (NHTSA, 2016). Rear-struck crashes account for approximately 5% of fatalities of all passenger vehicles.

Previous research has shown multiple factors contribute to rear-end crashes, such as gender, age, and alcohol use, environment (time, weather conditions), road condition (surface and physical characteristics) (Li et al., 2014; Mendez & Izquierdo, 2010), vehicle type (Nikiforos, 2008) and the number of traffic lanes (Meng & Qu, 2012; Kim et al., 2016). However, research and studies on the rear-end impact crash characteristics in ASEAN countries, especially in Malaysia are lacking (Cicchino & Zuby, 2019). Therefore, this research serves as a preliminary study to investigate the characteristic of rear-end impact crash, in order to develop preventive programs in Malaysia.

In recent years, much attention has been given to increase the safety of car occupants. In Southeast Asia, the Car Assessment Program for Southeast Asia (ASEAN NCAP) advocates this using vehicle safety technology. On 15 November 2018, it published its 2021-2025 roadmap pushing the safety agenda further (see Figure 2). For 2021-2025, the assessment clutches are based on four pillars: Adult Occupant Protection (AOP), Child Occupant Protection (COP), Safety Assist, and Motorcyclist Safety. While the roadmap is comprehensive enough in improving occupant protection, its focus is more on frontal and side collision. Further scrutiny of the roadmap revealed limited features directly addressing rear-end crashes, such as Automatic Emergency Braking technology (AEB) for the city and interurban, advanced safety assist technology, and rearview technology.

ASEAN NCAP 2021-2025	AOP		COP		Safety Assist		Motorcyclist Safety	
	Item	Max	Item	Max	Item	Max	Item	Max
	Frontal	16	Frontal	16	*EBA*	6	*BSD / BSV*	8
	Side	8	Side	8	*SBR(Fr.)*	3	*Rear View Technology*	4
	HPT Evaluation	8	CRS Installation	12	*SBR(Rr.)*	1.5	*AHB*	2
			Vehicle Based Assessment	13	*SBR(Rr.) Advanced*	1.5	Pedestrian Protection	2
			Child Presence Detection	2	*AEB City*	2.5		
					AEB Inter Urban	3.5	*[Advanced MST]**	2*
					Advanced SAT	3	**BONUS POINT*	
Score		32		51		21		16
Weighting		40%		20%		20%		20%

Slanting = Fitment Rating System

** To add 2 points MAX to total MS point*

	AOP (%)	COP (%)	Safety Assist (%)	Motorcyclist Safety (%)
5 ★	80	75	70	50
4 ★	70	60	50	40
3 ★	60	30	40	30
2 ★	50	25	30	20
1 ★	40	15	20	10

Figure 2: ASEAN NCAP Roadmap 2021 – 2025 Rating Protocols

2.0 METHODOLOGY

2.1 Data Source

The researchers accessed the primary database from *Bukit Aman Traffic* Investigation and Enforcement (*JSPT*), the department under The Royal Malaysia Police (RMP) POL 27. Data for this research were accident rates between 2016 and 2018 and they were carefully selected, processed and analyzed to ensure accuracy of interpretations and subsequent findings. Hence the selected data:

i. were based on the first impact of rear-ends collision that involved multiple vehicles (see Figure 3). The triangles represent the vehicles. The top corner of the triangles is the front of the vehicles.

ii. involved 2,718 cases of rear-end collisions. As vehicle data had to be considered in this analysis, driver, and vehicle factors were added to the dataset. The dataset comprised 8,308 vehicles involved in crashes.
iii. rear-end impact crash characteristics were vehicle (the type of vehicle, speed limit, and main part vehicle damage) characteristics and injury pattern of drivers.

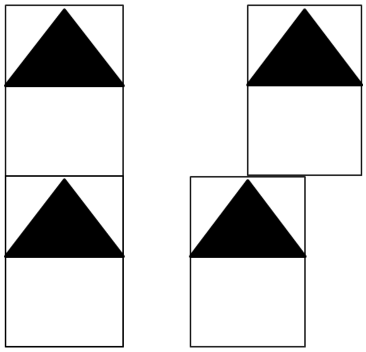

Figure 3: Rear-end crash configuration (first impact)

2.2 Data Analysis

Statistical Packages for Social Sciences (SPSS) software (volume 25.0, IBM Corp., New York, USA) was used to analyze the data. Descriptive analysis was used to obtain frequency and percentage. In addition, inferential analysis (chi-square analysis and odd ratio) was performed to investigate the distribution of rear-end impact characteristics.

3. RESULTS AND DISCUSSION

3.1 Vehicle Characteristics

3.1.1 Crash Type

Table 1 shows the type of crash that occurred in rear-end crashes. This type of crash is represented as a type of crash for each case in rear-end crashes. The highest percentage of crash types in multiple vehicles were 46.5% involving fatal crashes, 30.4% not severe crashes, 17.4% severe crashes, and the rest involving only vehicle damages. Most of the vehicles involved in fatal crashes were motorcycles. Isa et al. (2011) and Abdul Manan and Varhelyi (2012) found that the absence or improper use of helmets raises the risk of death and injury.

Table 1: Type of rear-end crash severity

Type of crash	Frequency	Percent
Fatal	1,263	46.5
Severe	472	17.4
Not severe	837	30.8
Damaged only	146	5.4

3.1.2 Type of Vehicles

Table 2 shows the number of different vehicle types involved in rear-end crashes based on whether they were the striking or struck vehicle in the crash. The motorcycle was the biggest contributor to rear-end crashes (40.3%), followed by occupant car (36.3%), lorry (16.3%), four-wheel (3.8%), bus (1.6%), and other vehicles (1.6%), such as bicycle and van. In Australia however, Baldock et al. (2005) found that it was occupant car that was involved in most rear-end crashes. This could be explained by the fact the proportion of the motorcycle population in Malaysia was 5% higher than passenger cars. Abdul Manan and Varhelyi (2012) also reported that in Southeast Asia, a crash involving a motorcycle, more than any other vehicle, results in fatality and serious injuries.

Therefore, including motorcycle safety in the roadmap of ASEAN NCAP is vital. This research shows solid evidence based on data in placing motorcyclist safety at the forefront of the road safety agenda to ensure the safety of motorcyclists in Southeast Asia. Furthermore, to address this high involvement of motorcycles in crashes, related technology should consider motorcycles as their main target feature, among others. For example, a good AEB technology for the region should work with small size motorcycles as well.

Table 2: Vehicle type in rear-end crashes

Vehicle Type	Frequency	Percentage
Motorcycle	3,319	40
Occupant Car	2,992	36
Lorry	1,346	16.2
4-Wheel Drive	317	3.8
Bus	133	1.6
Others	201	2.4

3.1.3 Speed Limit

Table 3 shows the speed limit at the location of the crashes. The highest percentage of crashes occurred at areas where the speed limit is 70 kilometers per hour (km/h) (26.9%), 17.7% of crashes happened at the location with a speed limit of 90 km/h, followed by 16.7% at the speed limit of 110 km/h, 11.6% at the speed limit of 80 km/h, while 11.1% of crashes happened at the speed limit of 50 km/h. Morris (1989) reported that rear-end impacts at as little as 8 km/h could give rise to significant damage and injuries. On average, Aarts and Van Schagen (2006) suggested that a 1% change in speed would lead to a 2% change in the injury suffered in accidents, a 3% change in severe injury accidents, and a 4% change in fatal accidents. Getting into a rear-end collision while driving slow (under 48.28 km/h) may cause whiplash injury (neck is forcibly pushed forward and then backward, or vice versa) (Castro et al., 1997).

3.1.4 Damaged Vehicle Parts

Table 4 shows the main vehicle part damaged in rear-end crashes. The cause of rear-end collisions is the car behind crashing into the car in front. Therefore, the data showed most damages occurred in the frontal side (41.0%), followed by the rear side (37.6%), various sides (13.5%), left side (2.6%), right side (2.3%), and at the top of the vehicles (0.1%). Interestingly, 2.9% of vehicles were undamaged in this type of crash. A possible explanation for this is the crash has occurred at a slower speed rate. The results of this study support the view passengers and drivers in rear-end crashes must be provided with an extra layer of protection and safety.

Table 3: Speed limit

Speed (km/h)	Frequency	Percent
50	302	11.1
70	732	26.9
80	314	11.6
90	480	17.7
110	454	16.7
Others	436	16.0

Table 4: Main parts damaged in rear-end crashes

Vehicle Main Parts Damage	Frequency	Percent
Front	3,413	41
Rear	3,127	37.6
Various	1,122	13.5
Undamaged	238	2.9
Left Side	214	2.6
Right Side	189	2.3
Top	5	0.1
Total	**8,308**	**100**

3.2 Injury Pattern

3.2.1 Injury Level

Figure 4 shows the percentage of the severity of driver's injury, namely (1) fatal, (2) severe injury, (3) injury, and (5) no injury in rear-end crashes in Malaysia between 2016 and 2018. It is shown that the highest percentage of injury levels among drivers were fatal (16.8%), injury (14.3%), and severe injury (8.1%). A total of 60.8% did not suffer from any injury. Even at low speeds, a rear-end collision can have a violent impact. The head can quickly hit the steering wheel or dashboard and cause a concussion or other trauma. Head impact injuries can worsen in a matter of hours.

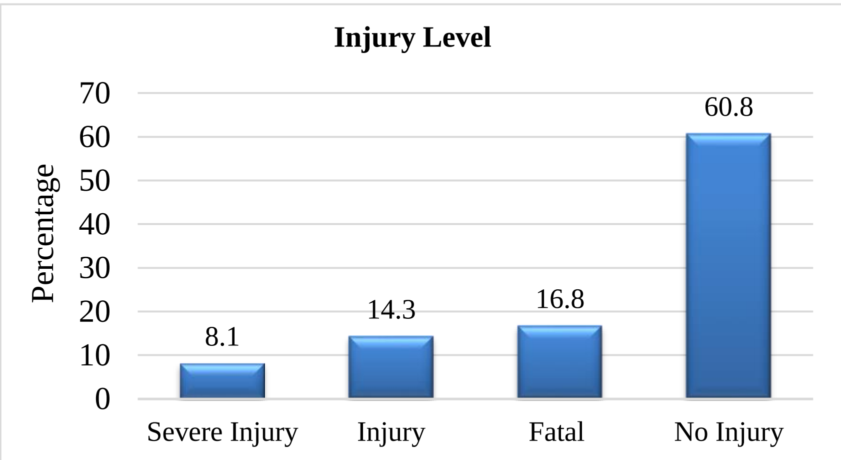

Figure 4: The percentage of driver's injury level

3.2.2 Body Injury

Figure 5 shows the distribution of body parts injury in multi-vehicle rear-end crashes. The absence of injury for both males (67.2%) and females (10.2%) indicates only the vehicles suffered damage. A total of 6.1% male and 0.63% female suffered injuries and out that 5.1% and 0.5% male and females respectively suffered head injuries. Additionally, male drivers suffered from a leg injury (5.2%), hand injury (2%), chest injury (0.89%), back injury (0.5%), neck injury (0.3%), and buttock injury (0.2%). Head injury relates to head retraction leading to whiplash. Stemper et al. (2004) suggested that high impact velocities result in a high magnitude of head retraction. According to Connolly (2017), whiplash condition is common in a rear-impact crash where the neck and head flipping back against the headrest cause long-term consequences. The injuries experienced during a rear-end collision will vary depending on the speed of the vehicle. But even a minor wreck can cause severe damage to the body. When another vehicle hits yours from behind, its momentum is shifted to your car – and your body.

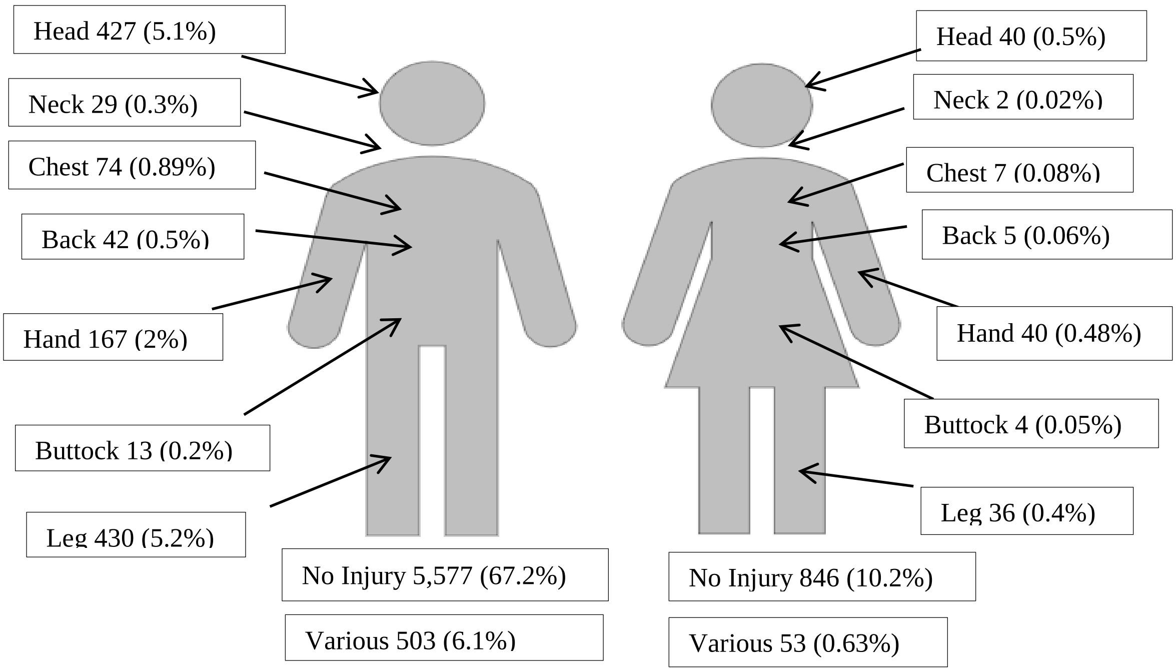

Figure 5: Percentage of injury according to body parts (left - male, right - female)

3.3 Association between Speed Limit and Type of Crash

Table 5 shows the cross-tabulation of speed limit and type of crash. While the speed limit does not necessarily represent the operating speed, it provides an association between speed and fatality. The highest fatality crashes occurred at the speed limit area 110 km/h (23.6%) followed by 70 km/h (23.2%), 90 km/h (19.7 %), 80 km/h (10%) and 50 km/h (9.3%) and others (14.2%). The most interesting finding is the significant association between speed limit and type of crashes. The speed limit of 90 km/hour had a 1.68 higher likelihood of leading to a fatal crash than that of 50 km/hour ($\chi 2$ (1) = 12.20, p <.00). Furthermore, the speed limit of 110 km/hour had a 2.97 times higher likelihood of resulting in a fatal crash than that of 50 km/hour ($\chi 2$ (1) = 51.72, p <.00). However, the observed association between speed limit ≤ 80 km/hour and type of crash is not significant ($\chi 2$ (1) = 0.08; 0.07, p >.00).

The findings have important implications for developing strategy and relevant technology toward reducing the number of road traffic fatalities due to rear-end crashes. The AEB in vehicles is one of the emerging technologies that can prevent imminent accidents and reduce a collision's severity. The most basic AEB systems work at low speeds to prevent or reduce the severity of minor collisions in urban areas. The findings highlight the need for having the AEB work at a wider range of speed, and not just at low speed. With the significant odds of fatality of rear-end collision starting at 90 km/h, relative to 50 km/h, effective AEB systems need to at least consider 90 km/h as the minimum speed it can operate.

Even though the odds of fatality are not significantly higher than one for the case of 80 and 70 km/h, this is relative to 50 km/h as the reference. Should the reference be reduced to 30 km/h, for instance, the results may change with the likelihood for the odds to be higher.

Table 5: Cross-tabulation of speed limit and type of crash

Speed Limit (km/h)	Type of Crash		Chi-Square	Odd Ratio
	Fatal Frequency (%)	Non-Fatal Frequency (%)		
50	118 (9.3)	184(12.6)	Reference	
70	293 (23.2)	439 (30.2)	0.08	1.04
80	126 (10)	188 (12.9)	0.07	1.04
90	249 (19.7)	231 (15.9)	12.20*	1.68
110	298 (23.6)	156 (10.7)	51.72*	2.97
Others	179 (14.2)	257 (17.7)	0.29	1.09
Total	1,263 (100)	1,455 (100)		
Note: *sig < 0.001				

3.4 Association between Main Vehicle Part Damage and Injury Level

Table 6 shows the cross-tabulation of main vehicle part damage and injury level. The highest percentage of fatality crashes occurred at the front (52.6%) followed by various parts (24.8%), rear (18.6%), others (14.2%), right and left part (1.5%), and undamaged (1%). The most interesting finding is a significant association between main vehicle part damage and injury level. Various part damage has an 80% higher likelihood of fatality than rear part damage ($\chi2$ (1) = 344, p <.00).

Furthermore, rear part damage has a 33% lower likelihood of fatality than front part damage ($\chi2$ (1) = 220.77, p <.00). However, rear part damage was shown as the second-highest part damage for rear-end crashes that contributed to fatal and other injuries. Most of the crash centers have given priority to frontal and side crash tests. The results of the current study further support the idea of including the rear crash test in-car safety assessment programs.

Table 6: Cross-tabulation of main vehicle parts damaged in rear-end crashes

Main Vehicle Parts Damaged	Injury Level		Chi-Square	Odd Ratio
	Fatal Frequency(%)	Non-Fatal Frequency (%)		
Rear	259 (18.6)	2,868 (41.5)	Reference	
Front	733 (52.6)	2,680 (38.8)	0.00*	0.33
Right	21 (1.5)	168 (2.4)	0.17	0.72
Left	21 (1.5)	193 (2.8)	0.43	0.83
Top	0 (0)	5 (0.1)	0.50	-
Various	346 (24.8)	776 (11.2)	0.00*	0.20
Undamaged	14 (1)	224 (3.2)	0.19	1.45
Total	**1,394 (100)**	**6,914 (100)**		
Note: *sig < 0.001				

4.0 CONCLUSION

This paper has presented a preliminary analysis of the characteristics of rear-end crashes in Malaysia. It is additionally one of the first attempts to investigate this topic in the context of Malaysia. The analysis and subsequent findings have provided a useful and new perspective on rear-end impact crash in Malaysia, as well as a better understanding of their characteristics. The findings suggest that first, there is a significant association between speed limit and type of crash, and second, a significant association between main part vehicle damage and injury level. There is limited information on a struck and striking vehicle in a rear-end crash that involved multiple vehicles. Further research is needed to fully understand the significant factors that contribute to a rear-end impact crash in Malaysia

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