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Examining Fatal Motorcycle Crashes in Malaysia: Rider Age, Road Attributes and Collision Partner Dynamics

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Abstract: - High severity crashes involving motorcycles in Malaysia were analyzed to understand the crash characteristics, crash partner, and crash scenarios. This would involve studying how these variables influence the occurrence and severity of fatal crashes. Based on the examination, countermeasures are emphasized from the perspective of technologies, particularly those available on passenger vehicles. The objective of this study is to identify key risk factors and provide insights for improving road safety policies and intervention strategies. The highest age group involved in motorcycle crashes are among 16-20, followed by 21-25. 62.7% occurred in daylight, 90.5% during good weather and 75.4% occurred in midblock. By comparing the engine capacity to the total industry volume, the highest risk is on motorcycles>250 cc, as the production is only 0.29%, but contributes to 4.55% of fatal crashes. The highest crash partners are passenger cars at 30.84%, followed by trucks at 26.64% and single-vehicle accidents at 19.64%. In single crash accidents, road departure represents 56.7%, and control loss, 43.3%. The mandatory ABS in new motorcycles in Malaysia may help in reducing the number of stability losses during emergency braking. Except for rear-end crashes, passenger cars are the highest collision partner in all crash scenarios. Considering the frequency of crash scenarios and crash compatibility, crash avoidance technologies that could help reduce fatalities include autonomous emergency braking, blind spot detection, and lane-keeping assist.

Keywords: - crash avoidance technology**,** crash type, motorcycle fatal crashes**,** motorcycle safety, pre-crash scenario**,** road fatalities,

I. Introduction

Motorcycles are Malaysia's second most popular mode of transportation, coming after passenger vehicles. In 2023, motorcycles represent 46.2% of the total vehicles registered in Malaysia. The majority on roads have engine capacity below 125cc, but for the last five years, there has been a shifting of demand towards motorcycles with engine capacity of 126-250 cc [1]. Popular demand is due to convenience, inexpensive maintenance, low fuel consumption, and ease of handling during congestion. However, the high popularity comes with concern for the modes' vulnerability. For decades, motorcyclists have ranked first as Malaysia's highest contributor to traffic fatalities. A study by NHTSA (2022) revealed that motorcycles are four times more likely to result in injuries and 24 times more likely to be involved in traffic fatalities per 100 million miles traveled in the United States than passenger vehicles.

The countermeasures for reducing the number of motorcycle crashes are created by conducting in-depth investigations and examining the root cause. Talbot et al., (2020) examined the cause of motorcycle crashes in the United Kingdom and reported that 87.8% of the cases in the junction were due to other drivers ignoring motorcyclists' right of way. The most common error among other drivers reported by the same study is due to missed observation, leading to misjudgment. For motorcyclists, late observation and insufficient skills are highlighted when other drivers enter from minor to major roads. Kome Fondzenyuy et al. (2024) focused on the motorcycle loss of control in the curve cases representing 64% of the single-crash vehicles. The most frequent cases occurred due to high speed, followed by a miscalculation of force by the rider, resulting from misjudgments of the situation. Brown et al. (2021) investigated selected two-wheel crashes from six European Countries from 2015 to 2017. The highest motorcyclist's crash occurred when the opponent vehicle turned left, and the motorcycle driving straight followed by the opposite direction. The major factor for motorcycle crashes is errors of observation, which represent 38% for riders and 66% for other road users. The author emphasized that in most cases, the motorcycle has the right of way and if appropriate action is taken by the other vehicle, the crash can be prevented. These findings exhibit the potential of technological advancement in preventing a crash or minimizing the impact.

The mandatory Anti-Lock Braking System (ABS) for motorcycles in Malaysia starting in 2025 may take time to witness the benefits. Meanwhile, the evolution of safety technology in passenger cars has shown rapid development. The New Car Assessment Program (NCAP) has significantly contributed to this phase. The improvement has greatly reduced the number of crash fatalities involving passenger cars. Car occupant fatalities in the European Union have reportedly dropped by 44% from 2010 to 2016 [4]. Even though passenger cars contribute the largest share of registered vehicles in Malaysia, they have accounted for only 21% of traffic fatalities for the past ten years [5]. It is to be noted that the efficiency of the technologies depends on the crash type and the correct use of the technologies. Blind spot technology, advanced rear view, and rear cross-traffic may improve the conspicuity issues by alerting other drivers to the existence of a motorcycle. Lane keep assist is beneficial, especially when

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the motorcycle or passenger car unintendedly changes lanes. Antilock braking system, forward collision warning, and autonomous emergency braking are catered for limited reaction times. Auto high beams and adaptive driving beams are targeted for low visibility issues. Several studies have highlighted passenger car technologies that may help reduce motorcycle crashes [6], [7] .

Despite the evolution of technologies that show potential in addressing road safety issues, their effectiveness in preventing localized car-motorcycle collision problems is under-explored. Our work aims to identify major risk factors and offer insights to enhance road safety policies and intervention strategies. Puthan et al. (2021) emphasized the importance of identifying predominant crash partners and configurations in developing standards. The classification of motorcycle-passenger vehicle crash scenarios was derived from in-depth crash investigation conducted by MIROS. The findings from this study will help identify possible interventions from the perspective of technology to prevent or minimize the severity of crashes.

II. Methodology

MIROS is an agency under the Ministry of Transport Malaysia and conducts accident investigations for research purposes. The MIROS data from 2007 to 2024 encompasses high-severity crashes all over Malaysia, involving at least one fatality or more. This study analyzed high-severity crashes investigated by the MIROS team involving at least one motorcyclist fatality. There was a total of 262 crashes involving 418 motorcycles, resulting in 261 riders and pillion fatalities. The motorcycle rider is the person managing the motorcycle and the pillion is the person accompanying the rider. The pre-crash scenario was categorized based on pre-event movement, the initial contact point of the vehicle, the sequence of the event crash, and the final rest position. Collision with the motor vehicle is categorized based on the movements of the vehicle before impact.

III. Result and Discussions

Riders Age

Of the cases investigated, 96% of the motorcyclist riders were males and the remaining were females. Fig. 1 shows the age distribution of the riders involved in crashes, comparing data from MIROS with present data from the Royal Malaysian Police (RMP) for the year 2023. The most represented age group is 16-20, followed by 21-25, which aligns with RMP data. This age range may be associated with inexperience and deficiencies in skills of handling motorcycles. Data from the Road Transport Department (RTD) Malaysia in 2023 also indicates that individuals aged 16 to 25 received the highest proportion of traffic summons (35%). In the United States, the highest number of fatalities involving motorcycles are at the age of 25-34, with the number of fatalities among 21 to 24-year-olds increased by 16% in 2022 compared to 2021[9]. The young age relates to inexperience in decision-making and handling of motorcycles [10]. In different studies, Dubois et al. (2020) related speed violations and aggressive riding among young riders to the factors contributing to crashes.

Another significant aspect of the crash data revealed that 7% of the riders aged 11-15 were riding without a valid license, and approximately 5% of riders were found not wearing helmets. In Malaysia, the legal age for obtaining a motorcycle license (Class B2) is 16 years old and helmet wearing is mandatory. Underaged riders (below 16) are not legally permitted to operate motorbikes, making their use of these vehicles a violation of traffic laws. Enforcement challenges arise as underaged riders often operate in rural areas or smaller towns where monitoring is less stringent.

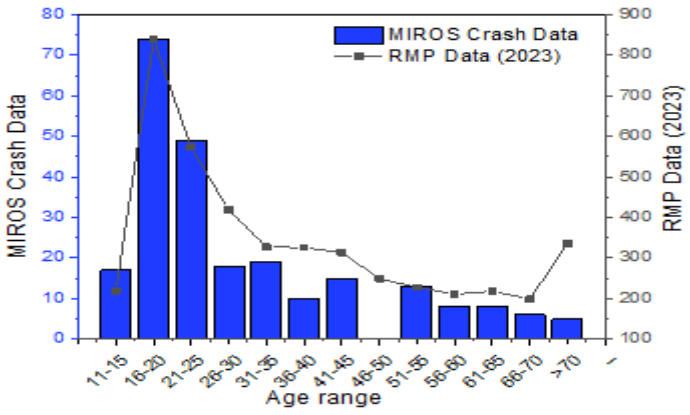

Fig. 1 Age distribution of riders involved

Road Environment and Weather

The crashes occurred more often in daylight (62.7%), followed by 25.8% at night with streetlights and the remaining 11.5% at night without streetlights. A high number of occurrences in daylight may be due to most activities using motorcycles occurring during daylight. 90.5% of the crashes occurred during good weather, while the remaining 9.5% happened in rainy days. 75.4% of the crashes occurred at midblock, while the remaining 24.6% occurred at the junction, with the highest occurrence at the T junction (13.1%). This was followed by the crossroad and merging lane (4.4%), Y junction 1.6%, multi-leg junction 1.2%,

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staggered junction 0.8%, and roundabout at 0.4%. Just over half of the cases (54%) occurred in a single carriageway with 2 lanes (50%).

Fig. 2 exhibits the reported weather conditions during the crash and the pre-collision movement of the collided motorcycles. The highest crashes occurred during good weather, in all types of motorcycles' pre-collision movement. More importantly, motorcyclists are in the forward movement at 76.9% of cases.

The attributes of road curvature and weather in motorcycle crashes are shown in Fig. 3. A large proportion of crashes occur predominantly in good weather on straight and even roads. Motorcycle ABS has been proven to be highly effective in increasing stability and reducing brake distance and time on dry and straight roads [13]. The movement of the Malaysian government in regulating ABS for motorcycles above 150 cc is an important countermeasure to help motorcyclists regain control of their vehicles during emergency braking. Thus, mandatory ABS is a crucial step in tackling the issues of fatal motorcycle crashes on straight, even and dry roads. In contrast, technologies such as traction control and curve speed warning for motorcycles are not critical to be implemented.

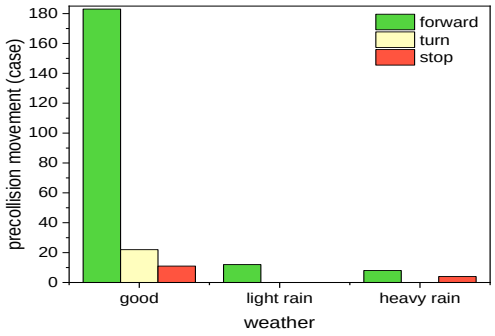

Fig. 2 Pre-collision movement and weather conditions

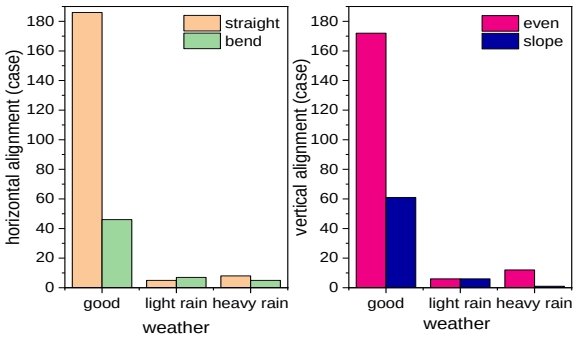

Fig. 3 Crash scene road geometry and weather condition

Motorcycle and Collision Partner

In Fig. 4, the motorcycles involved are categorized based on engine capacity, cc. As the cases investigated are high-severity crashes with fatalities, the motorcycle <126 cc dominates the number by 66.76%. By comparing with the total industry volume (TIV) of motorcycles in Malaysia from 2010-2019, the domination is due to a high number of <126 cc motorcycles (67.84%) on the road. For every <126 cc motorcycle produced, there is a possibility that one could be involved in a fatal road crash. For motorcycles 126-250cc, the number involved in motorcycle crashes are 28.79%, while the TIV is 31.87%. The ratio of motorcycle crashes to TIV for 126-250 cc is 0.9. For motorcycles >250 cc which represents 4.15% of the crashes, the TIV is relatively low at just 0.29%. This suggests that motorcycles with higher engine capacities of >250 cc have a higher risk of being involved in fatal crashes. Similar findings were reported by Evans (2021), where higher engine power motorcycles are involved in a significant proportion of fatal accidents. Countermeasures introduced by the government to regulate ABS for motorcycles 150 cc and above may help to reduce or mitigate risk for 15.06% of motorcycles involved in the crash. While there is an argument that motorcycles with high engine capacity (≥250cc) might be equipped with ABS, the owner may turn off the features. The proper regulations enforcement will help in ensuring the motorcycles on the road are fitted with ABS and prevent users from disabling the features.

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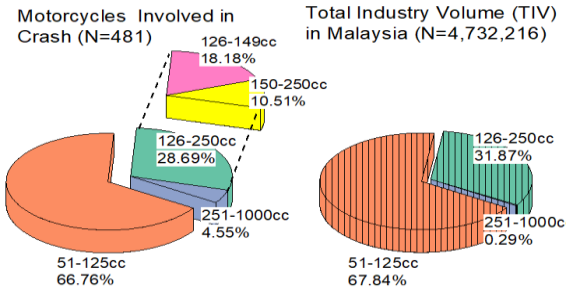

Fig. 4 Motorcycles involved in crash vs total industry volume (TIV)

Fig. 5 shows the proportion of motorcycle crash opponents. The most frequent collision partner is passenger vehicles at 30.84% followed by trucks and trailers at 26.64%. The third highest cases are single-vehicle crashes at 19.63%. This collision partner pattern for the investigated sample is consistent with Malaysian crash data reported in 2022, where the highest number are collisions with passenger vehicles (28%) [13]. However, the second highest cases are single-vehicle crashes at 25% followed by collisions with trucks and trailers at 14%. Report by Aarts et al. (2016) also highlighted that passenger cars are the most common collision partners of motorcycles in Europe. De Craen et al. (2014) suggests that car drivers do not anticipate encountering motorcycles on the road, making it more challenging to notice and recognize them. In response to this issue and taking advantage of the advancement of safety assist technology introduced in passenger cars, motorcyclist safety is among the important safety features valued by the ASEAN NCAP assessment [17]. It is noted that ASEAN NCAP is the first NCAP in the world that assesses passenger cars focusing on motorcyclist safety as one of the assessment pillars.

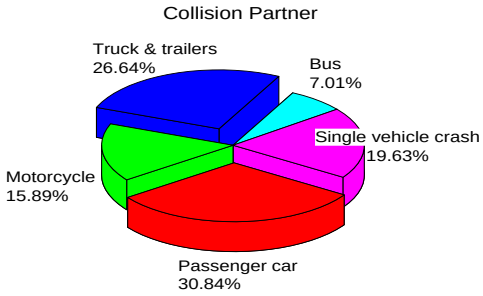

Fig. 5 Fatal motorcycle crashes collision partner

The frequency of crash scenarios can be seen in Fig. 6. The scenarios are divided into eight categories of collision. The opposite direction leads with 72 cases, followed by rear-end (61 cases) and single-vehicle accidents (SVA) with 42 cases. In contrast to Europe, where most motorcycle crashes occur at junctions, local cases may require different approaches to address the unique circumstances. In the opposite direction cases, the issue of speed and driver's or rider's response during an emergency can influence the outcome. Also, very high percentages of fatal crashes occur when motorcyclists drift into vehicles going in the opposite direction, as opposed to other vehicles drifting onto motorcycles. The crash avoidance technology could help prevent these motorcycle crashes by alerting the other driver to the presence of the motorcycle, or vice versa.

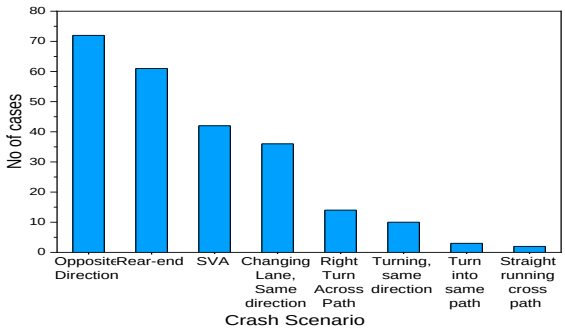

Fig. 6 Collided motorcycle pre-collision movement

Single-vehicle crash configuration

In the context of single vehicle crash configuration, 84.6% are in contact with road furniture and the environment, while another 6.7% are involved in collisions with animals. Pre-crash scenarios for single-crash motorcycles are categorized into two, which

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are road departure represents 56.7%, and loss control, 43.3%. 95% of the riders involved in single crash motorcycles resulted in fatalities, while another 5% sustained severe injuries. The National Transport and Safety Board report highlighted that although single motorcycle crashes are infrequent, they carry a higher risk of fatalities [16]. These scenarios may be prevented using ABS, especially for loss control cases. A report by the Road Transport Department (RTD) found that road summons to motorcycles is due to driver licensing 84%, vehicle technical issue 12% and traffic offenses at 2% [14]. Vehicle technical issues may include vehicle modification, thus contributing to the vehicle not meeting required standards. Thus, by mandating ABS, the motorcycle must meet the standard for front braking. The move targeted higher cc motorcycles, and in the future, if the effect is positive, may be introduced to lower cc.

Two-vehicle crash configurations

Crash configurations of multiple vehicle crashes categorized according to collision partners are plotted in Fig. 7. Apart from rear end crashes, passenger vehicles account for the highest number of crash partners across all crash configurations. Vehicle compatibility plays a significant role in contributing to the high number of fatalities. Prioritizing crash avoidance technologies is essential to reducing this type of crash.

In 54.2% of the opposite-direction cases, the crash partner was a passenger car. 59.7% happened due to motorcycles drifting into the opposite lane, which contributed to 87.9% of motorcyclist fatalities. 32.6% of the cases happened when motorcycles encountered bend roads and 34.9% in slope roads. AEB in passenger cars can help reduce the risk when a motorcycle suddenly veers in the opposite direction. In 40.3% of cases where other vehicles drift into opposite lanes, it contributes to motorcyclist fatalities of 89.7%. In this case, Lane Keep Assist (LKA) may help warn the driver in case they enter the opposite lane.

Almost 50% of the rear impact crashes occurred with the truck, followed by passenger cars and buses. Of 61 rear-crash cases, 63% occurred in daylight, 95% during good weather, and 67% on a dual carriageway. Just under two-thirds of the crashes involve motorcycles striking an opponent vehicle, while in the remaining 36.5% of cases, the motorcycle was struck. Forward Collision Warning (FCW) for motorcycles to keep a safe distance may help to reduce the risk. High Beam Assistant may help in identifying the object forward. Rear underrun protection and reflective markers in the truck may improve the visibility of the vehicle. In 16.4% of cases of passenger cars striking motorcycles, AEB and FCW in passenger cars can help in avoiding or reducing the risk of collision. Both technologies are designed to emphasize vehicles traveling in the same direction, thus preventing rear-end crash [6]. Cicchino (2017) reported that FCW and AEB can reduce rear-end crashes by 13% and 12% respectively, and the combination of both resulted in a reduction of 20% cases. With the development of ASEAN NCAP's new protocol for 2026-2030, AEB-detecting motorcycle groups will be included in the assessment.

Next, in changing lanes, same direction cases, 63.9% of cases occurred when motorcycles changed lanes, during good weather (95.7%) and 60.9% occurred in single carriageway. Again, the highest number of crash partners was contributed by passenger cars at 41.7%. Meanwhile, 36.1% of cases occurred when other vehicles were changing lanes, and 30.8% of cases happened on the bend road. The technologies that can be used in this case are blind spot technology and lane keep assist. Blind spot technology has been reported to reduce the lane changing crashes by 14% [19] .

In a right turn across the path, motorcycles turn right, and other vehicles turn right contribute 50% in the cases. However, motorcyclist fatalities are 100% in the cases of other vehicles turn right. Talbot et al., (2020) related that in the case of turning across path, lateral direction, motorcyclists often misjudged the situation to react before the crash occurred due to insufficient skills that contribute by high speed or late braking. AEB and ABS may help if the motorcycles are aware and taking the appropriate action.

In turning, the same direction, 90% of the cases occurred when other vehicles were turning, motorcycles driving straight or turning, contributed to 77.8% of motorcycle fatalities. In the opposite cases where motorcycles are turning, motorcyclist fatalities are 100%. The blind spot technology, particularly for the offside side and AEB might be critical for this case. In another scenario involving turning into the same path, 100% of the cases occurred when the motorcycle entered another lane. The last scenario of straight running cross path which resulted in 100% motorcyclist fatalities, motorcycle ABS and vehicle AEB are essential in minimizing the risk.

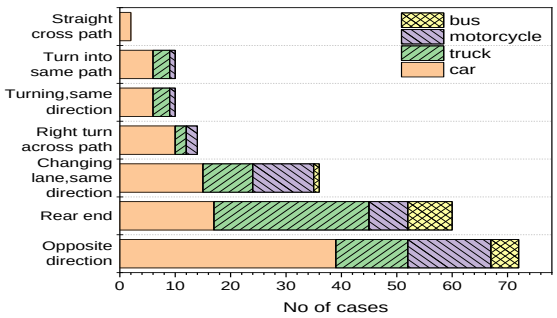

Fig. 7 Crash configurations of multiple vehicle crashes according to crash collision partners

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IV. Conclusion

This study sets out to determine the key risk factors in fatal motorcycle crashes and possible countermeasures to reduce the number. Motorcycle crash fatalities are highest among individuals aged 16-20 years. Even though low cc motorcycles <126cc recorded the highest fatalities, motorcycles >250 cc pose higher risk due to their lower industry volume. Most frequent collision partner are passenger cars, followed by truck and trailers and single vehicle accident. In single vehicle crashes, road departure represents 54.6% and control loss 43.3%. Opposite direction crashes reported the highest, followed by rear end crashes. Regulating the use of ABS in motorcycles could be one of the effective solutions in reducing the number of fatalities. Other crash avoidance technologies discussed include blind spot technology, lane keep assist, AEB, FCW, and adaptive driving beam. The crashes investigated may not represented the whole motorcycle crashes in Malaysia. However, the data is useful to activate the possible countermeasures that may reduce the number of traffic fatalities involving motorcyclists.

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