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A Review of Motorcycle Safety Technologies from the Motorcycle and Passenger Car Perspectives

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REVIEW **Open Access**

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Abstract – *Motorcycle riders have been the top contributor to road deaths for over a decade in Malaysia. With proper safety technology systems installed on the upcoming models, it is predicted that motorcycle crashes and deaths can be reduced in the next decade. This study aims to review the past, recent, and upcoming vehicle safety technologies from the motorcycle and passenger car perspective that can potentially help reduce motorcycle crashes and injury risks. Various safety technologies have been introduced for passenger cars such as anti-lock braking systems, electronic stability control, lane keep assistance, traction control, blind-spot detection, autonomous emergency braking, and many more. With the requirements of ASEAN NCAP, these technologies are introduced to make passenger cars safer and to avoid road collisions, especially with the motorcycle. However, the opposite is true for motorcycles where only expensive motorcycles have these safety technologies, while for lower-capacity motorcycles, only basic and compulsory technologies are introduced even though this group remains the top contributor to motorcycle crashes and road deaths in Malaysia. Therefore, it is suggested that more safety technologies be introduced for motorcycles especially lower-capacity models. While for passenger cars, there are newer technologies that can be introduced to improve the current offerings to enhance the safety of passenger cars and other vehicles on the road and reduce the risk of road fatalities.*

Keywords: Motorcycle, safety technologies, ASEAN NCAP

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1.0 INTRODUCTION

The motorcycle is the main mode of transport for the majority of Malaysians to commute to work especially in the city where road congestions are the norm. Due to its smaller size, the motorcycle enables its rider to weave in and out of traffic, splitting between lanes to allow the

rider to arrive at a destination earlier or on time (Ibrahim et al., 2019; Abdul Khalid et al., 2020a; Abdul Khalid et al., 2020b). However, these advantages can take a turn for the worse for the country's road accident statistics, where thousands of motorcyclists have been involved in crashes every year, with the number constantly on the rise (Royal Malaysia Police, 2018). This contributes to over 60% of motorcyclist fatalities in Malaysia as the group continues to top the road deaths statistics for more than a decade (Abdul Manan et al., 2018; Royal Malaysia Police, 2018). Despite the many initiatives including studies, campaigns, and programs at national and international levels (Hamzah et al., 2018; Solah et al., 2019; Alias et al., 2020; Sitthiracha & Koetniyom, 2020), there has been no significant improvement in the number of motorcyclist fatalities since the last decade.

Based on The Royal Malaysia Police road crash statistics, the most common collision types are head-on, rear, lateral, and loss of control situations involving single and multi-vehicle crashes (Kak & Abidin, 2019; Rashid et al., 2019). These common collision types are potentially avoidable and road crashes can be reduced by introducing safety technologies to vehicles (Araujo et al., 2017; Kumaresh et al., 2017; Teoh, 2018; Kassim et al., 2019; NHTSA, 2019).

Vehicle safety technologies can also assist motorcyclists to brake in time, maneuver safely, and be alert to their surroundings aside from assisting passenger car drivers with warnings on the presence of motorcycles and other vehicles, braking and avoiding collisions; although the majority of road crashes were due to human errors (Sultan et al., 2016; Allen et al., 2017; Abdul Manan et al., 2018).

With the emerging safety assist technologies worldwide, it is expected that such technologies can help reduce road crashes and save the lives of motorcyclists who have been involved in over 4,000 road fatalities in Malaysia each year. This study aims to review the current safety technologies in motorcycles and also passenger cars in Malaysia that can potentially help to reduce multi-vehicle collisions and enhance motorcyclists' safety.

2.0 LITERATURE REVIEW AND MARKET SURVEY

2.1 Safety Technologies on Motorcycles

This section will discuss the current safety technologies installed on motorcycles in Malaysia that can potentially reduce the risks of road crashes; whether involving a single motorcycle or a motorcycle with another vehicle. In this literature review, the term "motorcycle" only represents powered-two-wheelers (PTW) of category L1 and L2 under the United Nations (UN) definition and excludes other motorcycle categories.

2.1.1 Regulation Concerning Motorcycle Safety

Malaysia's Road Transport Department (RTD/JPJ) is committed to the UNECE World Forum for Harmonization of Vehicle Regulations (WP.29), where all UN regulations on vehicles will be harmonized and implemented in Malaysia in stages (Lamin et al., 2012). The regulations aim to ensure all motorized vehicles are produced according to specific safety standards to help reduce user injury severity and thus, prevent road crash fatalities.

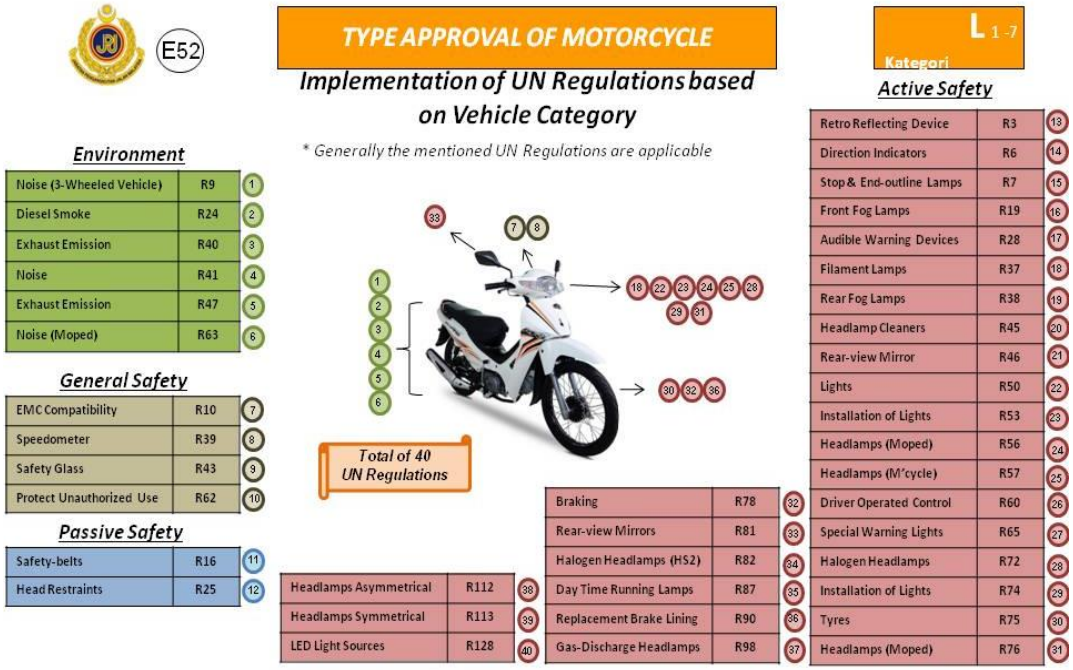

Figure 1: Current UN regulations implemented based on vehicle category L (1-7) (JPJ, 2018)

Figure 1 shows the list of UN regulations that have been gazetted for category L vehicles. In the list, there are few safety technologies included for mandatory installation on motorcycles (also Powered Two Wheelers – PTW). Passive safety only comprises the helmet. Active safety, on the other hand, involves the visibility or conspicuity of motorcycles such as retro-reflective devices, Daytime Running Light (DRL) for front and rear lights and signals. Other active safety devices include side or rearview mirrors and braking systems.

The DRL was introduced due to its ability to help motorcycles be in contrast to the surroundings and allow other road users to detect motorcycles in mixed traffic especially during the day (Abdul Khalid et al., 2020a; Lee & Sheppard, 2018; Sohadi, 2005; Solah et al., 2013). On the other hand, signal lights were introduced to warn other road users as an indicator of the motorcycle change in direction as well as provide a warning on the motorcycle's presence in the traffic (Isa et al., 2020). The retroreflective device is another initiative for motorcycle conspicuity as it helps the motorcycle to be more visible on the road at night (Abdul Khalid et al., 2020a). The mandatory installation of reflective plates at the rear and side body of the motorcycle somewhat contributes to motorcycle conspicuity at night even when the motorcycle is ridden without its rear lights. This, in turn, can potentially help motorcycles to be detected from a distance and reduce the risks of road crashes due to conspicuity issues (Abdul Khalid et al., 2020a).

A side or rearview mirror must be installed to help motorcyclists view their surroundings especially in their blind spot and can potentially help them avoid road collisions (Hashim et al., 2018; Azmi et al., 2019; Zaman et al., 2020). Although the braking system regulation does not specifically state what braking technology to be used, there is a minimum requirement of the motorcycle braking system. Nevertheless, a braking system technology such as Anti-Lock Braking System (ABS) is believed to be more efficient and should be considered to be in the regulation. The system should be made compulsory as it has helped to reduce the risk of road

crashes and injury severity (Ariffin et al., 2017; Kumaresh et al., 2017; Dinges & Hoover, 2018; Teoh, 2018).

2.1.2 Motorcycle Categories and the Different Safety Technologies

This section will discuss motorcycle categories that are well known in Malaysia. However, the categories are dissimilar to the definitions by UN (L category vehicle). The categories include (i) the "Kapcai" representing a cub-type motorcycle; (ii) the Scooter representing a motorcycle with an automatic transmission; and (iii) the Big Bike representing a motorcycle with an engine displacement of 250cc and above.

Table 1: Comparison between different types of motorcycle categories per their safety technology

Categories	"Kapcai"	Scooter	Big Bike
Common Engine Displacement	185cc and below	200cc and below	250cc and above
Cost (RM)	4,000 – 11,000	6,000 – 13,000	Above 15,000
Braking Technology	Drum and disc	Drum, Disc, Combined Braking System (CBS) and Anti-lock Braking System (ABS)	Disc, CBS and (ABS)
Other Advanced Safety Technology / Safety Assists	None	None	Motorcycle stability control (MSC), traction control, emergency hazard light, adaptive headlight, Electronic Tyre Pressure Monitor and others

Table 1 shows the comparison of safety technologies between the different motorcycle categories in Malaysia. As shown in the Table 1, the "Kapcai" is mainly a low cc motorcycle category with an underbone design. The highest cc registered in Malaysia under the Kapcai category is 185cc (Sharom, 2018). With an affordable price range, the Kapcai is usually offered with a basic braking technology comprising either the drum or disc brake type. Only one Kapcai model is registered with ABS technology. The Kapcai motorcycle does not feature any advanced safety technology or safety assists. Its low price may be the main reason why Kapcai lacks better safety technology and only fulfills the mandatory requirement by JPJ.

The Scooter, on the other hand, offers a much better braking technology than the Kapcai. The Scooter is usually a small cc motorcycle model (below 250cc) with an automatic transmission and both its brakes (front and rear) are located at each side of the handle. With an almost similar price range to the Kapcai, the Scooter offers better braking technology. A new 125cc and above Scooter model is observed to offer CBS technology while a more powerful type of Scooter with an engine displacement of 150cc and above is observed to feature ABS technology. This suggests the lower ranking of the Kapcai in terms of safety technology as compared to the Scooter. However, no additional advanced safety technology can be found on a rather low cc Scooter although higher cc Scooter models (250cc and above) do feature a more advanced safety assist technology (Honda, 2020; MODENAS, 2020; SYM, 2020; Yamaha Motor, 2020).

The third motorcycle category, the Big Bike, represents a motorcycle model with an engine displacement of more than 250cc. Pricier than the rest, it is no surprise that the Big Bike offers much better safety technologies and more advanced safety assists. Newer Big Bikes are equipped with CBS or ABS for better braking and stability control while braking. The Big Bike offers many other advanced safety technologies including the Motorcycle Stability Control (MSC), traction control, emergency hazard light, adaptive headlight, electronic tire pressure monitors, and many more. This shows that any upcoming motorcycle safety technologies will probably be introduced on the Big Bike first, compared to the other categories. However, as observed on the market, Big Bikes with more advanced safety technologies are more expensive and this proves that safety is still a luxury. This is why smaller and cheaper motorcycle models have fewer safety technologies.

From the observation, it is clear that the Kapcai offers the lowest safety features as compared to the rest. The Scooter category, which is almost in the same price range as the Kapcai, offers better safety technologies, especially for the braking systems. It is believed that the motorcycle braking system is one of the most important elements to potentially reduce motorcycle crashes and fatalities. Hence, it should be announced as a mandatory fitment on all motorcycle models, especially in Malaysia. The Big Bike, on the other hand, offers more advanced safety technologies than the rest. However, its capability to be ridden at higher speeds still makes it hard to control and this has contributed to road fatalities among Big Bike riders in Malaysia (Honda, 2020; MODENAS, 2020; SYM, 2020; Yamaha Motor, 2020).

2.1.3 Current Technologies to Enhance Motorcycle Safety

Various new technologies are being introduced for motorcycles in Malaysia. However, most are installed on the Big Bike motorcycles probably because of their high price, production and fitment costs, and maintenance. The following briefly explains the recently introduced safety technologies on motorcycles that can help save motorcyclists' lives on the road.

Motorcycle CBS

The CBS is a system that links the front and rear brakes of a motorcycle. This system allows the motorcyclist to apply both front and rear brakes by pressing a single brake lever and the amount of brake applied is controlled by a control valve. This type of braking system could help motorcycles to brake at a shorter distance, stop on time and potentially avoid a hazard or road collision from happening if the brakes are applied in the right way (Green, 2006).

Motorcycle ABS

The ABS offers a better braking experience; making the motorcycle more stable and easier to maneuver while braking. It operates by preventing the wheels from locking during braking especially in an emergency and this avoids the motorcycle from skidding and falling during braking. In turn, the system can help motorcyclists brake at a shorter distance and allow them to avoid hazards and road collisions without motorcycle skidding (Ariffin et al., 2017; Dinges & Hoover, 2018; Teoh, 2018).

Motorcycle Stability Control (MSC)

The MSC is another level of motorcycle technology that enables the motorcyclist to have better stability and control especially during braking and accelerating on straight and winding roads. By continuously monitoring the wheel rotation and speed, MSC provides the motorcyclist with effective stability and braking control while avoiding the motorcycle from falling during hard braking and cornering. This can potentially help the motorcyclist to improve motorcycle handling and also avoid high-speed crashes or loss of control crashes.

2.2 Safety Technologies on Passenger Cars

This section will discuss the current safety technologies on passenger cars in Malaysia that can potentially help reduce the risks of multi-vehicle road crashes and road collisions particularly involving a motorcycle. In this review, the term "passenger cars" represents the sedan car, hatchback, Sports Utility Vehicle (SUV), and Multi-Purpose Vehicle (MPV) that are sold in Malaysia.

2.2.1 Regulations on Passenger Car Concerning Motorcyclist's Safety

Similar to motorcycles, passenger car manufacturers in Malaysia are also required to follow the UN regulations gazetted by JPJ. Figure 2 shows the list of UN regulations that have been gazetted for category M1 vehicles (last updated in 2018). As shown in Figure 2, 59 UN regulations have been harmonized with their implementation being mandatory to the manufacturers of M1 vehicles sold in Malaysia.

The safety technologies include safety belts, airbags, retro-reflective devices, DRL, side and rearview mirrors, ABS, Electronic Stability Control (ESC), and many more. The mandatory installation of these technologies has, to a certain extent, reduced the number of road crashes, injury severities, and fatalities involving passenger car occupants (Royal Malaysia Police, 2018).

With the mandatory implementation of these safety technologies, it is hoped that road collisions involving passenger cars and motorcycles can be reduced. The mandatory installation of ABS in 2014 and ESC in 2016 (Kassim et al., 2017b) allow passenger cars to have better control and braking capabilities to avoid road collisions from happening especially with motorcycles in mixed traffic (Abdul Khalid et al., 2020b). However, the target has not been achieved as multi-vehicle crashes involving passenger cars and motorcycles are still frequent (Royal Malaysia Police, 2018). Clearly, there is a need to introduce better safety technologies in passenger cars that can help reduce the risk of road crashes.

2.2.2 ASEAN NCAP's Influence on The Fitment of Safety Technologies on Passenger Cars

Safety technologies in passenger cars are rapidly introduced in Malaysia. It can be observed that even the national cars (Proton and Perodua) with a cheaper price have introduced a lot of safety technologies similar to even continental cars. Safety technologies have now become affordable and car manufacturers are competing to introduce better safety technologies along with their products on the market.

Since the establishment of the New Car Assessment Program for Southeast Asian Countries (ASEAN NCAP) in 2011, safety technologies in passenger cars have experienced swift changes. ASEAN NCAP has played a big role in bringing safety technologies to Malaysia. Their crash tests, protocol, and requirement of the test have encouraged vehicle manufacturers to introduce more safety technologies to their vehicles (Abashah et al., 2020; Kassim et al., 2017a; Kassim et al., 2017b). The ASEAN NCAP star rating, which represents how safe the car is, has influenced manufacturers to design safer vehicles and also have become part of the selling points among car manufacturers (Kassim et al., 2017a).

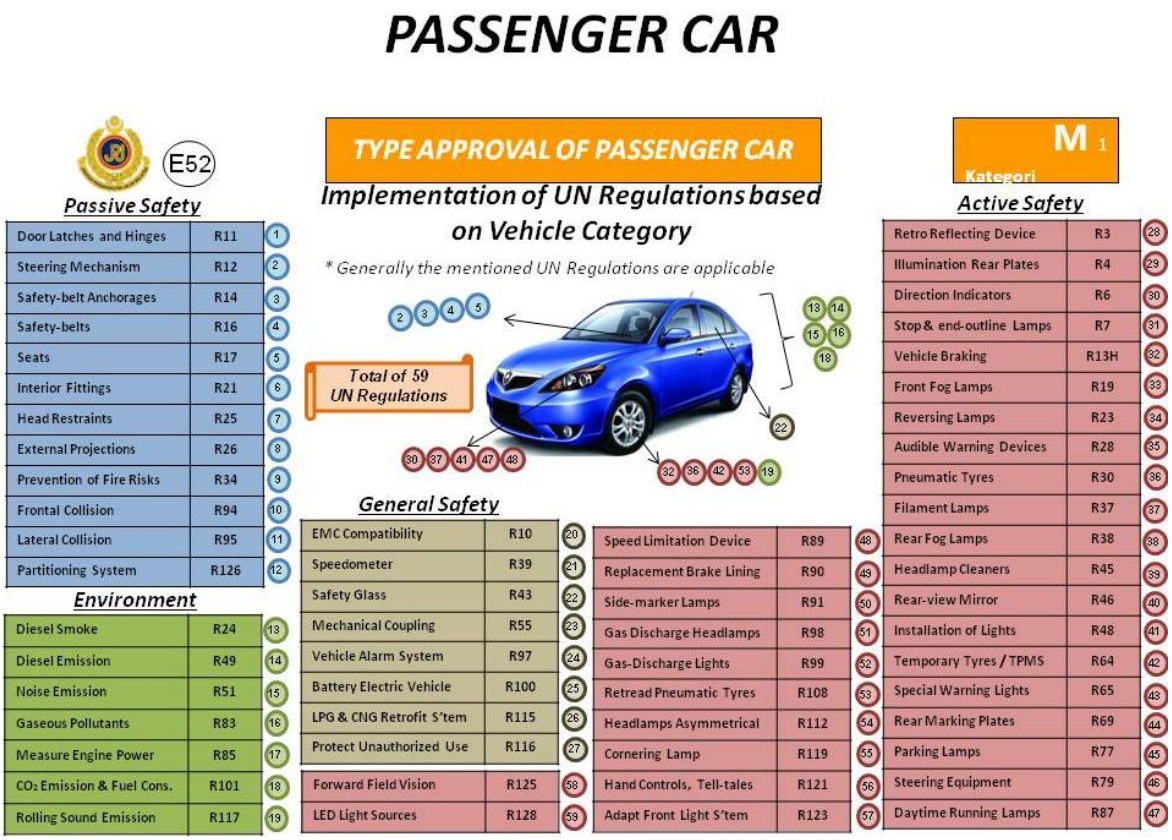

Figure 2: Current UN regulations implemented based on vehicle category M1 (JPJ, 2018)

ASEAN NCAP keeps updating its road maps and test protocols to ensure upcoming car models are safer than those on the market today. More safety technologies are introduced and the test protocols have become tougher to ensure that consumers will be offered safer cars. Since its establishment, ASEAN NCAP has played a pivotal part in the mandatory fitment of many safety technologies including the airbags (from single airbag for driver only to seven airbags), ABS, ESC, seat belt reminder, and many more. These technologies have contributed to lower injury severity during a crash and reduced the number of fatalities among passenger car occupants (Kassim et al., 2017b).

To date, ASEAN NCAP has introduced more safety assists technologies into their test protocols including the Blind Spot Technology (BST), Autonomous Emergency Braking (AEB), Lane Departure Warning, Forward Collision Warning, and many more. These technologies are introduced not only to save the passenger cars occupants but to also help avoid road collisions with other vehicles especially motorcycles (Baharuddin et al., 2019; Kassim et

al., 2019; Zaman et al., 2020). ASEAN NCAP has facilitated JPJ to mandate the fitment of relevant safety technologies on new vehicles and encouraged the consumers to choose safer cars. As the technologies become commonplace, the cost to install them has not become an issue anymore. It is not unusual to see an affordably priced new passenger car model is equipped with better safety technologies.

In its latest protocol, ASEAN NCAP has included motorcycle safety as part of their rating pillars and this is another milestone and challenge for car manufacturers to introduce better safety technologies related to motorcycle safety to receive the highest rating. This is a piece of great news especially for motorcyclists as the relevant safety technologies can help reduce collisions between passenger cars and motorcycles and avoid road fatalities among motorcyclists.

2.2.3 Current Safety Technologies to Save Motorcyclists from the Passenger Car Perspectives

There are various safety technologies in passenger cars that can save motorcyclists' lives on the road. In recent times, car manufacturers have introduced more motorcyclists' safety technologies in their vehicles compared to what motorcycle manufacturers have fitted in their production. The following explains the current safety technologies that are introduced that can potentially reduce the risk of road crashes between passenger cars and motorcycles, thus, saving motorcyclists from road fatalities.

ABS

The ABS is a more efficient braking technology to allow the driver to brake without skidding and avoid the car from colliding with the hazard ahead. The technology also allows the driver to brake at a shorter distance and in time which can help the driver from colliding with other vehicles during emergency braking.

ESC

This technology provides more stability, better handling, and control of a car during emergencies or loss of traction. The ESC monitors all wheels and controls the car by automatically applying the brake to any required wheels when it detects a sudden loss of steering control. This allows the car to have better stability and control, especially during an emergency while avoiding skidding.

Forward Collision Warning (FCW)

The Forward Collision Warning (FCW) alerts the driver to a potential hazard ahead while driving. The system continuously monitors the surroundings of the car including the speed and distance of any vehicle or object in front and provides a warning to the driver if the car is traveling too close to the vehicle or object in front. Hence, this system can potentially help the driver to avoid a frontal crash.

Autonomous Emergency Braking (AEB)

The AEB is also known as crash avoidance assistance or brake assist and will automatically brake the car if the driver fails to respond to a potential hazard ahead. The system operates by continuously monitoring the speed of the car, speed, and distance of the vehicle or object in front. This system includes FCW where it will warn the driver before automated braking is applied. This AEB is essential to help the driver brake in time and avoid a collision from happening especially with a motorcycle in mixed traffic (Baharuddin et al., 2019).

Lane Departure Warning (LDW)

The Lane Departure Warning (LDW) helps the driver by providing a warning when the car starts to depart from its original lane especially on a highway when the turn signal is not activated. The LDW helps in reducing crashes due to driver errors such as distraction or drowsiness. With this system, the driver can avoid side collisions from happening, especially with a motorcycle lane splitting on a highway (Mansor et al., 2020; Rudin et al., 2018).

Lane Keep Assists (LKA)

The LKA is an advanced safety assist in the LDW, where the former automatically reacts when the driver fails to respond to the LDW. LKA helps the driver to maneuver automatically and ensures the car stays on its lane unless there is a turn signal activated to change the lane. This system helps the driver to avoid side collisions especially involving a lane-splitting motorcycle on a highway (Mansor et al., 2020).

Blind Spot Technology (BST)

The BST is a warning system that warns the driver of any vehicles or objects that are in the blind spot. Driver blind spots are usually located in the rear and side area and it is a common driver view limitation while driving. BST operates when a vehicle or object is traveling in the driver's blind spot area, providing a visual warning to the driver and an audio warning as the driver attempts to change the lane. This system helps the driver to avoid a blind spot collision especially with the motorcycle as its smaller size contributes to the blind spot of the driver (Azmi et al., 2019; Hashim et al., 2018; Kassim et al., 2019; Zaman et al., 2020).

3.0 CONCLUSION

Based on this review, it can be seen that the introduction of safety technologies on the motorcycle is still lacking as compared to the passenger car. Despite various motorcycle safety technologies being developed, motorcycle models are still produced based solely on the regulations by JPJ. Motorcycle manufacturers seem to lack the initiative to introduce more safety technologies, especially on smaller engine motorcycles.

In contrast, safety technologies are swiftly introduced in passenger cars. In fact, passenger cars manufacturers have installed more motorcyclist's safety technology compared to what motorcycle manufacturers have done with their motorcycles. Although there is a minimum set of requirements by JPJ for a car to be sold in Malaysia, passenger car manufacturers have continued to offer better safety technologies beyond the mandatory regulation. The presence of an independent consumer group, ASEAN NCAP, through its safety

rating system has contributed to the emergence of safety technologies in passenger cars in Malaysia.

With the success of ASEAN NCAP in pushing for new safety technologies on passenger cars, the onus is on the motorcycle industry in Malaysia to have a similar independent body to regulate a safety rating system for motorcycles. It is essential to form a similar consumer group in the hope that manufacturers will introduce more safety technologies on their motorcycles especially the smaller engine "Kapcais" – as this group forms the majority on Malaysia's roads.

Nevertheless, despite the many safety technologies being introduced in passenger cars, there is still a high number of multi-vehicle collisions involving passenger cars and motorcycles. Therefore, more exploration is required to develop or introduce better safety technologies that can reduce the risk of multi-vehicle collisions, alleviate road injury severity and decrease the number of crashes and fatalities involving motorcyclists in Malaysia.

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