



UNIVERSITI PUTRA MALAYSIA

**DETERMINATION OF RISK FACTORS ASSOCIATED WITH SEVERITY
LEVEL OF MOTORCYCLE-PASSENGER CAR CRASHES**

AHMAD NOOR SYUKRI BIN ZAINAL ABIDIN

FK 2019 33



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LEVEL OF MOTORCYCLE-PASSENGER CAR CRASHES**

By

AHMAD NOOR SYUKRI BIN ZAINAL ABIDIN

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfillment of the Requirements for the Degree of Master of Science**

March 2019

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DEDICATION

I would like to dedicate this work to:

ALLAH SWT for His Blessings

My beloved parents, who believed in me and were always there for me, providing their prayers and full support at all times

**Hj Zainal Abidin bin Mohamed
Hjh Halimah bt Kassim**

My significant other, my dear wife who relentlessly keeps supporting me throughout this journey

Nur Farahaizan bt Idris

My enthusiastic children, who keep asking for answers

**Ahmad Adam Rayyan
Nur Ayra Marissa**

My siblings and friends, whose encouragement keep the spirit up

Thank you for all the supports, guidance, encouragements and trusts

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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LEVEL OF MOTORCYCLE-PASSENGER CAR CRASHES**

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AHMAD NOOR SYUKRI BIN ZAINAL ABIDIN

March 2019

Chairman : Associate Professor Nawal Aswan Abdul Jalil, PhD
Faculty : Engineering

This study involves hospital-based on-the-spot (OTS) investigation on motorcycle-passenger car crashes with the aims to determine the risk factors involved in these crashes in which had represented approximately 38% of overall fatal motorcycle crashes in Malaysia. Standby period was performed in three 8-hour shifts in weekly alternate basis to ensure randomness of the investigated cases and to provide 24-hour coverage in order to represent the entire crash population. 55 crashes fulfilling the pre-determined criteria were investigated during one year data collection period in Kajang area. The crashes were reconstructed, analysed and injury details were coded according to Abbreviated Injury Scale (AIS). Morning crashes were 4.7 times more likely to occur during weekdays while night crashes had 6.1 times higher likelihood of occurrence during weekends. Male riders and riders aged ≥ 25 years old were found to be dominant (89.1% and 63.6% respectively), mostly as single riders (87.3%). Passenger cars were more often at fault (61.8%) as compared to motorcycles. However, no significance difference in impact speeds was found for different types of crash partners ($p > 0.05$). 54.5% of the crashes involved situations whereby both vehicles were travelling in same direction, with one turning and the three most dominant crash classifications involved crashes at intersections. Side impacts were the highest crash configurations (40%) and 3.75 times more likely to result in riders suffering $MAIS \geq 3$ injuries. 58% of the side impact crashes involved small angular side impacts and 61% involving motorcycles impacting the passenger cars. $MAIS \geq 3$ injuries had an increasing trend with the increase of motorcycle travelling speed. Motorcycle travelling speed < 15 km/h had 12.5 times higher likelihood to result in riders $MAIS \leq 2$ injuries while lower extremities were the most injured body region sustained by riders (31 %). In regards to passenger car components, front tires were identified as the most damaged component caused by impacts from the motorcycles (21.8%), followed by front fenders and front bumpers (20% each). Moreover, $MAIS 3$ injuries were most dominant when passenger cars' front fenders and front bumpers were damaged (45.5% and 41.7%, respectively).

The developed injury severity model has found that motorcycle impact speed, maximum wheel deformation and crash participant at fault status were significant predictors in predicting riders suffering MAIS \geq 3 injuries. Riders were found to have a 1.5 likelihood increase in sustaining MAIS \geq 3 injuries for every increase in impact speed and 23 times higher likelihood when passenger car was at fault. Meanwhile the injury type model concludes that motorcycle wheelbase deformation and crash participant at fault status were significant to predict riders lower extremity injuries. Riders were 4.8 times having the risk of suffering such injuries when crash partner was at fault and 1.02 times more likely to suffer such injuries with every decrease in wheelbase deformation. In conclusion, the study has presented meaningful information on evaluating risk factors and understanding the characteristics of motorcycle–passenger car crashes using real world data. It has also established introductory data on motorcycle riders’ injuries severity for future improvement of motorcycle safety, specifically in crashes with passenger cars.

Key words: *In-depth crash investigation, motorcycle crash, passenger car, injury severity*

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENENTUAN FAKTOR RISIKO TAHAP KEPARAHAN KEMALANGAN MOTORSIKAL–KENDERAAN PENUMPANG

Oleh

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Kajian ini melibatkan siasatan berasaskan hospital ke atas kemalangan melibatkan motorsikal dan kenderaan penumpang dengan objektif bagi menentukan faktor risiko berlakunya kemalangan tersebut yang mana merangkumi 38% daripada jumlah kemalangan maut melibatkan motorsikal di Malaysia. Tempoh bersedia bagi pasukan penyiasat dijalankan dalam tiga peringkat 8-jam yang ditukarganti pada setiap minggu bagi memastikan kerawakan kes kemalangan yang disiasat, dan membolehkan liputan 24 jam bagi mewakili keseluruhan populasi kemalangan. Sejumlah 55 kes kemalangan yang memenuhi kriteria ditetapkan telah disiasat dalam tempoh setahun di kawasan Kajang. Kemalangan tersebut telah dibinasemula, dianalisis dan maklumat kecederaan penunggang dikodkan menggunakan *Abbreviated Injury Scale* (AIS). Kemalangan waktu pagi didapati 4.7 kali ganda lebih cenderung berlaku pada hari biasa manakala kemalangan waktu malam pula adalah 6.1 kali lebih cenderung berlaku pada hari minggu. Penunggang lelaki dan penunggang berumur sehingga 25 tahun didapati dominan (masing-masing 89.1% dan 63.6%), kebanyakannya sebagai penunggang tanpa pembonceng (87.3%). Kenderaan penumpang lebih kerap melakukan kesalahan (61.8%) berbanding motorsikal. Walaubagaimanapun, bagi kelajuan impak, tiada perbezaan signifikan antara jenis kenderaan penumpang berlainan ($p > 0.05$). Sebilangan besar kemalangan (54.5%) melibatkan situasi di mana kedua-dua kenderaan bergerak pada arah yang sama, dengan satu kenderaan sedang membelok, manakala tiga klasifikasi kemalangan paling dominan melibatkan kemalangan di persimpangan. Perlanggaran sisi merupakan konfigurasi perlanggaran tertinggi (40%) dan adalah 3.75 kali lebih cenderung mengakibatkan kecederaan MAIS ≥ 3 kepada penunggang. 58% daripada perlanggaran sisi tersebut melibatkan kemalangan sisi sudut kecil dan 61% berlaku melibatkan motorsikal melanggar kenderaan penumpang. Kecederaan MAIS ≥ 3 juga menunjukkan corak peningkatan dengan pertambahan kelajuan motorsikal. Kelajuan motorsikal < 15 km/h adalah 12.5 kali ganda lebih cenderung mengakibatkan kecederaan dengan tahap keparahan MAIS ≤ 2 kepada penunggang dan anggota

bawah badan merupakan bahagian anggota yang paling banyak tercedera bagi penunggang (31%). Berkenaan komponen kenderaan penumpang, tayar hadapan merupakan komponen yang paling kerap mengalami kerosakan akibat impak daripada motorsikal (21.8%), diikuti dengan fender hadapan dan bumper hadapan (20% setiap satu). Kecederaan tahap MAIS3 adalah paling kerap berlaku apabila fender hadapan dan tayar hadapan kenderaan penumpang mengalami kerosakan (45.5% dan 41.7%, setiap satu). Model keparahan kecederaan yang telah dibangunkan telah kelajuan impak motorsikal, perubahan maksimum bentuk roda motorsikal dan status kesalahan kenderaan sebagai pembolehubah ramalan signifikan dalam meramalkan tahap kecederaan $MAIS \geq 3$ bagi penunggang. Penunggang didapati 1.5 kali lebih berkemungkinan mendapat kecederaan tahap $MAIS \geq 3$ bagi setiap peningkatan km/j kelajuan impak dan 23 kali ganda lebih cenderung apabila kenderaan penumpang melakukan kesalahan. Model jenis kecederaan pula merumuskan bahawa perubahan bentuk jarak roda motorsikal dan status kesalahan kenderaan merupakan pembolehubah signifikan bagi meramalkan kecederaan anggota bawah badan penunggang. Penunggang adalah 4.8 kali lebih berisiko mendapat kecederaan anggota bawah badan apabila kenderaan penumpang melakukan kesalahan dan 1.02 kali ganda lebih cenderung mengalami kecederaan berkenaan dengan setiap penurunan perubahan bentuk jarak roda. Kesimpulannya, kajian ini telah membentangkan maklumat yang berguna berkenaan penilaian faktor risiko dan memahami ciri-ciri kemalangan motorsikal-kenderaan penumpang menggunakan data kemalangan sebenar. Ianya juga telah memberi maklumat awal mengenai keparahan kecederaan penunggang motorsikal untuk penambahbaikan tahap keselamatan penunggang pada masa akan datang, khususnya melibatkan pelanggaran dengan kenderaan penumpang.

Kata kunci: *Penyiasatan kemalangan secara mendalam, kemalangan motorsikal, kenderaan penumpang, keparahan kecederaan*

ACKNOWLEDGEMENTS

Firstly, I would like to express my greatest praise and gratitude to Allah SWT for giving me the energy to pursue this challenging work. My highest appreciation goes to my wife who believes in me that I could reach the destination and complete this endeavour. My sincerest gratitude and gratefulness to my supervisors, Associate Prof. Dr. Ir. Nawal Aswan Abd. Jalil and Prof. Dr Wong Shaw Voon for their continual supports since the journey began a few years back. My deepest appreciation also goes to all medical specialists, medical officers and staffs of the Emergency Department of Kajang Hospital for their cooperation and assistance in allowing me to conduct the real world investigation and providing the injury information.

I would also like to thank all my superiors and friends in MIROS for their great support and sport, for allowing me the chance to focus on this thesis.

Thank you all for the spirited efforts.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

AIS	Abbreviated Injury Scale
CC	Crash Configuration
CDC	Collision Deformation Classification
FN	False Negatives
FP	False Positives
FRP	Final Rest Positions
ISS	Injury Severity Score
MAIS	Maximum AIS
MLEI	Motorcycle Riders Lower Extremities Injuries Probability Prediction
MOIS	Motorcycle Riders Overall Injury Severity Probability Prediction
MPC	Motorcycle-Passenger Car
MPV	Multipurpose Vehicles
MRC	Maximum Residual Crush
MROADS	MIROS Road Accident Database System
MVA	Motor Vehicle Accidents
NH	Normal Hours
OH1	Afternoon Shift
OH2	Night Shift
OR	Odds Ratio
OV	Opposing Vehicle
PDoF	Principle Directional of Force
PoI	Point of Impact
SPSS	Statistical Package for the Social Sciences
SUV	Sport Utility Vehicles
TN	True Negatives
TOL	Tolerance Statistic Value
TP	True Positives
VIF	Variance Inflation Factor

CHAPTER 1

INTRODUCTION

1.1 Motorcycle Ownership in Malaysia

Throughout the years, motorcycle has become one of the most common type of vehicles used on the road, particularly in the Asia region due to its size-convenience and affordable price. Evidence has suggested that increasing congestion, the availability of parking, and travel costs are encouraging the purchase of mopeds (up to 50cc) and scooters (over 50cc) for transport. In the US, a significant increase in the number of motorcycles registered was observed in the last decade (a 75% increase from 1997 to 2006 (WHO, 2009).

In Malaysia, a similar trend was also imminent. The composition of annually registered vehicles on the Malaysian road consist of mainly motorcycles, passenger cars, buses and lorries and 50% of the total registered vehicles are motorcycles (Vien, et al, 2006). Motorcycle ownership in Malaysia has increased rapidly from 0.13 motorcycles per person in 1990 to 0.23 motorcycles per person in 2001. Malaysians tend to purchase smaller size motorcycles in the range of 70 cc to 115 cc. Relatively, large motorcycles are also available on the road but are not as practical as the small size motorcycle because during traffic congestion, there is not enough space for the large motorcycles to weave in and out of other vehicles. Nevertheless, majority of motorcycles owners in the country belong to the lower and middle-income group, thus lower price motorcycles, generally speaking range between 70 cc to 115 cc are the better option. In 2002, the number of motorcycles estimated on Malaysian road was approximately 5.8 million units (Highway Planning Unit, MOW).

In terms of the demand for motorcycles in Malaysia, the market will continue to sustain and further grow in the future due to several factors. One of those is traffic congestion. As a result of the increasing number of vehicles on the road every year, traffic congestion has worsened especially in city centres. On another note, the lower income group still depends heavily on motorcycles due to the affordable retail price and to save cost on petrol. Parking spaces are also a lot easier to find for motorcycles as compared to cars. Therefore, motorcycles are the preferred mode of transport in these situations. Apart from that, inefficient public transport also prompted higher motorcycles demand in the country.

1.2 Crashes involving Motorcycles

In Malaysia, road crashes have resulted to more than 6000 fatalities every year and the numbers were increasing from year to year since 2007 (Senbil et al., 2007). Every year in Malaysia, approximately 60% of road crash fatalities were the result of

motorcycle crashes (Thomas et al., 1999). Motorcyclist are also found to contribute almost 70% of all injuries (death, serious injuries and minor injuries) in road crashes. In terms of structural designs, due to low level of safety protection and inferior structural integrity of the motorcycles as compared to other types of road motor vehicles, riding a motorcycle is about managing risk. Motorcycles are smaller, lighter, and more manoeuvrable, require balance, and in most cases afford an elevated view of the road compared to cars. Unlike car drivers, motorcyclists are directly exposed to the environment in which the machine is operating. The motorcycle itself offers very little protection to the rider and pillion rider during crashes.

Hazard associated to motorcycle is significant due to the mixed traffic flow on roads. Although this has become an established fact in Malaysia, and solution for traffic segregation i.e. through setting up exclusive motorcycle lanes, other issues such as high building cost of those infrastructures and enforcement issues have resulted in sluggish effective intervention to tackle the issue. Recent data indicates that deaths and injuries attributable to motorcycle crashes are becoming a larger portion of public health problem.

A report by the World Health Organization (WHO) highlighted that worldwide, motorized 2 or 3 wheelers had sum up a total of 23% of the entire road traffic death in 2003 and the proportion was up to 34% for South East Asian region. Motorcycle and moped crashes are characterised to some extent by similar risk factors according to previous literatures. Risk factors common for both motorcycle and moped crashes include exceeding speed limits, inappropriate speeds, alcohol use, unlicensed riding, holding a foreign licence, helmet non-use, male gender, younger and older rider age, rider inexperience and riding for recreation (Greig et al., 2007; Haworth et al., 2009; Lardelli-Claret et al., 2005; Lin and Kraus, 2009; Moskal et al., 2012). In terms of the motorcyclist characteristics, poor visibility generally increased the severity of the crash. In another study, it was found that motorcycle crashes were more severe in speed zones of 80 km/h or more, on curves, in single vehicle crashes, on weekends and between the hours of 6pm and 6am.

A Swedish study of moped and motorcycle crash injuries from 1987 to 1999 reported that motorcycle and moped riders were respectively 10 and 20 times more likely to be injured in a crash than car occupants per distance travelled (Aare and Holst, 2003). Per distance travelled, the rate of motorcyclist deaths is approximately 30 times the rate for car occupants while the corresponding rate for a serious injury is approximately 41 times higher as indicated by a study in Australia. When comparing new motorcycles with new cars, the odds of fatal or serious injury to a motorcycle rider involved in an injury crash were almost eight times the odds for a car driver. In addition, elevated rates for motorcyclist death and injuries are also found in other developed countries such as Malaysia.

1.3 Crash Partners in Motorcycle Crashes

A previous study on Australian motorcycle crashes concluded that more than half of fatal motorcycle crashes involve another vehicle as their crash partner in which the other vehicle is most often at fault. Commonly, this involves violations of the motorcyclist's right of way. However, there has been a prevailing public perception that motorcyclists are less risk averse than other road users based upon high-risk behaviours that include excessive speeding, riding without a helmet, or drinking and riding. Such factors may suggest increased risks of crash involvement, as well as an increased tendency for being found at-fault in the event of a crash. This issue is compounded by the fact that motorcyclists who are at-fault in crashes have also been shown to be more likely to be killed in the event of a crash (Savolainen and Mannering, 2007). Due to such concerns, past research has sought to identify factors associated with high-risk behaviors by motorcyclists (Horswill and Helman, 2003; Lin et al., 2004; Dandona et al., 2006; Chen, 2009; Wong et al., 2010). Despite this fact, motorcyclists were found to travel at higher speeds, exhibit shorter gap acceptance, and more aggressively overtake other vehicles in comparison to drivers (Horswill and Helman, 2003).

A Malaysian in-depth crash investigation study also confirmed that approximately 38% from the total fatal motorcycle crashes involved passenger vehicles (cars, SUVs & MPVs) as their crash partners and majority of the injuries involved frontal impact (40.0%). Compatibility of vehicles on vehicle-to-vehicle impacts is classified as the mass, stiffness and geometry compatibility, which are referred to as compatibility parameters. Previous research works have cited that incompatibilities between different groups of road users as one of the five key road safety problems that are persistent over time, between nations, and are not easily being solved. Higher compatibility means a more comparable, and overall, higher level of crash protection in both striking and struck vehicle. The inferior design features of the motorcycles may end up causing incompatibility issue between the motorcycles and the passenger vehicles in crashes.

The safety of vehicle occupants in a crash does not only depend on the safe design of the vehicle they ride, but also depends on the vehicle design aggressivity of the crash partner in which the vehicle was involved with in a collision (Haque et al., 2009). In road traffic crashes, vehicle aggressivity is measured in terms of the likelihood for it to result in casualties to the occupants of the other vehicle involved in the collisions.

1.4 On-the-spot Crash Investigations Approach

By focusing specifically on the motorcycle – passenger car crashes, this study interest does not only focus on the consequences of those crashes, but also in crash causation, road user behaviour, the effects of road engineering and ultimately how the impact take place and the injury occurred. Although judicial investigations

conducted by the authority are necessary to allocate blame, guilt or liability, they are not the most effective way to prevent road crashes from happening again.

In order to develop effective strategies to reduce road crashes and injuries, national administrations and the motor industry have long recognised the need to determine what is happening in the real world. However, much of the information that is necessary to understand these complex issues is found at the scene of the crash and is lost once the crash scene is cleared. This is best achieved through carrying out in-depth crash investigations, as noted by Mackay et al. (1985).

Mackay et al. (1985) has also stated that retrospective methods are not adequate for investigating pedestrian impacts and motorcycle crashes. Recent studies also proved that retrospective approach cannot be used to obtain perishable crash information such as tire marks on the road, blood stain on vehicle components, occupants contact marks on vehicles, the final resting position of the vehicles involved, visibility and many others. Such information is lost during the clearing of the crash scene and it is only by conducting on-the-spot investigations that these information is able to be retrieved.

Moreover, it is important to obtain answers to the questions how and why the crash and injury occur, to be able to develop adequate knowledge on improving current motorcyclist vulnerability issues particularly when involving passenger cars as crash partners. Thus, to avoid loss of information, particularly the volatile evidences, this project utilizes the on-the-spot investigation approach as the method of data collection. This enables the investigators to attend the scene of a crash within 15 minutes of the incident occurring, which allows the collection of crash data that would otherwise be quickly lost. Moreover, collaborations with hospitals as the treatment facility provides injury information of the involved occupants which is useful in establishing the relationship between the on-the-field crash information, injury mechanics and injury outcomes.

1.5 Problem Statement

Motorcycle safety is a major issue in Malaysia due to the consistently high number of crashes and fatalities recorded annually. Every year motorcycle fatalities were recorded approximately 60% from the overall road traffic fatalities and the involvement of passenger cars as crash partners in crashes involving motorcycles were also quite high with approximately 38% (Wing et al., 2013). Moreover, no study has been conducted on establishing in depth knowledge in motorcycle-passenger car crashes from the local context. Efforts in establishing such knowledge by utilizing national crash database by the Royal Malaysian Police (RMP) may be limited due to high numbers of under reporting and missing data especially on non-fatal cases. Furthermore, any efforts to conduct study using the national crash database will be limited to only the general variables and not on the in depth and technical variables i.e. vehicle crush profiles and impact speeds. Moreover, detailed

injury information of the victims i.e. injured body region and severity level is also not available thus disabling any efforts in understanding the injury mechanism of the involved victims. Thus, efforts in utilizing in-depth investigation study to obtain real world crash data together with the detailed injury information of the involved motorcyclists is needed to thoroughly comprehend the issue in motorcycle-passenger car crashes.

1.6 Research Questions

While previous studies mainly focus on improving the design of safety protections from the motorcycle point-of-view by methods of crash avoidance technologies such as Antilock Braking System (ABSs), passive safety equipment such as motorcycle airbags and airbag-equipped safety vest for motorcyclists, feasibility of such technologies needs to be considered particularly towards the effect on price increase of the motorcycles. This may become a burden to the lower income group who still depends heavily on motorcycles due to the affordable retail price.

On contrary, from the issues arise from motorcycle crashes, focus should be given in designing more “motorcycles friendly” passenger car design in order to reduce the injury severity outcomes of motorcyclists in collisions with passenger cars, particularly in frontal and side impacts where the proportion of injuries was the highest. In pedestrian safety technology advancement involving passenger vehicle structures, optimisation of the car front was done to minimize the injury cost converges to vehicle profiles with features known from earlier studies to be pedestrian friendly. Similar to that, a thorough study and analysis on impact characteristics of motorcycle–passenger car crashes towards injury mechanism of the involved motorcyclists was conducted in the study.

To enable such solution, sufficient knowledge on motorcycle-passenger car crashes needs to be established particularly in understanding the details of the crash and injury outcomes. Thus the research questions for this study is as followed:

- i. What are the crash and injury characteristics of such crashes?
- ii. What are the most common crash partner’s components involved?
- iii. What are the contributing factors to crash and injury occurrence?

Furthermore, first hand crash information involving crash dynamics, occupant-vehicle contact details, vehicle damage profiles and occupants injury details needs to be acquired. The answers to the said questions could be obtained through on-the-spot in depth investigation approach which was utilized in the study. The findings from this study served as baseline in describing the characteristics of the crashes, evaluating the risk factors and understanding motorcycle riders’ injuries severity for future improvement of motorcycle safety, specifically in crashes with passenger cars.

1.7 Objectives of the Study

In order to improve the design of current passenger vehicles to be more motorcycle friendly, a detailed knowledge on the injury outcome caused by different vehicle component contacts to different part of the human body needs to be established. This knowledge is essential in establishing the exact hypothesis for each and every crash dynamic occurred in a real world crash between these two modes of vehicles.

To provide the answer to that, the main objective of the study is to determine the risk factors associated with the severity level of motorcycle-passenger car crashes. Specifically, this study aims to address the following objectives to support the main objective mentioned beforehand. The specific objectives of the study are as follows:

- i. To identify crash and injury characteristics of motorcycle-passenger car crashes
- ii. To identify crucial passenger car structures and components which contributes to motorcyclists' injury severity
- iii. To develop an injury probability prediction model that predicts probability of motorcyclists' injury in motorcycle-passenger car crashes

1.8 Scope of the Study

Analysis on injury mechanism and kinematics of the involved motorcyclists with technical indications in the events of motorcycle-passenger cars crashes need to be understood. This study mainly involves focus areas of 'during crash' parameters towards the 'post-crash' outcome, as depicted in Figure 1, specifically related to the involved motorcyclists. The outcome of the study establishes the association and relationship between the 'during crash' parameters towards the 'post-crash outcomes' to the motorcycle and the rider which also takes into consideration the other potential effect such as restraint wearing etc as the mediator in the analysis. The focus of the study mainly involve interests in investigating and predicting the general behaviour of the motorcycles when impacting with passenger cars, specifically in understanding the kinematics of the motorcycle occupants in crashes with passenger cars.

The study also analyses contact interactions of the involved motorcyclists, critical vehicle components and structures, and the roads that are involved during impacts. In conducting the study, injury information of the involved motorcyclists and specific locations of direct impact with regards to vehicle structure is essential in determining the injury mechanism and occupants' kinematics upon impacts with specific parts of the passenger car structure. This knowledge provides crucial inputs and enable future vehicle designs that are more "motorcycles friendly" with lower risk of motorcyclists' injury severity in the event of motorcycle – passenger vehicle crashes.

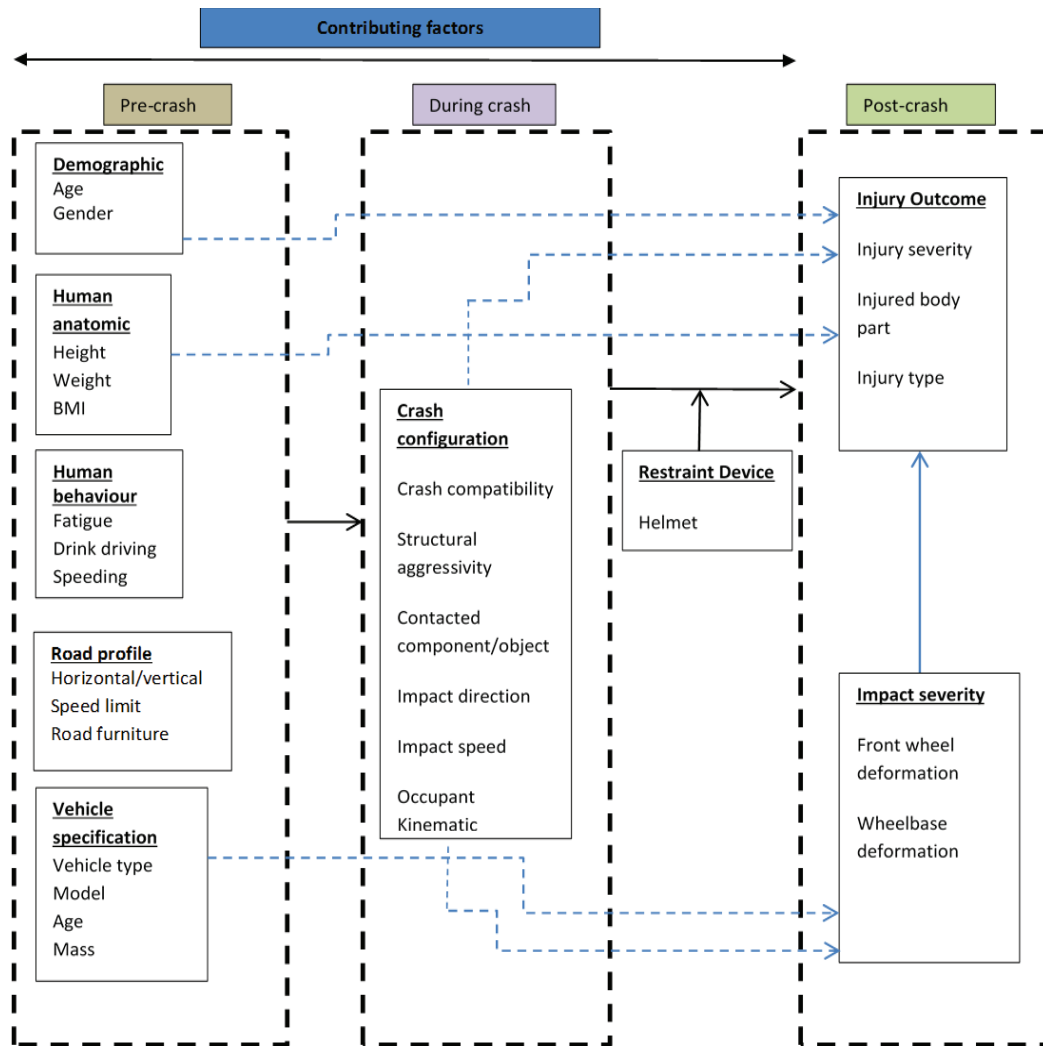


Figure 1.1 : Theoretical framework of the study

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BIODATA OF STUDENT

The student was born on the 25 August 1983 in Kuantan, Pahang. He received his early education in Sekolah Rendah Kebangsaan St Thomas, Kuantan and continued his secondary education in Sekolah Menengah Abdul Rahman Talib, Kuantan before entering Mara Junior Science College in Jasin, Melaka. After undergoing preparation course for Japanese undergraduate study at Universiti Malaya, he then pursued his tertiary education at the Kyushu Institute of Technology (KIT) Kitakyushu, Japan and graduated with a Degree in Science in Mechanical Engineering.



LIST OF PUBLICATIONS

Journal paper

Z.A. Ahmad Noor Syukri, A.J. Nawal Aswan, S.V. Wong, C.Y. Tan, Evaluating Risk Factors in Motorcycle – Passenger Car Crashes using Real-World Investigation (2018), *Journal of the Society of Automotive Engineers Malaysia*, Volume 2, Issue 1, pp 92-105, January 2018, e-ISSN 2550-2239

Z.A. Ahmad Noor Syukri, A.J. Nawal Aswan, S.V. Wong, Crash and Injury Characteristics of Motorcyclists in Motorcycle-Passenger Cars Crashes, *World Academy of Science, Engineering and Technology International Journal of Urban and Civil Engineering*, Vol:12, No:1, 2018

Conference/Proceeding paper

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Research/ Technical paper

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