Journal of the Society of Automotive Engineers Malaysia
Volume 5, Issue 3, pp 430-438, September 2021
e-ISSN 2550-2239 & ISSN 2600-8092

Analysis of Injury Severity involving of Passenger Vehicles' Occupants in Frontal Impact Collisions

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ORIGINAL ARTICLE **Open Access**

Article History:

Received
20 Oct 2020

Accepted
15 Apr 2021

Available online
1 Sep 2021

Abstract – *In Malaysia, Passenger Vehicles (PV) accounted for the second-highest proportion of vehicles involved in road crashes (13.5%) as well as the total number of casualties (18.6%) after motorcycles. This raised the alarm that a thorough investigation should be conducted on the injury severity of occupants in PV crashes involving frontal impact collisions. The objective of this study is to evaluate injury severity outcome based on the selected crash parameters for the front seat occupants involved in frontal impact collision. The data for this study was sourced from the MIROS crash investigation database (MICARS) from 2007 until 2019, during which MIROS had investigated a total of 975 cases in both East and West Malaysia. After filtering through the cases, a total of 129 frontal impact crashes (PV versus PV) involving 206 PV and 349 front seat occupants were selected for data analysis. From the total number of selected cases, 82 cases were involved in head-on collisions while 47 cases were involved in side-impact collisions. As a result, crash configuration, crush extent, airbag availability, and seatbelt wearing are strongly related to the level of injury severity of frontal seat occupants involved in a frontal impact collision. Meanwhile, collision types and occupant seating position do not appear to be significantly related to the severity of the occupants' injuries.*

Keywords: Frontal impact, front-seat occupants, passenger vehicles, injury severity, real-world data

Journal homepage: www.jsaem.my

1.0 INTRODUCTION

Around 1.25 million people died every year in traffic crashes around the world. The majority of people drive four-wheeled vehicles, while the rest either ride two-wheelers, bicycles, or are pedestrians (WHO, 2015). After motorcycles, four-wheeled vehicles such as cars, 4WDs, and vans account for the second-highest number of road crashes in Malaysia (13.5%). In 2018, a total of 6,284 lives were claimed in Malaysia due to road crashes. Out of that number, 1,167 (18.6%) people were in passenger vehicles.

Using data from the Royal Malaysia Police's Statistical Report 2018 (RMP, 2018), the graph in Figure 1 displays the number of passenger vehicles involved in road crashes over ten years, from 2009 to 2018. In comparison to other types of passenger vehicles, the graph illustrates that cars account for the largest number of passenger vehicles involved in road crashes. Furthermore, according to the data, the number of fatal occupants in passenger vehicles has remained nearly constant from 2009 to 2018, with a total proportion of fatal occupants of 24.5% of overall casualties over those ten years. Frontal collisions account for the majority of mishaps resulting in a serious or fatal injury to the occupants. According to MIROS data (2014-2016), the frontal impact was the cause of the most incidents, accounting for more than half of all investigation cases (57.7%).

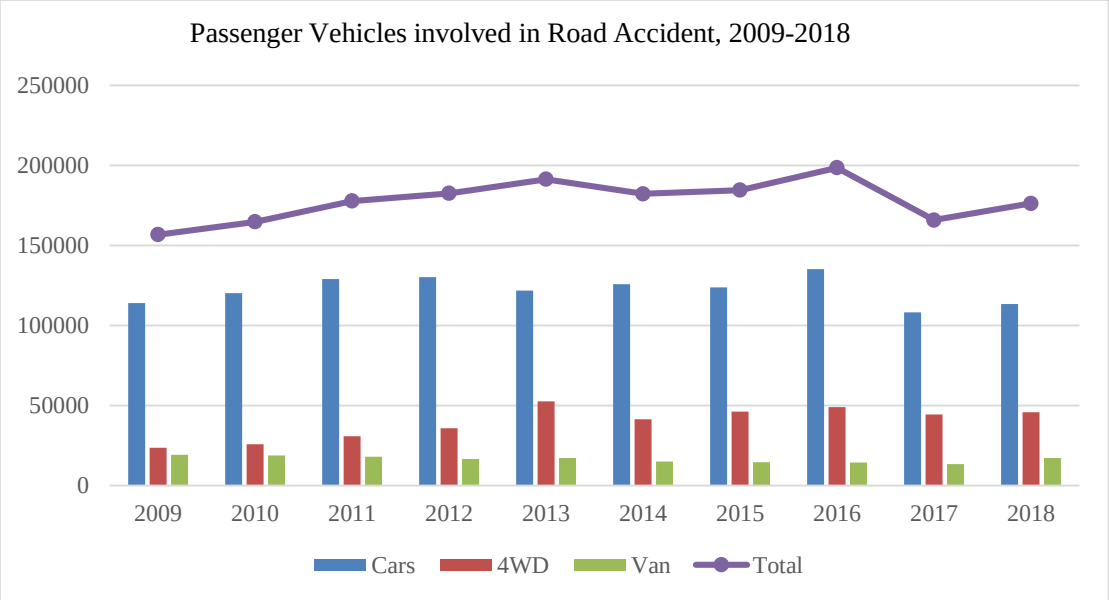

Figure 1: Number of passenger vehicles involved in road crashes from 2009-2018

According to a study that utilized the Crash Injury Research and Engineer Network (CIREN) database, among the most common injuries reported in frontal collisions were lower extremities, upper extremity, thorax, and abdomen injuries. Drivers in wide impacts were four times more likely than drivers in narrow impacts to receiving an AIS score of three or higher in a head injury (Conroy et al., 2008).

Furthermore, the safety of car occupants is dependent not only on the safe design of the vehicle they are riding in but also on the vehicle design aggressivity of the crash partner in a head-on accident (Buzeman et al., 1998). The casualties sustained by the occupants of the second vehicle involved in the crash are used to determine aggressiveness (Hollowell & Gabler, 1996). Vehicle compatibility of vehicle-to-vehicle frontal impacts is divided into three categories: mass, stiffness, and geometry compatibility. Moreover, whereas impact speed is positively connected with injury severity, other factors such as vehicle body types, damage intrusion, and Delta-V are likely to have an impact on occupant injury severity. To complement the occupant's protection in crashes especially in frontal impacts, airbags and safety belts are important vehicle safety features (Zainal Abidin et al., 2015).

Crash extent zones 2-5 (crush up to the A-pillar) and 6-9 (crush up to the pillar) were separated (crush through or beyond the A-pillar). The percentage of occupants with chest and spine injuries was higher in collisions with extent zones 2-5 than in collisions with extent zones 6-9 (Pintar et al., 2008).

Although Fatality Analysis Reporting System (FARS) includes limited information on individual incidents, it may be statistically examined to estimate the fatality decrease caused by the usage of seat belts and airbags in all frontal crashes, as well as select subgroups of frontal collisions. Seat belts and airbags are both helpful at lowering fatality risk in frontal collisions as the combination of seat belts and airbags is much more beneficial. When drivers and right-front passengers use 3-point belts, the National Highway Traffic Safety Administration (NHTSA) estimates that they reduce their fatality risk in frontal collisions by 40 to 64 percent (Kahane, 2000).

Frontal airbags have a lower fatality risk in frontal crashes, according to statistical analysis of FARS data, but significantly more when the major impact point is 12 o'clock (front-center or front-distributed) than 11 or 1 o'clock (front-corner). Airbags are also slightly more effective for adult passengers than for drivers, and unbelted people than for belted people, although their effectiveness in single-vehicle and multi-vehicle crashes is about the same. The combined effect of using seat belts and airbags is extremely significant. The anticipated combined fatality reduction for seat belts and airbags is at least 48.0% when compared to an unrestrained occupant in a seat position not equipped with airbags (Bean et al., 2009).

1.1 Objectives of Study

The objectives of this study are:

i. To identify the injury severity of the front seat occupants involved in a frontal impact collision.

ii. To evaluate injury severity outcome based on the selected crash parameters in frontal-impact collision.

2.0 METHODOLOGY

2.1 Scope of Study

The focus of this research will be on passenger vehicles involved in frontal crashes. The damage and crash severity will be identified and examined to determine the injury pattern and severity in the said type of collision.

2.2 Methods

Between 2007 and 2019, MIROS investigated 975 cases involving passenger vehicles, motorbikes, heavy vehicles, and other vehicles in both East and West Malaysia. The current analysis included cases from the Crash Investigation and Reconstruction Database (CIRD) that involved passenger vehicles in frontal collisions between 2007 and 2019.

A frontal crash is defined as a crash between passenger vehicles A and B where passenger vehicle B sustains frontal impact and damage. In a head-on collision, both passenger vehicles have frontal collisions. Meanwhile, in a side or rear-impact crash, the striking passenger vehicle has a frontal collision (Zainal Abidin et al., 2016).

Only front-seat occupants, including drivers and front passengers (FP), were included in this study, with rear passengers being excluded. Following the screening process, a total of 129 cases involving 206 passenger vehicles were chosen for this study. As many as 206 drivers and 143 front passengers in the passenger vehicles were involved in the total number of collisions.

Aside from that, 82 of the 129 cases included head-on crashes, while 47 were involved in side-impact collisions. Heavy vehicles and single-vehicle accidents (SVA) were omitted, and this study looked specifically into collisions between passenger cars and passenger cars. The steps taken in this study is illustrated in Figure 2 below:

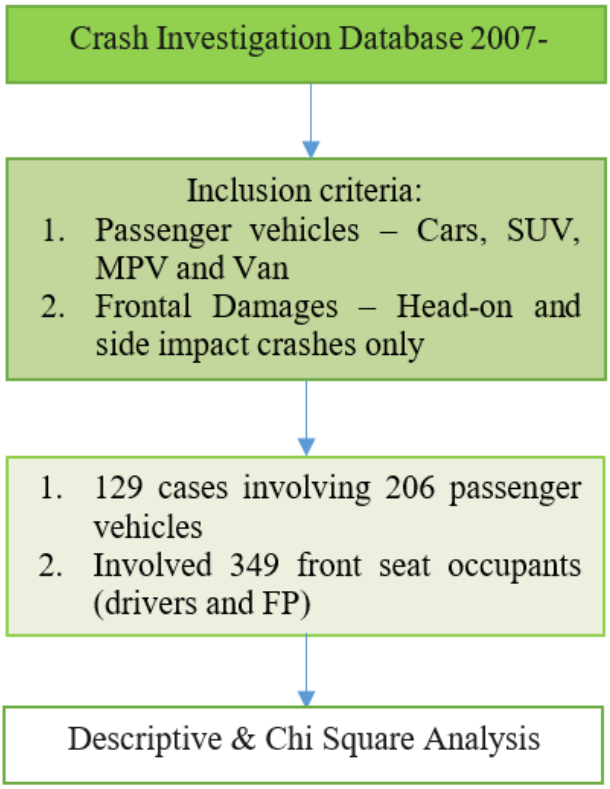

Figure 2: Method of the study

As stated in Table 1 below, the selected cases were analyzed to determine the parameters linked to frontal impact collisions. The relationship between the parameters and the severity of injuries suffered by vehicle occupants was then statistically evaluated using the descriptive and chi-square analysis in the Statistical Package for the Social Sciences (SPSS) software.

Table 1: Data description for this study

Independent Variable	Dependent Variable
Crash Configuration Head-on collision Side impact	**Injury Severity Level** Fatal Non-Fatal (Minor and severely injured, and uninjured)
Collision Type Offset Full frontal	
Crush Extent Zone 6-9 Zone 1-5	
Seat Position Driver Front passenger	
Airbag Availability Without airbag With airbag	
Seatbelt Wearing Unrestraint Restraint	

3.0 RESULTS AND DISCUSSION

3.1 Number of Vehicles by Crush Extent

Figure 3 depicts the various zones of a passenger vehicle involved in frontal impact collisions, which have been divided into nine zones or can also be referred to as crush extent. As a result, a majority of the vehicles (47.1%) recorded a crush extent of zone 3-5 while the lowest number of vehicles (7.3%) recorded a crush extent of zone 1-2.

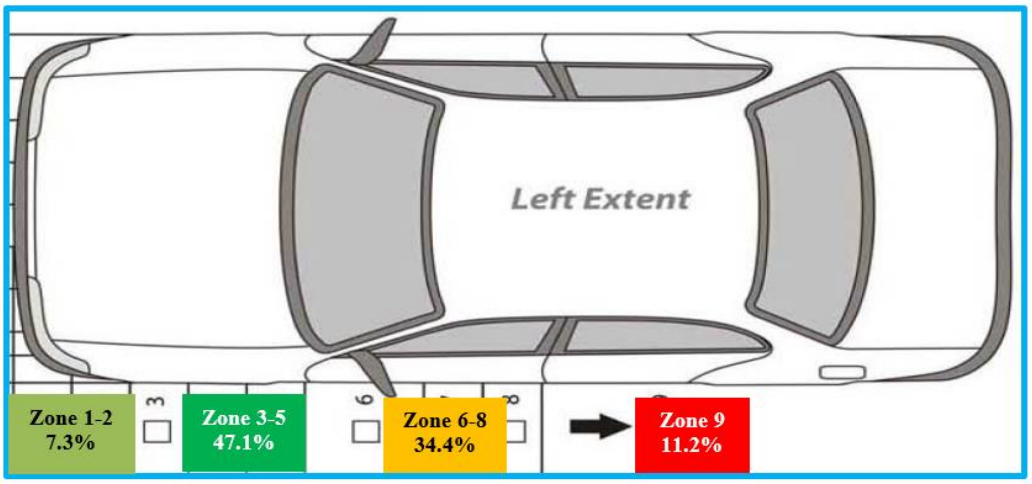

Figure 3: Percentage of number of vehicles by crush extent

3.2 Restraint Wearing among Front Seat Occupants

Figure 4 below shows the percentage of front-seat occupants in frontal impact crashes who were wearing their restraints at the time of the crash. The graph displays the percentage of front-seat passengers who were buckled up. According to the study, 59.2% of drivers wore their seatbelts, although only 42.0% of the front passengers were belted.

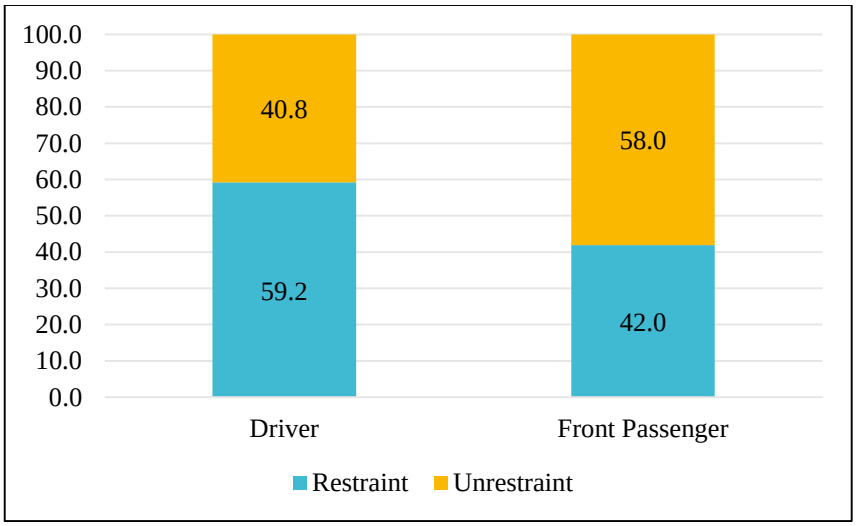

Figure 4: Percentage of restraint wearing among front-seat occupants

3.3 Injury Severity of Front Seat Occupants involved in Frontal Impact Collision

Meanwhile, Figure 5 below depicts the percentage of front-seat occupants injured severely in frontal impact collisions. The percentage of front passengers killed is substantially greater than the proportion of drivers killed, which is 65.0% and 55.8% respectively as shown in the graph. 44.2% of the drivers survived the frontal impact collision, while only 35.0% of the front passengers survived.

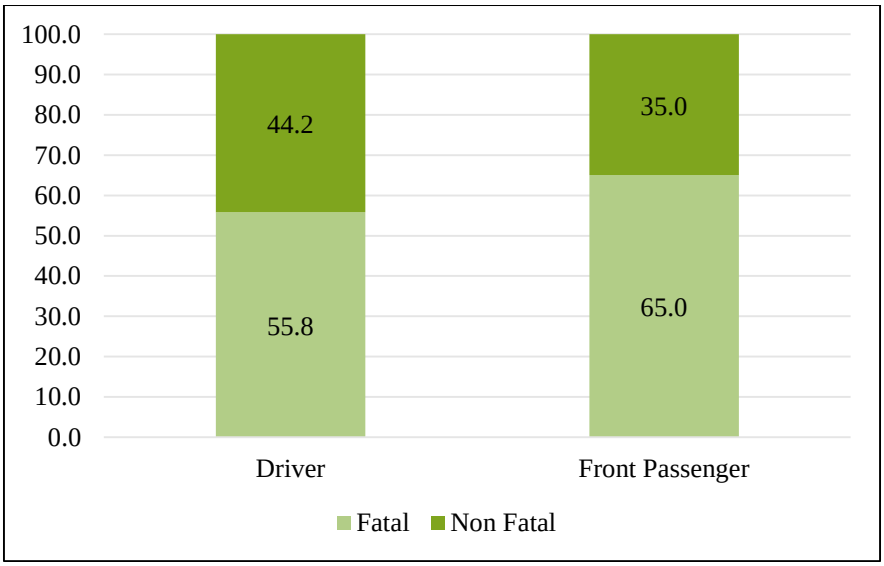

Figure 5: Percentage of injury severity of front seat occupants involved in frontal collision

3.4 Crash Configuration towards Injury Severity Level Association

In head-on collisions, the proportion of occupants who died was 69.2% higher than in side-impact collisions. Inferential analysis revealed that crash configuration had a significant relationship ($p<0.05$) with the severity of the occupants' injuries. As a result, individuals in a head-on collision are 2.33 times more likely to die than those in a side-impact crash as seen in Table 2 below.

Table 2: Percentage of injury severity related to crash configuration

Crash Configuration	Injury Severity (%)		p-value	OR
	Fatal	Non-Fatal		
Head On Collision (HOC)	176 (84.6)	99 (70.2)	0.001	2.33 (HOC : HIC)
Side Impact Collision (SIC)	32 (15.4)	42 (29.8)		

3.5 Crush Extent towards Injury Severity Level Association

The proportion of occupants' fatalities for the vehicle with crush extent of zone 6-9 was 38.4% higher than zone 1-5. Inferential analysis showed that crush extent did have a significant association ($p<0.05$) with the occupants' injury severity levels as displayed in Table 3 below. Hence, the occupants in the vehicle with a crush extent of zone 6-9 is 7.98 more likely to be fatal compared to zone 1-5.

Table 3: Percentage of injury severity related to crush extent

Crush Extent	Injury Severity (%)		p-value	OR
	Fatal	Non-Fatal		
Zone 6-9 (6-9)	144 (69.2)	31 (22.0)	0.0001	7.98 (6-9 : 1-5)
Zone 1-5 (1-5)	64 (30.8)	110 (78.0)		

3.6 Airbag Availability towards Injury Severity Level Association

Without airbags, the proportion of occupants who died was 53.8% greater than with airbags. Airbag availability had a significant relation ($p<0.05$) with the occupants' injury severity levels, according to inferential analysis. As a result, Table 4 below shows that people in vehicles without airbags are 3.20 times more likely to die than those in vehicles equipped with airbags.

Table 4: Percentage of injury severity related to airbag availability

Airbag Availability	Injury Severity (%)		p-value	OR
	Fatal	Non-Fatal		
Without Airbag (WOA)	160 (76.9)	72 (51.1)	0.0001	3.20 (WOA : WA)
With Airbag (WA)	48 (23.1)	69 (48.9)		

3.7 Seatbelt Wearing towards Injury Severity Level Association

The percentage of fatalities among occupants who did not wear seatbelts was 19.2% greater than the percentage of fatalities among those who did. Seatbelt use had a significant relation ($p<0.05$) with the severity of the occupants' injuries, according to the results of the inferential analysis in Table 5 below. Thus, unrestrained occupants are 3.37 times more likely to die than restraint ones.

Table 5: Percentage of injury severity related to seatbelt wearing

Seatbelt Wearing	Injury Severity (%)		p-value	OR
	Fatal	Non-Fatal		
Unrestraint (U)	124 (59.6)	43 (30.5)	0.0001	3.37 (U : R)
Restraint (R)	84 (40.4)	98 (59.5)		

4.0 CONCLUSION

According to this study, front passenger fatalities (65.0%) were higher than driver fatalities (55.8%), and one of the reasons for this is the higher rate of front passenger airbag unavailability (75.3%). Crash configuration accounted for the highest proportion of fatalities among front-seat occupants (69.2%). Inferential analysis revealed that crash configuration (OR=2.33), crush extent (OR=7.98), airbag availability (OR=3.20), and seatbelt wearing (OR=3.37) had a significant relationship ($p<0.05$) with the front seat occupants' injury severity level in frontal impact collisions. Finally, the severity of injuries sustained by front-seat occupants in a frontal impact collision is not substantially associated with collision type ($p=0.201$) or seat position ($p=0.085$).

ACKNOWLEDGEMENTS

This study would not have been possible without the support and motivation from Ir. Mohd Rasid Osman, the then Director of the Vehicle Safety and Biomechanics Research Centre (VSB), and also the team members of the Crash Reconstruction Unit (CRU), VSB.

REFERENCES

Bean, D. J., Kahane, C. J., Mynatt, M., Rudd, R. W., Rush, C. J., & Wiacek, C. (2009). Fatalities in frontal crashes despite seat belts and air bags – Review of all CDS cases – Model and Calendar Years 2000-2007 – 122 Fatalities. DOT HS 811 202, National Highway Traffic Safety Administration (NHTSA).

Buzeman, D. G., Viano, D. C., & Lövsund, P. (1998). Car occupant safety in frontal crashes: a parameter study of vehicle mass, impact speed, and inherent vehicle protection. Accident Analysis & Prevention, 30(6), 713-722.

Conroy, C., Tominaga, G.T., Erwin, S., Pacyna, S., Velky, T., Kennedy, F., Sise, M. & Coimbra, R., (2008). The influence of vehicle damage on injury severity of drivers in head-on motor vehicle crashes. Accident Analysis & Prevention, 40(4), 1589-1594.

Hollowell, W.T. & Gabler, H.C. (1996). NHTSA's Vehicle Aggressivity and Compatibility Research Program. In Proceedings, 15th International Technical Conference on the Enhanced Safety of Vehicles. Australia.

Kahane, C. J. (2000). Fatality Reduction by Safety Belts for Front-Seat Occupants of Cars and Light Trucks. NHTSA Technical Report No. DOT HS 809 199. Washington, DC: National Highway Traffic Safety Administration.

Pintar, F. A., Yoganandan, N., & Maiman, D. J. (2008). Injury mechanisms and severity in narrow offset frontal impacts. In Annals of Advances in Automotive Medicine/Annual Scientific Conference (Vol. 52, p. 185). Association for the Advancement of Automotive Medicine.

RMP (2018). Royal Malaysia Police Statistical Report 2018.

WHO (2015). Global Status Report on Road Safety. World Health Organization.

Zainal Abidin, A. N. S., Kak, D-W., Mohd Faudzi, S. A., Mohamad Radzi, M. A., Omar, A., Lamin, F., Zulkipli, Z. H., Mohd Yusoff, M. A., Mohamad Nor, N. A. F., Osman, M. R. & Wong, S. V. (2016). Factors influencing injury and damage severity in real world frontal impacts involving passenger vehicles. MIROS Research Report No. 184, Malaysian Institute of Road Safety Research.

Zainal Abidin, A. N. S., Kak, D-W., Osman, M. R. & Wong, S. V. (2015). Injury and damage severity factors in real-world passenger vehicles frontal impacts. IRC-15-40. IRCOBI Conference 2015.