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Non-Fatal Motorcycle Crash Configuration and Injury Severity at T-Junction in Malaysia

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Abstract – *Crash configuration or crash type analysis is one of the techniques for studying and understanding the mechanism of motorcycle crashes occurrence. The process involves the development of crash events with common causal pre-crash characteristics, such as driver behaviour, roadway situations, and movements of the involved vehicles. This study is focusing on nan-fatal motorcyclist on current data (5-year period: 2011-2015) and injuries pattern among motorcyclist associated with the crash type of the crash. The objectives of the study were to: (i) investigate trends of occurrence of crash configuration involved motorcycle crashes in Malaysia; (ii) identify injuries related to the crash configuration; and (iii) recognise the injuries severity of the corresponding crash configuration. A total of 642 accident cases with injury were found to occur at T-junction. From the 642 cases at T-junction, seven types of crash configuration were identified appropriately with the cases involved. They are approach turn, angle 1/2, rear-end, U-turn, sideswipe, overtaking and both turning. Approach-turn crashes with a passenger car in the process of making a turn while a motorcycle was travelling straight ahead on primary roads was the most common occurrence that causes collision among motorcycle and passenger car at T-junction in the study. Four body regions were the most common region to be injured in every crash type. They are lower extremity, upper extremity, face and head. Also, the study shows that the number of injuries at face region is more than the number of injuries to the head among rider that involved crashes at T-junction. However, in term of injury severity, the most hazardous crash types identified were among Angle 1/2 crashes where motorcycle from a minor road to the primary road.*

Keywords: Crash typing, crash configuration, injury pattern, T-junction, non-fatal motorcycle crashes

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1.0 INTRODUCTION

Malaysia is one of the developing countries in the Southeast Asian region which undergoes rapid economic growth since the year 1990s. The rapid economic growth has also increased the motorisation industry in the country. The cumulative number of vehicles in Malaysia specifically for motorcycle is growing by about 5 % from the year 2012 to 2013 that may indirectly cause the increasing number of crashes involving motorcycles in Malaysia.

Motorcycle has been an accessible mode of transport in Malaysia as 50 % of the total registered vehicles were motorcycles Leong et al. (2005). Almost 58 % of the vehicles compose of the motorcycle in ASEAN countries (WHO, 2009) due to its affordable price, fuel-saving, and size-convenient that ease the riders to move around especially within the hectic traffic congestion. Few studies (Padmanaban & Vitaly, 2009; Leong et al., 2005) found that heavy traffic congestion, availability of parking, travel costs, social-economic and inefficiency of public transport are the motivational factors of the motorcycle purchasing.

Alongside this, the number of injuries involving a motorcycle is increasing yearly. In Malaysia, approximately 60 % of road crash fatalities include motorcycle crashes, and almost 70 % of all injuries level in road crashes found to be motorcyclist (Zainal Abidin et al., 2018). According to Pang et al. (1999), a motorcyclist who sustained non-fatal injuries in crashes are commonly suffered a severe injury and require prolonged hospitalisation, which most of the injuries can result in permanent disability. Aware of the high trauma associated with motorcycle crashes, any effort to reduce the number and severity of these crashes is a top priority for Malaysia. Many studies are being conducted to understand the characteristics of motor vehicle accidents involving motorcycles.

Preusser et al. (1995) mentioned that crash configuration or crash type analysis is one of the techniques for studying and understanding the mechanism of crashes occur. This effort will help in targeted countermeasures. The study mentioned that crash configuration analysis involves the development of definitions that identify groups of crash events with common causal pre-crash characteristics, such as typical driver behaviour, roadway situations, and movements of the involved vehicles. According to them, can be conventionally developed in three steps: (1) analysing police crash reports and classifying crashes based on typical pre-crash behaviour situations; (2) reading additional reports to test the integrity of the preliminary classification; and (3) developing crash type definitions for each of the identified crash groups. Crash configuration of the motorcycle is quite extensive due to the relatively small size of a motorcycle compared to other vehicles.

Motorcyclists susceptibility to accident injuries in nature may act synergistically with the complexity of conflicting movements and manoeuvres between motorcycles and automobiles to increase motorcyclists' injury severities at junctions (Pai, 2009). Besides, a junction-type crash could be more severe to motorcyclists than a non-junction case as a result of the fact that some of the injuries crash such as angle collision commonly take place (Pai & Saleh, 2008). To determine if there are additionally feasible countermeasures that can reduce motorcycle crashes and crash injuries, a more thorough understanding of how and why these crashes occur, using more current and non-fatal data, is needed. Thus, the objectives of the study were to: (i) investigate trends of occurrence of crash configuration involved motorcycle crashes in Malaysia; (ii) identify injuries related to the crash configuration; and (iii) recognise the injuries severity of the corresponding crash configuration.

2.0 METHODOLOGY

The data were from closed files of the third-party bodily injury (TPBI) insurance claims database for the period 2011-2015 focusing on the motorcycles that involved in accidents with the passenger cars at T-junction. A total of 642 non-fatal motorcyclists (rider only) of third-party claimants were identified. Information regarding the demographic information, crash narratives and injury details were retrieved from various sources of the report such as police report, adjuster report, medical report, opinion report and assessment report available in the selected cases.

Narrative of the accident is very crucial to identify the crash configuration of each case. The injury information was on the rider of the motorcycle that was involved in an accident. Injury to the body region and severity coding used in this study are based on the Abbreviated Injury Scale (AIS), updated version 2008. The data obtained at T-junction was analysed to investigate further the relationship between identified crash types and injury sustained by body region by conducting a frequency table. Injury sustained by each victim in the study could be more than one.

3.0 RESULTS AND DISCUSSION

A total of 642 accident cases with injury were found to occur at T-junction. From the 642 cases, seven crash types were identified appropriately with the cases involved. The identified crash types are approach-turn, angle 1/2, rear-end, U-turn, sideswipe, overtaking and both-turning as shown in Figure 1. The result shows that approach-turn collision is the highest type of collisions (50 %) that involved motorcycle and passenger car at T-junction followed by Angle collision type 1 and 2 with 33.6 %.

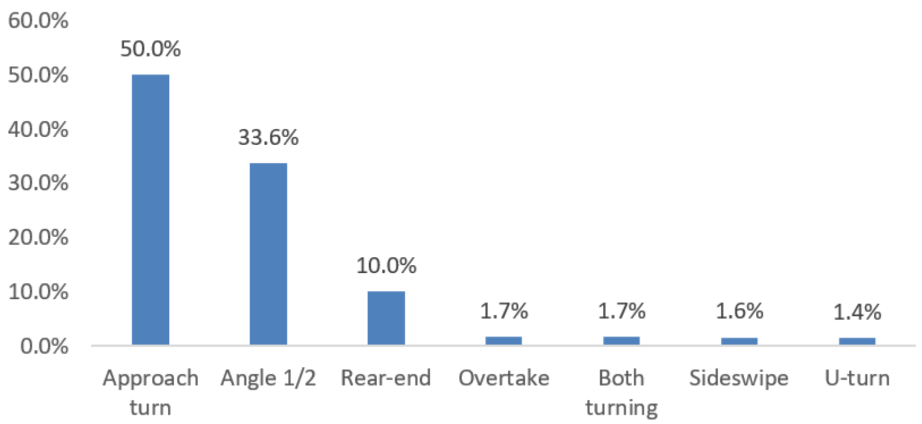


Figure 1: Type of identified crash configuration at T-junction

Both approach-turn collision and Angle 1/2 collision in this study, involved turning of motorcycle or passenger vehicle as pre-crash motion. Approach-turn collision involved the pre-crash motion of motorcycle or passenger car entering a minor road from the primary road (straight road). Meanwhile, Angle 1/2 collision is referring to the movement of a passenger car or motorcycle from a minor road to the primary road. Angle 1/2 collision is known as angle collision. Failed to give way to the motorcycle at the junction was the main contributing factor to these two types of collisions (Pai, 2009).

Both of the crash configurations involving side impact crashes where Zainal Abidin et al. (2018) and Kak & Zainal Abidin (2019) found that side impact crashes occurred when the passenger vehicles were at fault. Zainal Abidin et al. (2018) did define *"the at-fault situations"* is due to noncompliance to local traffic rules such as driving above speed limits, right of way issue and red-light running or driving negligence including turning without proper signalling, dangerous lane changes and others.

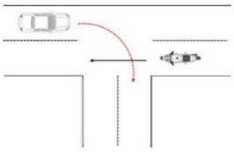
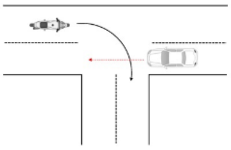
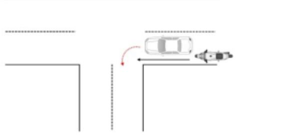
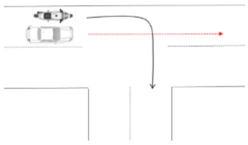
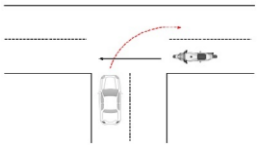
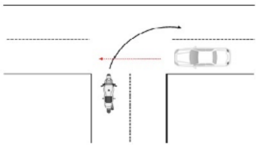
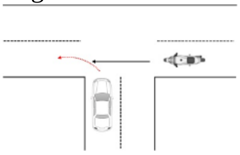
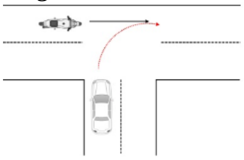
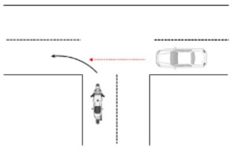
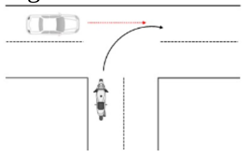
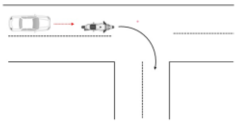
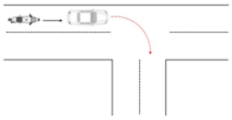
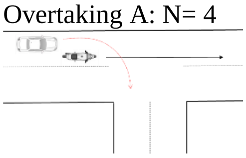
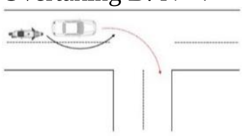
3.1 Categorisations of Crash Configuration

In each crash configurations, some subcategories have been considered based on the first vehicle making the said motion. All the identified crash types have been illustrated and defined in the schematic diagram in Table 1. In total, there are 16 crash types (main categories and subcategories) were identified to occur at T-junction based on the pre-crash motion made by each vehicle involved. As shown in Table 1, Approach-turn A1 collision is the dominant crash configuration in this study, followed by Angle 1 collision with 193 cases and 125 cases, respectively. This finding is similar to previous research which found that angle crashes, approach-turn crashes and head-on crashes were the most common motorcycle accidents at the junction (Pai, 2009). Same goes with Zainal Abidin et al. (2018), which agreed that small angle angular side impacts and sideswipes found to dominate in side impact crashes involving non-fatal motorcycle-passenger car crashes.

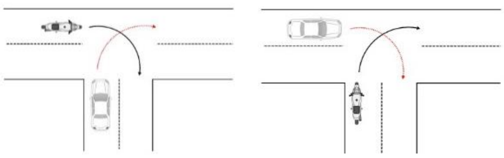
Carmai et al. (2018) found that when a motorcycle was travelling on a straight road and a passenger car moved across the path of the motorcycle which mirrors the crash configuration of Approach-turn A1 and A2 in the study, the speed of the motorcycle was usually greater than the passenger car. However, when a passenger car impacting the side of motorcycle such as Approach-turn B1 and Angel 2A, the speed for the passenger car is higher than the motorcycle. Also, in his simulation study mentioned that there is three possible impact point for the motorcycle when impacted by a passenger car, which is the rear wheel, mid of wheelbase length and front wheel.

In addition, rear-end collision contribute 10 % in crashes involving a motorcycle at T-junction with 77 % is motorcycle hit rear-end of the passenger vehicle. Kak & Zainal Abidin (2019) found that in this type of crash configuration, usually resulted from the motorcycle that was at fault. Other crash configuration at T-junction such as overtaking, both turning, sideswipe and U-turn has a small number of occurrences with less than 2 % respectively. Another study (Pai & Saleh, 2008), combined rear-end collision and sideswipe collision into one category of crash type known as a same-direction collision. They define same-direction collision as a collision which occurs while one motorcycle and one vehicle travelling from same-directions collide with each other. However, the data collection protocols in the study treated rear-end collision and sideswipe collision as two separate crash configurations as both crash configurations might lead to different injury distribution to the rider.

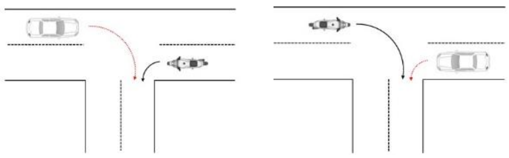
Table 1: Definition of crash configuration categories

Approach-turn (n=321)			
Approach-turn A1: N=193  Passenger car and motorcycle are at **opposite travel direction** and the **passenger car is making a turn**	Approach-turn B1: N=16  Passenger car and motorcycle are at **opposite travel direction** and the **motorcycle is making a turn**	Approach-turn A2: N=102  Passenger car and motorcycle are at **same travel direction** and the **passenger car is making a turn**	Approach-turn B2: N=10  Passenger car and motorcycle are at **same travel direction** and the **motorcycle is making**
Angle 1/2 (n=215)			
Angle 1A: N=125  **Passenger car is turning** to different direction of travel and **motorcycle is travelling straight**		Angle 1B: N=21  **Motorcycle is turning** to different direction of travel and **passenger car is travelling straight**	
Angle 2A L: N=28  Motorcycle is travelling straight and **passenger car is turning left** to **same** direction of travel	Angle 2A R: N=22  Motorcycle is travelling straight and **passenger car is turning right** to **same** direction of travel	Angle 2B L: N= 10  Passenger car is travelling straight and **motorcycle is turning left** to **same** direction of travel	Angle 2B R: N= 9  Passenger car is travelling straight and **motorcycle is turning right** to **same** direction of travel
Rear end (n=64)			
Rear end A: N= 15  Motorcycle is making a turn and passenger car hit motorcycle from rear.		Rear end B: N= 49  Passenger car is making a turn and motorcycle hit passenger car from rear.	
Overtaking (n=11)			
Overtaking A: N= 4  Passenger car is overtaking motorcycle and making a turn at T-junction		Overtaking B: N= 7  Motorcycle is overtaking passenger car at T-junction	

Both-turning (n=11)



Passenger car and motorcycle are making a **turn** to **different** direction of travel



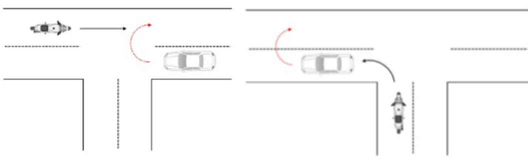
Passenger car and motorcycle are making a **turn** to **same** direction of travel

Sideswipe (n=10)

Passenger car and motorcycle are side by side are making a turn

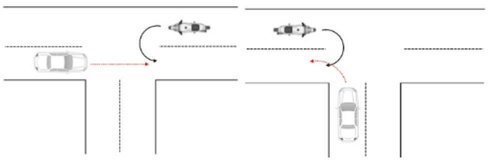
U-turn (n=9)

U-turn A: N=5



Passenger car is making a **U-turn** at T-junction

U-turn B: N= 4



Motorcycle is making a **U-turn** at T-junction

3.2 Injury Distribution and Injury Severity

Injury severity in each body region was identified according to crash type. Injury sustained by each victim in the study could be more than one. As for that, the number of injuries will not tally or equal to the number of case. At least one injury will be counted at a body region if there is a record of injury or injuries at that specific region. Overall injury distribution among motorcyclists crashed at T-junction according to body region is shown in Figure 2. The result shows lower limb is the highest (37.3 %) body region recorded to have injuries among motorcyclist that involved in an accident at T-junction followed by upper limb with 28.5 %. This result is consistent with Zainal Abidin et al. (2018) and Peek et al. (1994) where lower limb injuries were most common in non-fatal motorcycle crashes. Lower limb injuries can be very costly and may immerse social burden as it could contribute to the majority of long term complication and impairment among non-fatal motorcyclist (Pang et al., 1999).

Since this study is focusing on non-fatal motorcyclist data, explains the low percentage of head injury recorded among the motorcyclist as in Figure 2 which mirrors earlier study on non-fatal motorcyclist (Pang et al., 1999). The number of head injury was highest among fatal motorcyclist (Radin Umar, 2006). On the other hand, the most common injury of non-fatal motorcyclist regardless the body region was integumentary injuries such as abrasion, laceration and contusion where the injuries mainly affected the soft tissue (Pang et al., 1999; Radin Umar, 2006; Zulkipli et al., 2015; Mohd Faudzi et al., 2015).

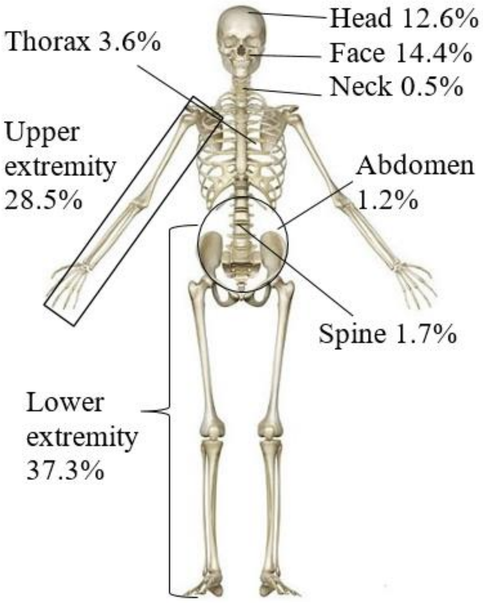


Figure 2: Distribution of injuries according to body region sustained by rider

Comparison among injury distribution of crash configuration in Table 2, a higher percentage of head and face injuries were found at Rear-end A collision where passenger car crashing into the rear of the motorcycle. Nevertheless, the injuries sustained at the head and other body regions were not serious as 93.3 % of motorcyclist in rear-end A collision suffered only MAIS 1-2 as shown in Figure 3. Another study shows a similar finding (Pang et al., 1999), in which most of the non-fatal motorcyclist only suffered a mild head concussion due to hitting the pavement.

In term of injury severity as depicted in Figure 3, majority of the motorcyclists that involved in crashes at T-junction suffered MAIS 1-2, which are minor to moderate injury level with 78.0 % compared to MAIS ≥ 3 injury level with 22.0 %. For Approach-turn A crashes, Approach-turn A appeared to be more dangerous compared to Approach-turn B crashes as a higher portion of riders suffered MAIS ≥ 3 was found in Approach-turn A crashes (A: 21.4 % vs B: 19.2 %). This finding mirrors the study by Pai (2008) that revealed motorcyclists were more injurious if motorcycle approaching straight collides with a vehicle travelling from the opposite direction and turning right into the motorcycle path crashes. For Approach-turn A crashes, researchers (Hurt et al., 1984; Peek-Asa & Kraus, 1996; Hole et al., 1996; Clarke et al., 2007) have suggested that the principal factors in this crash type could be the failure of a turning driver to see the approaching vehicle (e.g., look but did not see). The driver failed to adequately judge the time available to clear the intersection or to yield right of way to an approaching motorcycle.

In angle crashes, 41.5 % of the motorcyclists in Angle 1/2 B collision were exposed to serious injury outcome (MAIS ≥ 3) compare to Angel 1/2 A. The study revealed that the most hazardous crash patterns were angle perpendicular and angle oblique crashes. The crash is where one travelling-straight motorbike collided with a right-/left-turn car travelling from the minor road. This finding differs from another study by Pai (2009) such that injuries were most significant in collisions where a right-/left-turn motorcycle infringed upon the passenger car right-of-way.

Table 2: Distribution of injured body region by various types of crash

Crash configuration	Body region								Total
	Head	Face	Neck	Thorax	Abdomen	Spine	Upper	Lower	
Approach-turn									
A	66 (13.2%)	77 (15.3%)	4 (0.8%)	19 (3.8%)	3 (0.6%)	8 (1.6%)	146 (29.0%)	180 (35.8%)	503
B	6 (12.2%)	5 (10.2%)	0	3 (6.1%)	0	1 (2.0%)	13 (26.5%)	21 (42.9%)	49
Angle 1/2									
A	38 (11.8%)	46 (14.2%)	1 (0.3%)	11 (3.4%)	6 (1.9%)	7 (2.2%)	89 (27.6%)	125 (38.7%)	331
B	9 (11.5%)	10 (12.8%)	0	3 (3.8%)	2 (2.6%)	2 (2.6%)	19 (24.4%)	33 (42.3%)	78
Rear-end									
A	6 (20.7%)	6 (20.7%)	0	3 (10.3%)	0	0	7 (24.1%)	7 (24.1%)	29
B	10 (10.3%)	13 (13.4%)	0	1 (1.0%)	3 (3.1%)	1 (1.0%)	34 (35.1%)	35 (36.1%)	97
Overtaking	3 (14.3%)	3 (14.3%)	0	1 (4.8%)	0	1 (4.8%)	6 (28.6%)	7 (33.3%)	21
Both-turning	3 (16.7%)	0	0	1 (5.6%)	0	0	6 (33.3%)	8 (44.4%)	18
Sideswipe	1 (7.7%)	2 (15.4%)	0	0	0	0	4 (30.8%)	6 (46.2%)	13
U-turn	3 (17.7%)	3 (17.7%)	1 (5.9%)	1 (5.9%)	0	0	3 (17.7%)	6 (35.3%)	17

In comparison between rear-end crashes in Figure 3, Rear-end B crashes (motorcycle hit passenger car from the rear) were more severe as a higher portion of riders suffered MAIS ≥ 3 were found in Rear-end B crashes (20.4 %) compared to Rear-end A crashes (6.7 %). This injury severity of Rear-end B can be explained from a crash kinematic study done by Hynčík et al. (2019). The study showed that when a motorcycle impacting the rear-end of a passenger car, the rider will slide from the seat and lost the connection with the handlebars. Then when the linear movement of the motorcycle stopped, the rider body will rotate around the handlebars and whiplash may appear before the impact of the head to the rear window, which brought a severe neck injury. The rotational movement finally caused the impact of the rider's head to the rear window.

A motorcyclist has no steel frame of protection in the event of a crash. The severity of the accident and resulting injuries depend in part on the vehicles' speed at the time of impact. During any motorcycle crashes, a motorcyclist can be forcibly thrown from the bike and cause more severe injury to the motorcyclist. In addition, if the motorcyclist hits the car in front of them, they could fly from their bike onto the car itself. Both scenarios increase the likelihood of serious injuries. In such situations, you not only have to think about where the rider will land, but where the bike will land as well. Injuries are likely to occur if a motorcyclist hits the ground hard. However, if the motorcycle then falls on top of the rider, it could result in even more severe injuries.

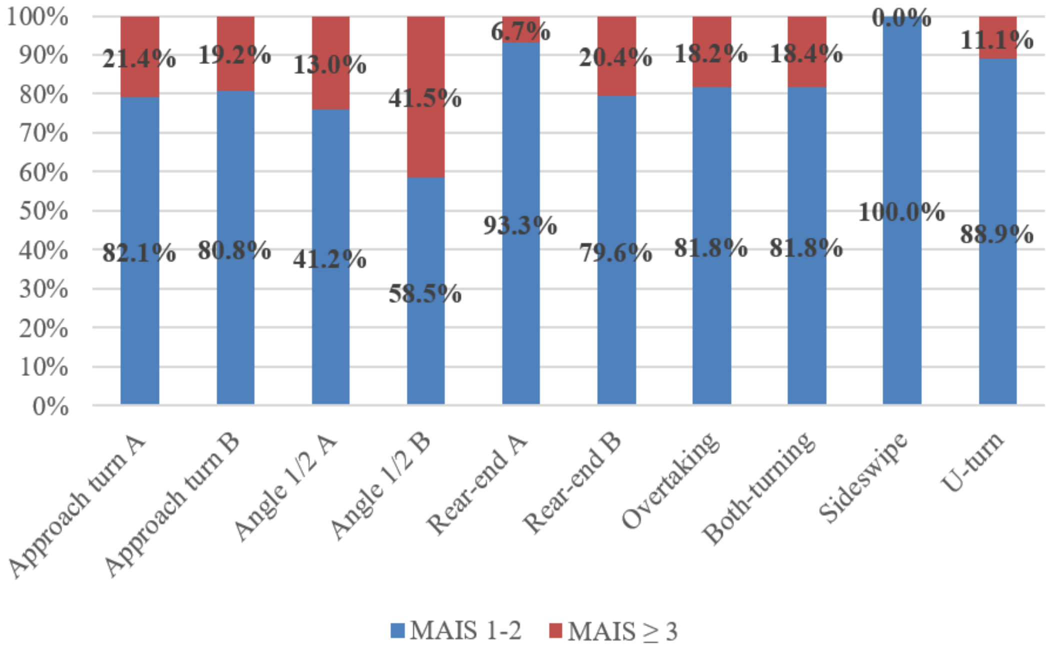


Figure 3: Injury severity of each crash configurations

4.0 CONCLUSION

From this study, it shows that approach-turn crashes with a passenger car making a turn while a motorcycle travelling straight ahead on primary roads was the highest crash configuration that causes collision among motorcycle and passenger car at T-junction in the study. Four body regions seem to be the most affected region in every crash type. They are lower extremity, upper extremity, face and head. In addition, the study also shows that the number of injuries at face region is more than the number of injuries to the head among rider that involved crashes at T-junction. However, in term of injury severity, the most hazardous crash types identified were among Angle 1/2 crashes where motorcycle from a minor road to the primary road.

This research provides information on the most hazardous road environment in Malaysia in term of crash frequency and injury severity at a particular crash configuration. The findings can be used to enhance enforcement efforts to prevent the same situation happened at T-junction. In term of future research, an examination on the location factors (signalised and un-signalised junction) and temporal factors associated with the junction-road crashes should be conducted. Besides, with the support from the police database on black spot area among T-junction in Malaysia could potentially be a fruitful method to improvise implementation of police-enforcement strategies.

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