Deliverable 1.1

Literature Review and Databases Description

WP1: Accident Data Study

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Executive Summary

The OASIM project aims to improve the safety of motorcycle users in the ASEAN region by establishing active safety test protocols representative of the accident situations in this region. Work Package 1 is dedicated to accident data study and the main accident scenarios between motorcycles and passenger cars in the ASEAN countries will be highlighted.

In the first part of the report, a literature review is carried out. The articles that were found concern motorcycle accidents in Cambodia, Malaysia, Singapore, Thailand and Vietnam. No literature was found for the other five countries of the ASEAN region. This raises the issue of data representativeness, which is addressed in this report. The main outcomes of the literature review could be summarised by the following:

- Angular/side impact scenarios appear to be the most important crash configuration in fatal motorcycle accidents in Thailand and Malaysia.
- In the Thailand insurance database, angular scenarios include on the one hand the cases where the other vehicle drives into the path of the motorcycle; and on the other hand, the cases where the motorcycle rides on the lane of the opposite vehicle. Moreover, specifically in Bangkok, rear-end collision is the most frequent crash scenario according to an in-depth accident study. The second crash scenario involves a motorcycle facing a turning vehicle, or a vehicle overtaking another vehicle or driving in the motorcycle lane.
- In Cambodia, head-on and right-angle/side-swipe accidents are predominant and account for 36% and 37%, respectively.
- Motorcycle passengers account for 11% to 24% of fatalities in Thailand, Malaysia, and Cambodia.
- Children are significant users of motorcycles either as riders or passengers.

The second section of the report describes two ASEAN accident databases made available for the project: one from Malaysia and one from Thailand. First, an overview of these databases is provided (selection process, number of cases and variables). Then, the list of common variables set up to jointly exploit the data is presented. Furthermore, the specific methodology, tailored to specificity of each database, to identify the most frequent accident scenarios is detailed: same scenarios from Malaysian and Thai database are set up based on the collision type, the damage on the motorcycle and the movement of the motorcycle. The most prevalent scenarios in each database are then ranked. The top 6 of both all injury severity and fatal or serious injury accident scenarios are compared. Eventually, the most common motorcycle accident scenarios are identical in Malaysia and Thailand (in different proportion, however):

- Head-on scenarios
- Angular scenarios with frontal impact on the motorcycle
- Angular scenarios with lateral impact on the motorcycle
- Rear-end scenarios with a rear impact on the motorcycle

Finally, the list of relevant accident- and collision-characteristic related variables describing each scenario is presented.

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1. Introduction

With 43% of fatalities among their road users, the South-East Asian countries have the higher rate of death among riders of motorized 2- and 3-wheelers (according to the Global Status report on Road Safety 2018). The Association of Southeast Asian Nations (ASEAN), an intergovernmental organization created in 1967, represents ten countries: Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam.

With pedestrians and cyclists, motorcyclists are considered as Vulnerable Road Users (VRU) as they respectively account for 26% (pedestrians and cyclists) and 28% (motorcycles) of all deaths in the world. Looking at the ASEAN countries situations, their proportion goes up to 59% of the fatalities on the road. Since 2011, the ASEAN New Car Assessment Program (ASEAN NCAP) aims to elevate vehicle's safety standards. ASEAN NCAP places high importance on motorcyclist safety and claim to become the most challenging protocol of a kind. Thus, the Motorcyclist Safety Pillar was specifically created in the 2021-2025 Roadmap, to urge the automotive industry to reduce motorcyclist's road traffic deaths through new technologies. The industrial consortium Overall ASEAN market Safety Improvement for Motorcycles (OASIM), coordinated by UTAC was set off in September 2020 with the support of the ASEAN NCAP. The OASIM project aims to improve the motorcyclist safety in the ASEAN region by promoting an official rating.

The first Work Package (WP1) aims at providing a set of accident scenarios representative of the main accident situations between passenger cars and motorcycles in the ASEAN region.

First, a literature review has been carried out to gather motorcycle accidents data on every ASEAN-area country. It focused on accident configurations identification, and on their description according to variables or characteristics that might be of interest for the other Work Packages of the project. A special notice has been made on the representativeness of the available information. If confirmed by further statistical analyses to be carried out in WP1, the information will be used to help determined which are the relevant test scenarios for the ASEAN NCAP test procedure.

Then, two ASEAN accident databases were made available for the project, one from Malaysia and one from Thailand. An overview of these databases is provided (selection process, number of cases, variables and their values). The list of common variables set up to jointly exploit the data is presented.

Finally, the specific methodology, tailored to specificity of each database, to identify the most frequent accident scenarios is detailed. The list of relevant accident- and collision-characteristics related variables describing each scenario is presented.

It is worth noting that the scope of the project concerns all accidents on any type of road and involving one passenger car and one powered two- or three- wheeler (define as in the Glossary) in the 10 countries of the ASEAN region.

2. Glossary

This glossary gives the definition of basic terms used in accidentology.

Accident: Sudden, unexpected, unintended and extraneous event in which a person has been harmed.

Traffic Accident: Accident in the scope of road traffic which ends in material damage or personal injury.

Accident with personal injury: Accident in which persons are injured or killed, irrespective of whether there is a material damage or not.

PDO accident: Property damaged only. Accident in which there are only damages to the vehicle or to the infrastructure. Nobody is injured in the accident.

Single vehicle accident: Accident with only one involved vehicle.

Participant of a traffic accident: All vehicle drivers and pedestrians that have been injured or whose vehicles have been damaged or caused damages.

Side-swipe: Accident configuration where there is very little overlap on both vehicles.

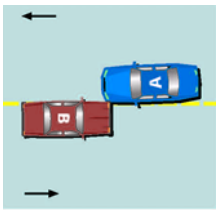


Figure 1: Side-swipe accident configuration

Driver: Occupant that drives the car/pick-up.

Rider: Occupant that rides the motorcycle.

Fatally injured, killed: Persons who die within 30 days as a result of the accident.

Seriously injured: Persons that become in-patient treated for more than 24 hours in the hospital, as a result of the accident.

Slightly injured: Injured person who stayed less than 24 hours in hospital as a result of the accident.

KSI – Killed or Seriously Injured accident: accident with fatally injured or seriously injured persons.

AIS: The Abbreviated Injury Score is a scale used to give a score for injury severity. It is a coding based on anatomical injury description. A code and an AIS score are assigned to each injury. The values range from 1 to 6 with the following meaning (the probability of being killed increases from AIS 1 to AIS 6 which always results in fatality):

1 = Minor injury

2 = Moderate injury

3 = Serious injury

4 = Severe injury

5 = Critical injury

6 = Maximal injury

Two- or three-wheelers: The table below gives an illustration of the different type of the two- or three-wheelers considered in the report. When the exact type of motorcycle is described in the article gathered in the literature review, it will be mentioned. Otherwise, the generic term of motorcycle (MC) will be used.

Two-wheeler scooter

Three-wheeler scooter

Motorcycle

Side car

Figure 2: Illustration of two- or three-wheels scooter, motorcycle, and side car

Passenger car: The table below illustrates different type of passenger cars and pick-up that are taken in account within the scope of the analysis. A pick-up truck is a light goods vehicle with one or two seat rows and with an open part at the back. Those type of vehicle are included in the analysis of OASIM accident data study and all included in “passenger car” reference within the report.

Passenger car – type sedan

Pick-up truck

Passenger car – type SUV

Passenger car – type SUV

Figure 3: Illustration of passenger cars and pick-up

3. Literature review

3.1. Data collection

3.1.1. Keywords and results

The following keywords have been used to select the articles:

- Accident
- Scenario
- Motorcycle/Powered two wheelers
- ASEAN and the 10 different countries: Brunei Darussalam, Cambodia, Indonesia, Laos PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam.

Twenty articles were found relevant regarding the subject.

The following table illustrates the titles of the relevant articles, and the corresponding journal or conference title and year of publication.

Table 1: List of articles selected for the literature review.

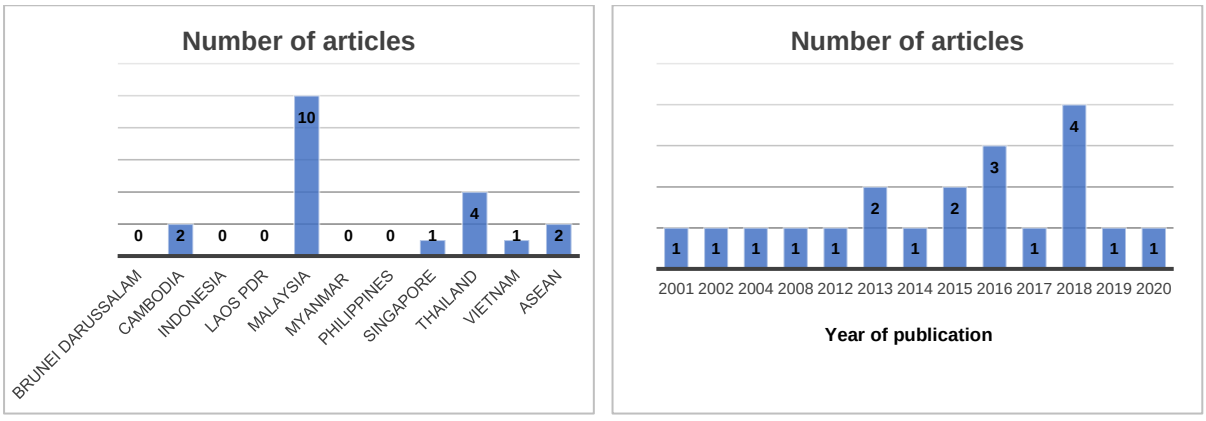
Title	Journal/Conference	Year/Country
Motorcycle accident causation and identification of countermeasures in Thailand, Volume 1: Bangkok study	Final report, September 2001	2001/Thailand
An analysis of motorcycle injury and vehicle damage severity using ordered probit models	Journal of Safety Research	2002/Singapore
The patterns of traffic accidents in Thailand	ESAR Conference Proceeding	2004/Thailand
Crashes with roadside objects along motorcycle lanes in Malaysia	International Journal of Crashworthiness	2008/Malaysia
Motorcycle fatalities in Malaysia	International Association of Transport and Safety Sciences	2012/Malaysia
Identifying contributing factors to fatal and serious injury motorcycle collisions involving children in Malaysia	AAAM Conference Proceeding	2013/Malaysia
Commuter motorcycle crashes in Malaysia: An understanding of risks factors	AAAM Conference Proceeding	2013/Malaysia
Safety System for Child Pillion Riders of Underbone Motorcycles in Malaysia	Traffic Injury Prevention	2014/Malaysia
Fatal motorcycle crashes: a growing public health problem in Cambodia	International Journal of Injury Control and Safety Promotion	2015/Cambodia
Injury Pattern among Motorcyclists involved in Traffic Crashes	IRCOBI Conference Proceeding	2015/Malaysia
ASEAN Regional Road Safety Strategy	Association of Southeast Asian Nations (ASEAN) Report	2016/ASEAN

Factor analysis of motorcycle crashes in Malaysia	Journal of the Malaysian Institute of Planners	2016/Malaysia
Injury Severities among Riders and Pillion Riders in Non-Fatal Crashes in Malaysia	IRCOBI ASIA Conference Proceeding	2016/Malaysia
Factors associated with motorcyclists' speed behaviour on Malaysian roads	Transport research – Part F	2017/Malaysia
An insight of World Health Organization (WHO) accident database by cluster analysis with self-organizing map (SOM)	Traffic Injury Prevention	2018/ASEAN
Traffic problems in Southeast Asia featuring the case of Cambodia's traffic accidents involving motorcycles	International Association of Transport and Safety Sciences	2018/Cambodia
Road characteristics and environment factors associated with motorcycle fatal crashes in Malaysia	International Association of Transport and Safety Sciences	2018/Malaysia
Motorcycle Accident Scenarios and Post-Crash Kinematics of Motorcyclists in Thailand	Journal of the Society of Automotive Engineers Malaysia	2018/Thailand
Analysis of rider and child pillion passenger kinematics along with injury mechanism during motorcycle crash	Traffic Injury Prevention	2019/Thailand
Analysis of motorcycle microscopic characteristics at roundabouts under mixed traffic condition-a case study of Viet Nam	Journal of Traffic and Transportation Engineering	2020/Viet Nam

The World Health Organization website and the ASEAN website were also queried (https://who.int and https://data.aseanstats.org).

3.1.2. Number of articles by country and year of publication

The numbers of articles according to the countries, and according to the years of publication are described in the Figure 4.



(a) *(b)*

Figure 4: Distribution of the number of articles according (a) to the country and (b) to the year of publication

Figure 4(a) shows that the articles only covered five countries out of ten of the ASEAN countries. Two covers the ASEAN region on the whole. The data mainly focus on Malaysia and Thailand. No data on accident configurations were found for Brunei Darussalam, Indonesia, Laos PDR, Myanmar, Philippines. If no data were found for these countries, the representativeness of accident scenarios in Malaysia and Thailand should be studied with regard to the accidents that happen in other ASEAN countries.

As to the years of publication of the articles, figure 4(b) shows that the articles are distributed on a relatively large period of time (from 2001 to 2020) with an important number of recent articles (12 articles since 2015). This would help keeping track of possible changes in accident configurations over time and would hopefully help validating the most recent scenarios.

3.2. Data and context

In this section, data on motorcycles within the ASEAN area are illustrated. These data are useful to quantify the representativeness of the available information, articles and database on the ASEAN region scale.

3.2.1. Population and density

The ASEAN statistics website (https://data.aseanstats.org) shows that more than 649 million people live in ASEAN region (Table 2). This represents 8% of the worldwide population.

Table 2: ASEAN population and land area by country (2018)

Country	Total land area	Total population	Density
	Km^2	Thousand	Persons per km^2
Brunei Darussalam	5 765	442,4	77
Cambodia	181 035	15 981,8	88
Indonesia	1 916 862	265 015,3	138
Lao PDR	236 800	6 887,1	29
Malaysia	331 388	32 385,0	98
Myanmar	676 576	53 625,0	79
Philippines	300 000	106 598,6	355
Singapore	720	5 638,7	7 833
Thailand	513 140	67 831,6	132
Viet Nam	331 230	94 666,0	286
ASEAN	**4 493 516**	**649 071,5**	**144**

Data shows that ASEAN gathers extreme population's density, the number of inhabitant par km^2 ranging from 29 in Lao PDR to 7 833 in Singapore. The situation of Singapore is very far from the other ASEAN countries.

3.2.2. Vehicle fleet

The following figure describe the proportion of each type of vehicle in the fleet (all registered vehicle within a year) of the ASEAN countries. Data were provided by (WHO, 2018) for all countries except Indonesia and Viet Nam (ASEAN, 2016). Data concern 2016 numbers.

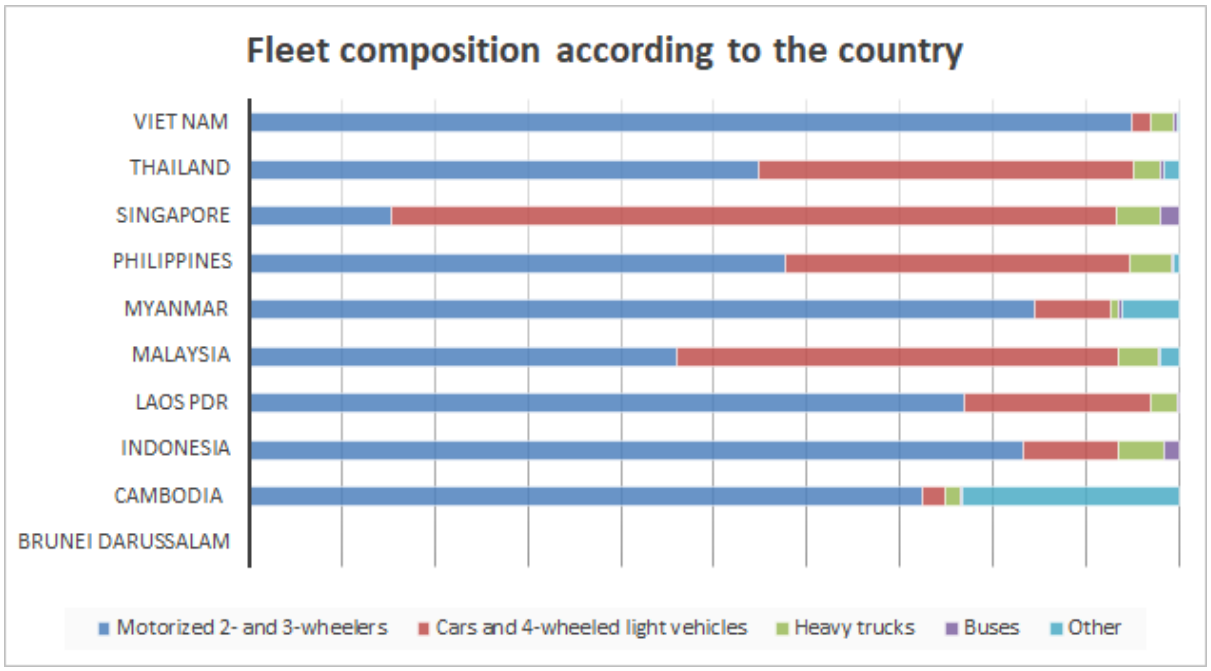


Figure 5: Fleet composition according to the country

Viet Nam exhibits the highest proportion of motorcycle within the fleet (about 95%). In Cambodia, Indonesia, Laos PDR and Myanmar around 70-80% of the fleet is composed of motorcycles. Then, there is a group of countries (Malaysia, Philippines, and Thailand) where motorcycle represent about 50% of the vehicle fleet. Singapore is the country showing the less important proportion of motorcycle in its fleet. The type of vehicle is not described in the data within the "Other" category. Regarding the fleet compositions, interaction between motorcycle and passenger cars seems to be the most likely to happen.

Traffic in ASEAN countries can be described as a mixed one, motorcycles representing the highest proportion of traffic. At the city level, the observations are similar, as shown in the table below ((L. T. Trinh, Sano, Hatoyama, & De Silva, 2020). Motorcycles share the road with a small proportion of passenger cars.

Table 3: Proportion of motorcycles in traffic in different ASEAN cities

Country	City	% of motorcycle among traffic
Indonesia	Pakem	87%
Malaysia	Penang	66%
Thailand	Bangkok	55%
Viet Nam	Hanoi	89%
Viet Nam	HoChiMin	93%

3.2.3. Numbers of motorcycle

The following figures give details on the number of registered 2-and 3 wheelers (MC) in each country and their proportion in the fleet for the year 2016 (https://data.aseanstats.org)

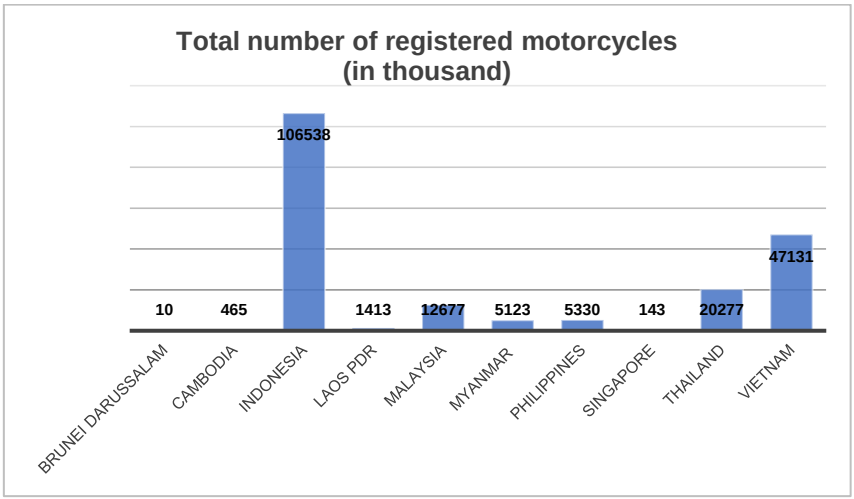


Figure 6: Number of registered motorcycles in ASEAN countries (ASEAN stat website – 2016)

The figure above highlights the number of motorcycles in Indonesia, but it must be noticed that Indonesia has the highest population in ASEAN. Viet Nam is also one of the most populated country. Both countries have a high density of population.

The Figure 7 summarizes the Figure 5 and gives the proportion of 2 or 3-wheelers (MC) in the fleet.

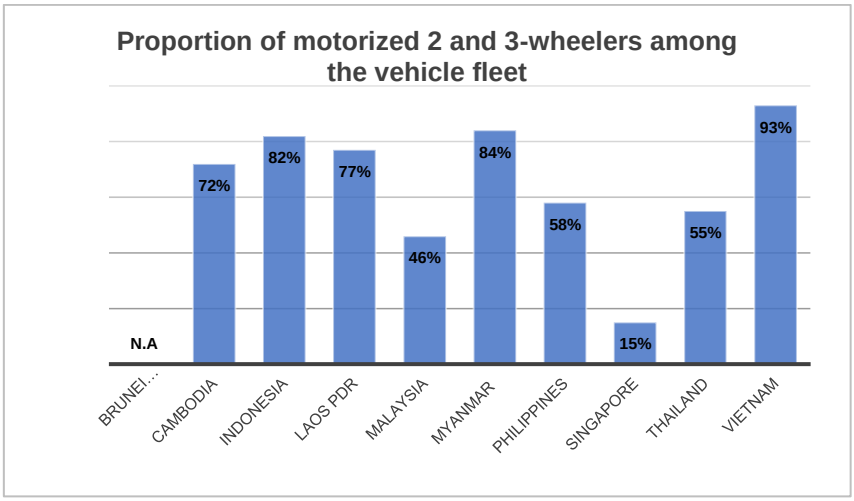


Figure 7: Proportion of motorized 2-3 wheelers among the fleet within ASEAN countries (WHO 2018)

ASEAN mixes countries with very different proportion of motorcycle in the traffic. This will have an influence in transportation interaction.

3.2.4. Fatality rate per population

Figure 8 presents the deaths related to traffic road accident per 100 000 population. Each value includes all types of road user (car passenger, pedestrian, motorcyclist, bicyclist…). The figure shows the high discrepancy within ASEAN countries regarding the importance of road traffic death. Thailand experiences the highest rate in ASEAN with 32,7 death per 100 000 whereas In Singapore the rate is only at 2,8. Malaysian and Viet Nam also show a high rate around 25. per 100 000 inhabitants, Myanmar Cambodia and Lao PDR show similar rate at a lower level. Philippines and Indonesia have similar results.

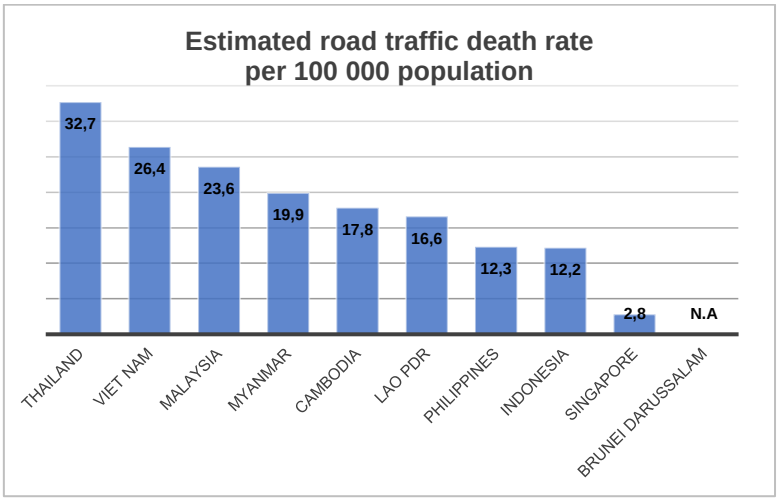


Figure 8: Road traffic death rate per 100 000 population. From Who 2018.

3.2.5. Motorcycle per population

The following figure describes the number of 2- or 3-wheelers related to the population of the country. The higher rates are observed for Viet Nam, Malaysia, Indonesia, and Thailand (generally in relation with high motorcycle fleet). In comparison, in Myanmar, Philippines and Singapore the number of 2- or 3-wheelers per 1 000 population is very low.

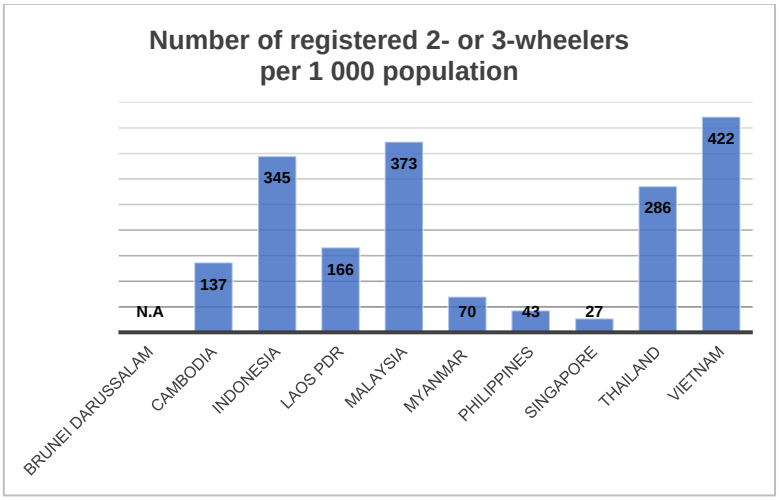


Figure 9: Number of registered 2- and 3-wheelers per 1 000 population. (Kitamura, Hayashi, & Yagi, 2018)

3.2.6. Motorcycle proportion among road traffic fatalities

The proportion of motorcyclists among the traffic accident fatalities show high discrepancy among ASEAN countries (Figure 10). Whereas it is above 70% in Thailand and Cambodia, it represents only 23% of the fatalities in Myanmar. Lao PDR and Malaysia show similar percentages. About half of the road fatalities in Philippines and Singapore concern motorcyclists. (An update of the figure is provided in Annex 1)

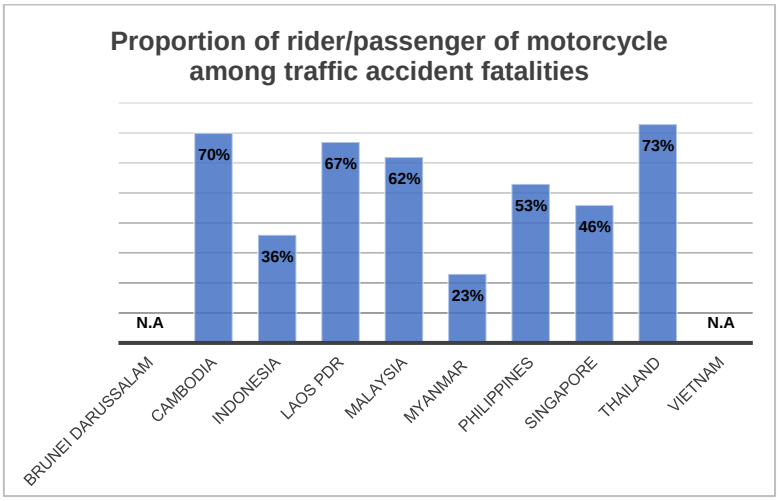


Figure 10: Proportion of motorcycles among road accidents fatalities. (Kitamura, Hayashi, & Yagi, 2018)

Indonesia, Philippines, and Viet Nam account for more than two thirds of the ASEAN population (see Table 2). The countries for which most articles were found (Malaysia and Thailand) represent only 15% of the population in the ASEAN area but have high fatality rates attributed to motorcyclists (see Figure 10). These facts should be taken into account when it comes to consider the representativeness of the articles analysed in this report.

3.2.7. Road network characteristics

According to ASEAN regional road safety strategy (2016), the characteristics of the countries are described in Table 4.

Table 4: ASEAN countries characteristics regarding road and population.

ASEAN country	Road network (km)	Proportion of paved road	Proportion of the population living in urban area	Motor vehicle per km of road
Brunei Darussalam	3 127	93%	predominantly urban	91
Cambodia	53 711	11%	20%	6
Indonesia	503 604	90%	52%	235
Laos PDR	56 331	18%	64%	-
Malaysia	144 403	81%	73%	70
Myanmar	151 298	Express way = 587 km	30%	9
Philippines	270 000	86%	45%	28
Singapore	3 496	100%	predominantly urban	278
Thailand	180 053 (not including local road)	Express way = 450 km	48%	50
Viet Nam	280 000	-	32%	7

When it comes to road network and proportion of people living in urban area, there is high disparity in ASEAN countries as shown in Table 4. There are few paved roads in Cambodia and Lao PDR, compared to Indonesia, Brunei, and Singapore for instance. Furthermore, Singapore and Indonesia show a high number of motor vehicle per road km. These data point out the different traffic configuration within the ASEAN countries.

3.2.8. Speed limit values in ASEAN

The Table 5 gathers information about speed limit in ASEAN countries (WHO, 2018). Rural speed limits are homogenous within the countries. In urban area, speed limit ranges from 30 kph (in some part of Singapore) to 80 kph (in Thailand) and even 90 kph (in Malaysia). Highway speed limit are all above 90 kph and reach 120 kph in Thailand and in Viet Nam.

Table 5: Speed limit in ASEAN countries (WHO, 2018)

Country	Urban speed limit	Rural speed limit	Highway speed limit
Brunei Darussalam	50 kph	65-80 kph	100 kph
Cambodia	40 kph	90 kph	100 kph
Indonesia	50 kph	80 kph	100 kph
Laos PDR	40 kph	90 kph	no motorway
Malaysia	90 kph	90 kph	110 kph
Myanmar	48 kph	90 kph	100 kph
Philippines	40 kph	80 kph	N.A
Singapore	30 kph to 70 kph	no rural road	90 kph
Thailand	80 kph	90 kph	120 kph - motorcycles not allowed
Viet Nam	60 kph	90 kph	120 kph

The table describing global speed limits, speed limit concerning motorcycle may slightly differ. In some country (Malaysia at least) motorcycles are not allowed to ride on motorway.

3.3. Accident scenario and type of collision

The scenario identification focuses on motorcycle against passenger car accidents. The situation in each ASEAN country is analysed and described according to the available literature.

3.3.1. Malaysia

In Malaysia, according to (Abdul Manan & Várhelyi, Motorcycle fatalities in Malaysia, 2012), loss of control accounts for 21% of motorcycle fatal accidents and angular/side-swipe for 27,5%. Side-swipe is a collision between the lateral side of two vehicles travelling in the same or opposite direction. The analysis is based on 2000-2009 accident data.

A second analysis in Malaysia (Oxley, Ravi, Yuen, Hoareau, & Hanis Hashim, 2013), studied a specific type of motorcycle accident. It focuses only on accidents where a child was travelling on the motorcycle. In their analysis, angular/side impacts represent 30% of these specific crashes against a passenger car crashes; head on collisions stands for about 25% in the study.

3.3.2. Thailand

The situation in Thailand is essential to look at, as it is the country where motorcyclist fatalities are the more important, even though their proportion in the vehicle fleet is not among the highest

The Thai insurance company database (Road Accident Victims Protection Co Ltd RVP) was used to analyse motorcycles accidents (Julaluk, Koetniyom, & Hossain, 2019). This database includes accidents from all severity levels from years 2014 and 2015. Loss of control was the main accident scenario (58%) according to this database. When focusing on fatal and severe motorcycle accidents, the angular/side-swipe configuration appears as the most frequent scenario in Thailand (30,5%).

The most detailed description of motorcycle accidents configurations in ASEAN region is provided by (Vira Kasantikul, 2001). This article is based on the in-depth analysis of 723 motorcycle accidents in Bangkok.

The following figure illustrates the proportion of each scenario, representing 83% of the cases.

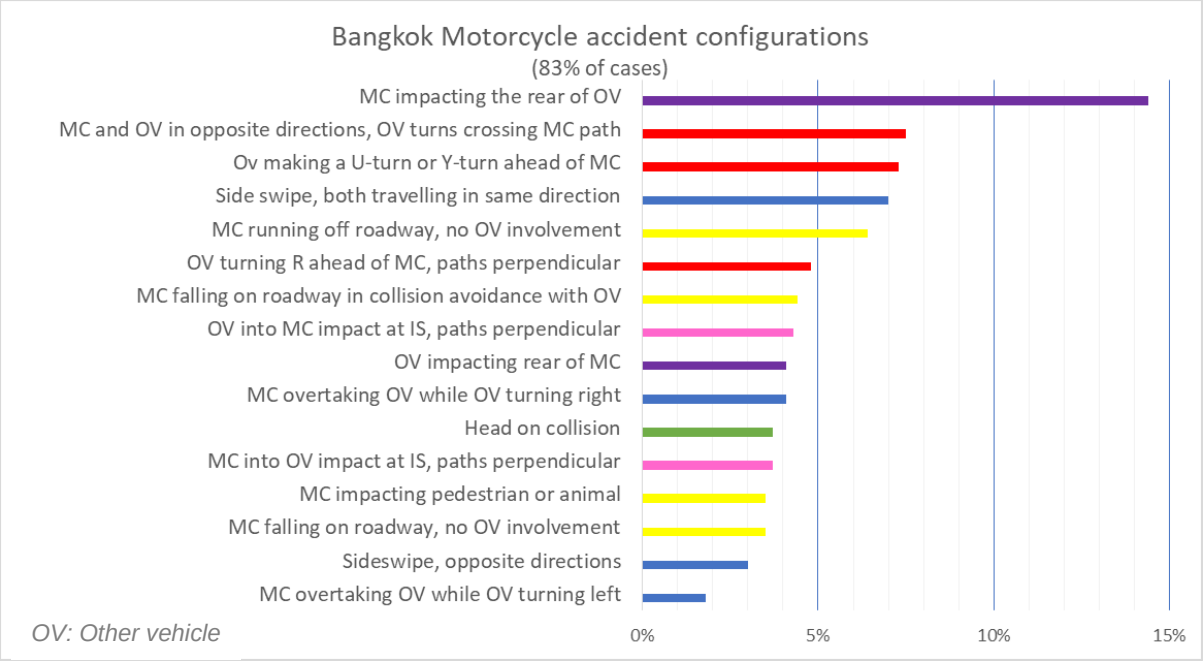


Figure 11: Motorcycle accident configuration in Bangkok, Thailand. (Vira Kasantikul, 2001)

The different scenarios are illustrated in the following colours:

- **Purple:** rear-end collisions. Representing 18,5% of the cases, motorcycle colliding with the rear of the opponent vehicle is the most frequent configuration with 14% of the cases. Half of the scenarios involve a stationary truck on the side of the road at night. Visibility is the main issue in those accidents.
- **Red**: this includes cases where the motorcycle and the opponent vehicle come from opposite direction face to face, the opponent vehicle turning ahead of the motorcycle. Vehicles might also come from perpendicular road. It represents 19,6% of the scenarios.
- **Blue**: this gathers sideswipe cases, and those where the motorcycle was overtaking while the opponent vehicle was turning. It represents 15,9% of the accidents.

- **Yellow**: single vehicle accidents. The motorcycle runs off the road, falls on roadway or hits a pedestrian or an animal. It represents 17,8% of the scenarios.
- **Pink**: this scenario deals with intersection accidents, both vehicles travelling in perpendicular roads. None of the vehicles was turning. It represents 8,05% of the cases.
- **Green**: head-on collisions are characterized in this group and represent 3,7% of the cases.

Rear-end collisions are highlighted through the results as well as accidents where the opponent vehicle turns ahead the motorcycle. Accidents with side swipe or overtaking manoeuvres are the third most common ones. The analysis done on accidents occurring in whole Thailand provides the same trend in these kinds of configurations. The analysis has been done for all injury severities; no breakdown for fatal and severe injury was available.

A third Thai study (Carmai, Koetniyom, Sungduang, Abu Kassim, & Ahmad, 2018) summarizes the accident scenarios of an insurance company database (2014 and 2015 data). Accidents with all level of severity (slight injury to fatal injury) are gathered in this database. Loss of control accidents, accounting for 60% of the cases, were not further investigated as they do not involve other road users. Lateral/side-swipe accidents represents 30%-33% of the cases, split in two scenarios: the motorcycle impacting the lateral side of the opponent vehicle; and the opponent vehicle impacting the lateral side of the motorcycle; the opponent vehicle being a passenger car in 40% of the cases.

These scenarios can be described as follow (the authors do not precise the proportion of each scenario):

Motorcycle impacting lateral side of the passenger car: it occurs when the opponent vehicle, while overtaking, changing lane or turning, moves into the path of the motorcycle. In those cases, the speed of the motorcycle is usually higher than the speed of the passenger car. The frontal part of the motorcycle collides with the lateral side of the passenger car. These cases are illustrated in Figure 12, as it is described in the article:

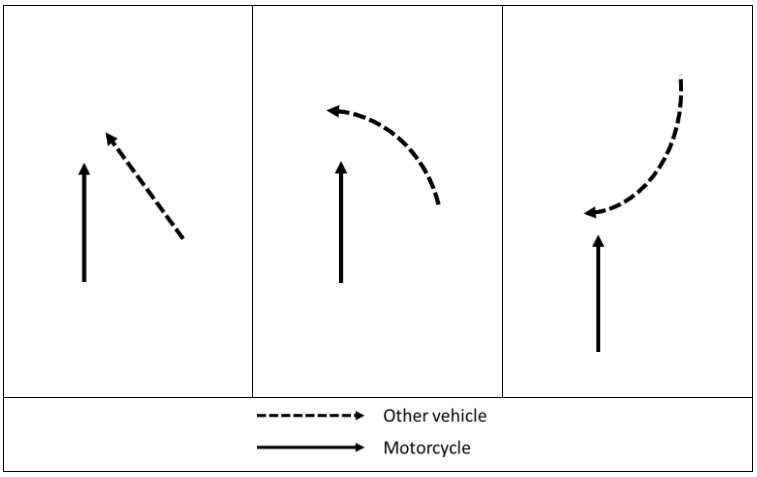


Figure 12: Motorcycle colliding with OV while OV moves into the path of the motorcycle

Motorcycle impacted on its lateral side by the opponent vehicle: the motorcycle moves into the path of the opponent vehicle as shown in Figure 13. In this scenario the motorcycle overtakes or changes lane. In T intersection the motorcycle turns and rides on the road of the passenger car. The frontal part of the opposite vehicle collides with the lateral side of the motorcycle.

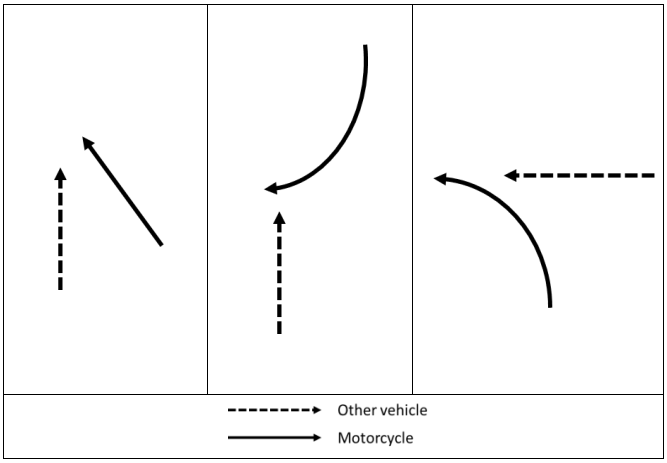


Figure 13: OV colliding with motorcycle while motorcycle moves into the path of the OV

3.3.3. Cambodia

In Cambodia, the type of collision observed on motorcycle is distributed as follow in Figure 14, (Kitamura, Hayashi, & Yagi, 2018) :

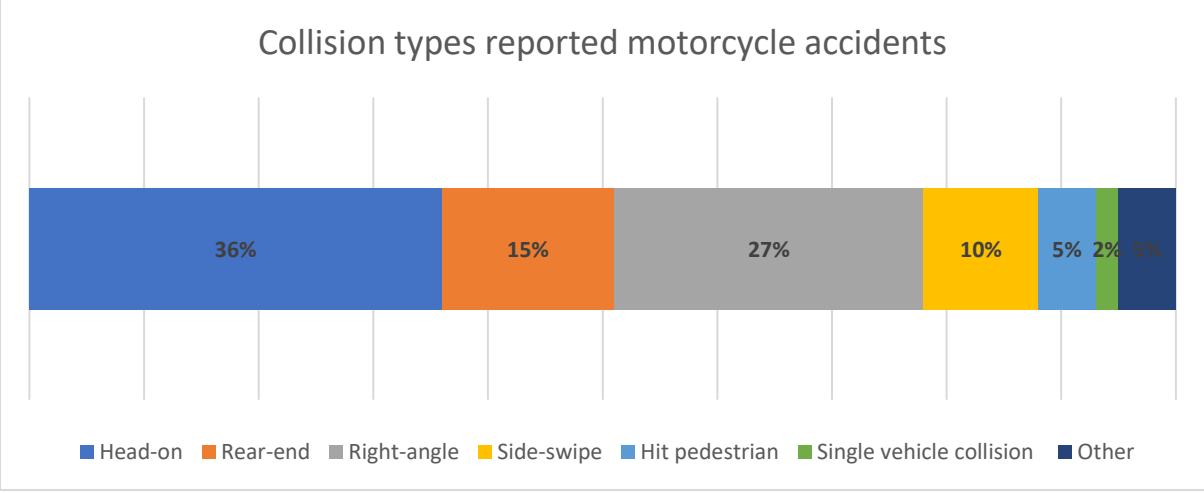


Figure 14: Collision type reported for motorcycle accidents in Cambodia. (Kitamura, Hayashi, & Yagi, 2018)

Head-on (frontal impact for both vehicles) and right-angle/side-swipe account for about the same proportion of accidents (36% and 37%). Then, 15% of the motorcycles are involved in a rear-end collision. However, a distinction cannot be made between the cases where the motorcycle impacts the rear of another vehicle and the cases where the motorcycle is impacted at the rear.

3.3.4. Brunei Darussalam, Indonesia, Lao PDR, Myanmar, Philippines, Singapore, Viet Nam

No motorcycle accident scenarios data were found for these 7 countries.

3.3.5. Conclusion

To sum-up, rear-end and angular collision scenarios turn out to be the most common situations for motorcycle accidents. Rear-end collision includes both frontal and rear impact on the motorcycle. Then, angular collision scenarios can be defined as a situation leading to a side collision, whether the motorcycle enters the path of the opponent vehicle or the opposite vehicle turns in front of the motorcycle. In the Malaysian study (Abdul Manan & Várhelyi, Motorcycle fatalities in Malaysia, 2012), angular/sideswipe scenarios represent around 25% of fatalities among the motorcyclists.

Loss of control scenario represents a significant number of situations; it has not been further analysed as this situation not including a passenger car is out of the scope of the project.

The conclusion on the accident scenario and type of collision is based on Malaysian and Thai data. Indeed, no detailed data were found for the other countries of ASEAN.

3.4. Impact point

When scenarios are not precisely described, impact points on the motorcycle are of interest.

3.4.1. Thailand

In (Vira Kasantikul, 2001), the first point of impact on the motorcycles involved in accident located in Bangkok. The first impact point is defined as the first impacted part of the motorcycle according to the chronology of the accident. Therefore, it is the most important to deduce the pre-crash scenario. For example, when a motorcycle collides with a passenger car and then falls on the road and slides, the motorcycle sustains several impacts, the first is against the passenger car. The figure below shows that the first impact happens at the frontal part of the motorcycle in 70% of the cases (pure frontal or left or right frontal parts).

Figure 15: Distribution of first impact on motorcycle. (Vira Kasantikul, 2001)

3.4.2. Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Viet Nam

No data on motorcycle collision type were found for these countries.

3.5. Location of the motorcycle accidents

Motorcycle accident locations gives information about speed limits, infrastructure, type of traffic and its characteristics.

3.5.1. Malaysia

In Malaysia, according to (Abdul Manan & Várhelyi, 2012), 61% of motorcycles fatalities happen in rural area and 66% on a straight road.

In (Oxley, Ravi, Yuen, Hoareau, & Hanis Hashim, 2013), the authors focus on accidents involving children as motorcycle users. They noticed that the majority of collisions (75,6%) occurred on rural roads, in 50-70km/h speed limit areas. In major and small cities, only 9,1% of accidents involved children on motorcycle.

Another study (Abdul Manan, Várhelyi, Çelik, & Hashim, 2018) makes the link between infrastructure and the number of vehicle involved in the accident (all severity level). Single motorcycle accidents are associated with curved road section. When it comes to motorcycle-other vehicle accidents, it mainly occurs in 90kph-limited rural locations. Accidents involving more than two vehicles mainly happen on expressway roads, with higher speed limits.

3.5.2. Cambodia

In Cambodia, 33% of 2- or 3-wheelers fatalities occur in urban area. Regarding the type of road, 69% of deaths in motorcycle accidents occur on national highways (Kitamura, Hayashi, & Yagi, 2018). Highways may be located in urban area, especially in big cities network.

3.5.3. Singapore

According to (Quddus, Noland, & Chor Chin, 2002), motorcycle accidents occurring in a bend are more severe. Indeed, the probability of fatality is increased by 72% for these accidents. Accidents on two-way streets, dual carriageways (roads with separate carriageways), and expressways (high speed roads) result in more severe accidents than those on one-way road, according to the authors. This is related to the higher speed limits allowed on those road categories.

3.5.4. Brunei Darussalam, Indonesia, Lao PDR, Myanmar, Philippines, Thailand, Viet Nam

No data on motorcycle accidents location were found for these countries.

3.6. Motorcycle speed

Motorcycle speeds are key data to describe the accidents and to build representative accident scenarios. Detailed data were available through the in-depth analysis carried out in Bangkok (Vira Kasantikul, 2001).

3.6.1. Thailand

In (Vira Kasantikul, 2001) initial speed and collision speed were calculated. The initial speed is the motorcycle speed just before the precipitating event leading to the crash. The collision speed is the motorcycle speed when it impacts the obstacle. Table 6 displays the speeds median values for all the 723 accidents, both non-fatal and fatal cases. All the accidents occur in urban area, i.e. the Bangkok city.

Table 6: Median value for initial and collision speeds (kph)

	Initial speed	Collision speed
All accidents	39 kph	31 kph
Non-fatal accidents	38 kph	30 kph
Fatal accidents	50 kph	48 kph

The median initial speed is 39 kph and the median collision speed is 31 kph. Median speeds are higher in fatal crashes than in non-fatal crashes. In fatal crashes, no significant difference is noticed between median initial and collision speed. The graphs below describe the distribution of the initial speed and collision speed for the motorcycles.

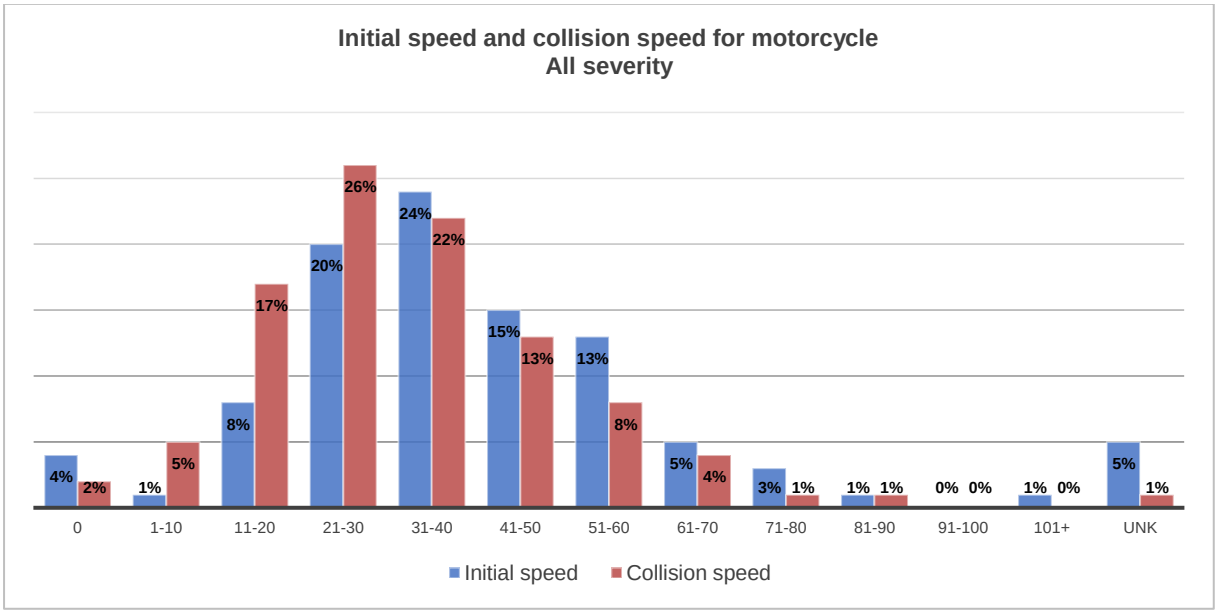


Figure 16: Motorcycle initial speed and collision speed (kph) in all severity accidents. Data from (Vira Kasantikul, 2001).

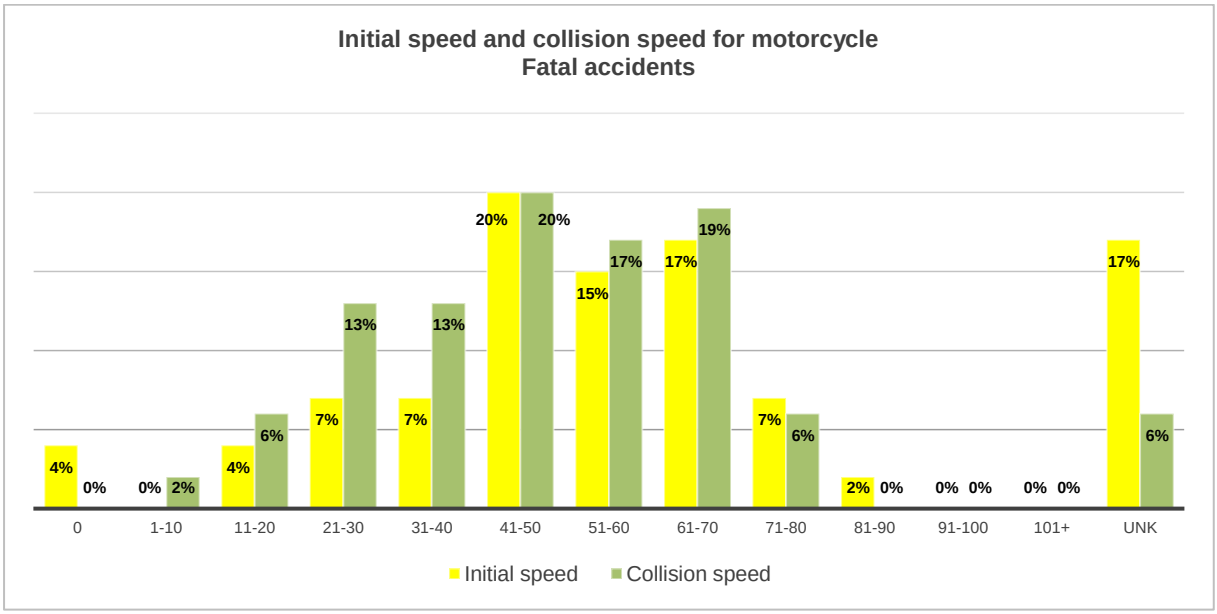


Figure 17: Motorcycle initial speed and collision speed (kph) in fatal accidents. Data from (Vira Kasantikul, 2001).

Fatal accident speeds distribution is shifted to the right compared to the whole distribution, thus, illustrating the highest speed value in fatal crashes compared to all severity injury one.

According to the same data (Vira Kasantikul, 2001), median initial speed of the opposite vehicle is estimated at 27 kph, and the median collision speed at 21 kph. The distributions are detailed in the graph bellow (no split by accident severity available):

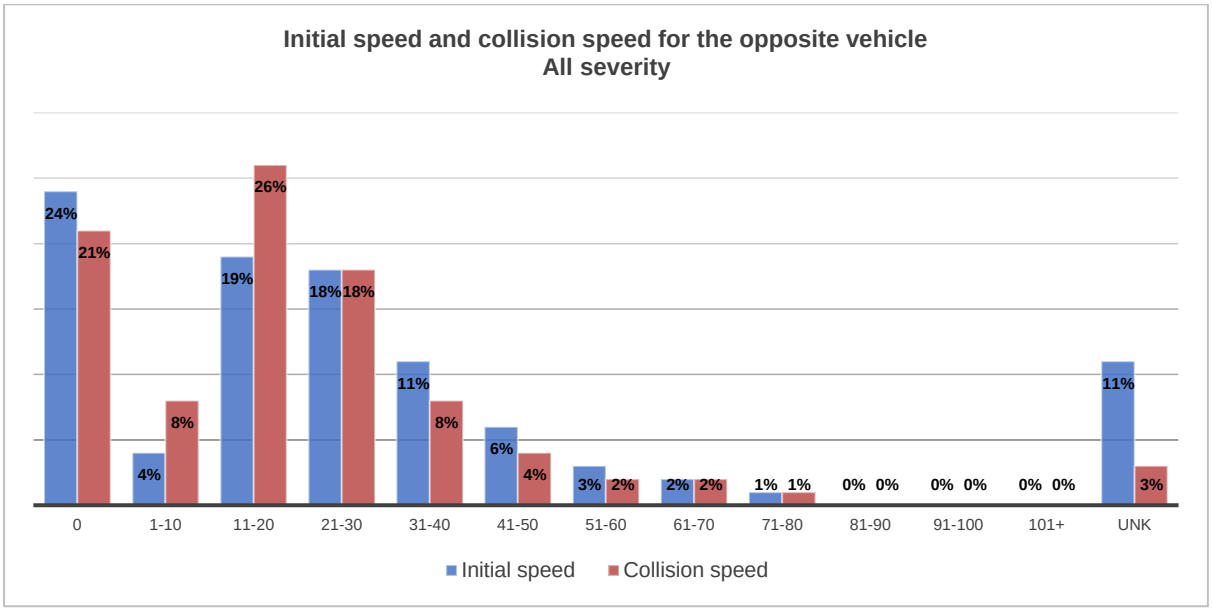


Figure 18: Opposite vehicle initial speed and collision speed (kph) in all severity accidents. Data from (Vira Kasantikul, 2001)

The speed distribution is very different between the motorcycles and the opposite vehicles. 21% of the opposite vehicle were stopped when the crash occurred, whether they were waiting or parked. Most of the opposite vehicle crashed at a speed between 11 kph and 20 kph,

whereas 26% of the motorcycle crashed between 21 and 30 kph. It should be noted that it would have been interesting to cross-reference the motorcycle and the other vehicle speeds.

Speed data are not provided according to the different scenarios and where published in 2001. The OASIM project data analysis aims, among other goals, to update this literature review with recent speed analysis and distribution over the main accident scenarios.

3.6.2. Cambodia, Malaysia

If speed data are not available for these countries, the literature mentions the occurrence of overspeeding. Overspeeding is often noted as a risk factor in motorcycle accident. In Cambodia, 38% of the motorcycle casualties are linked to speed issue (Kitamura, Hayashi, & Yagi, 2018).

In Malaysia, (Abdul Manan, Ho, Arif, Abdul Ghan, & Várhelyi, 2017), motorcycles speed was analysed and the authors noticed that 42.2% of 2- or 3-wheeled were riding above the road speed limit.

As a reminder, Cambodia and Malaysia have similar speed limits in rural area (90 kph), whereas Malaysia shows higher speed limits in urban area than Cambodia (90 kph versus 40 kph).

3.6.3. Brunei Darussalam, Indonesia, Lao PDR, Myanmar, Philippines, Singapore, Viet Nam

No data on motorcycle speed were found for these 7 countries.

3.7. Driver Age and gender

This paragraph describes the motorcycle rider's characteristics.

3.7.1. Malaysia

In Malaysia, according to (Abdul Manan & Várhelyi, Motorcycle fatalities in Malaysia, 2012) men account for 94% of motorcycle fatalities. Another study on motorcycle crashes in Malaysia (Zulkipli, Hamzah, Mohammed, & Abdul Rahman, 2015) reveals that 31% of the involved motorcyclists were between 17 and 20 years old.

3.7.2. Thailand

In Thailand (Vira Kasantikul, 2001), the median age of motorcycle riders involved in a crash is 27 years old and 96% of them are male.

3.7.3. Cambodia

In Cambodia (Kitamura, Hayashi, & Yagi, 2018), 85% of the riders killed in motorcycle accidents are male. 20-29-years-old-men account for 40 % of motorcyclist deaths whereas women of the same age group only account for 4% of motorcycle fatalities (WHO 2013). Finally, according to (Roehler, Ear, Parker, Sem, & Ballesteros, 2015), men have 7 times more risk to die in a motorcycle crash then women.

3.7.4. Singapore

According to the study done by (Quddus, Noland, & Chor Chin, 2002), even if young male motorcyclists are more likely to be involved in accidents, older drivers (more than 60 years old) are more fragile. When the older riders are involved in an accident; they sustain injuries of higher severity compared to the younger riders.

3.7.5. Brunei Darussalam, Indonesia, Lao PDR, Myanmar, Philippines, Viet Nam

No data on the motorcycle driver age and gender were found for these countries.

So, several studies highlight that young people and especially young men are at highest risk in motorcycle accidents.

3.8. Passengers

This part raises the issue of passengers and children as motorcycle users.

3.8.1. Malaysia

Regarding fatalities, passengers account for 11% of motorcycle fatalities in Malaysia (Abdul Manan & Várhelyi, Motorcycle fatalities in Malaysia, 2012).

3.8.2. Thailand

In Thailand, 20% of casualties concern passengers (Carmai, Koetniyom, Sungduang, Abu Kassim, & Ahmad, 2018).

According to (Vira Kasantikul, 2001) one third of motorcycle crashes in Bangkok involved a rider with a passenger. Percentage is even higher when considering the overall country, where 45% of the motorcycle crashes occurred with a passenger.

3.8.3. Cambodia

According to (Kitamura, Hayashi, & Yagi, 2018), passengers represents 24% of motorcycle fatalities in Cambodia

3.8.4. Singapore

In Singapore, the study done by (Quddus, Noland, & Chor Chin, 2002) on Police accident data shows that in many cases motorcycles carry a passenger and that injury severity is higher when there is a passenger on the motorcycle.

3.8.5. Brunei Darussalam, Indonesia, Lao PDR, Myanmar, Philippines, Viet Nam

No data on the motorcycle passengers were found for these countries.

According to Malaysia Thailand Cambodia and Singapore data, the presence of motorcycle passenger is an important issue in term of casualties' in road accidents.

3.9. Children

3.9.1. Malaysia

According to (Oxley, Ravi, Yuen, Hoareau, & Hanis Hashim, 2013), in 2011, almost 50% of children killed on Malaysian roads were motorcycle riders and 18 % were motorcycle passengers.

A study based on Malaysian motorcycle accidents analysed pairs of riders and passengers. The distribution of adult and children as rider and passenger is shown below (Zulkipli, Faudzi, & Syed Noh, Injury Severities among Riders and Pillion Riders in Non-Fatal Crashes in Malaysia, 2016).

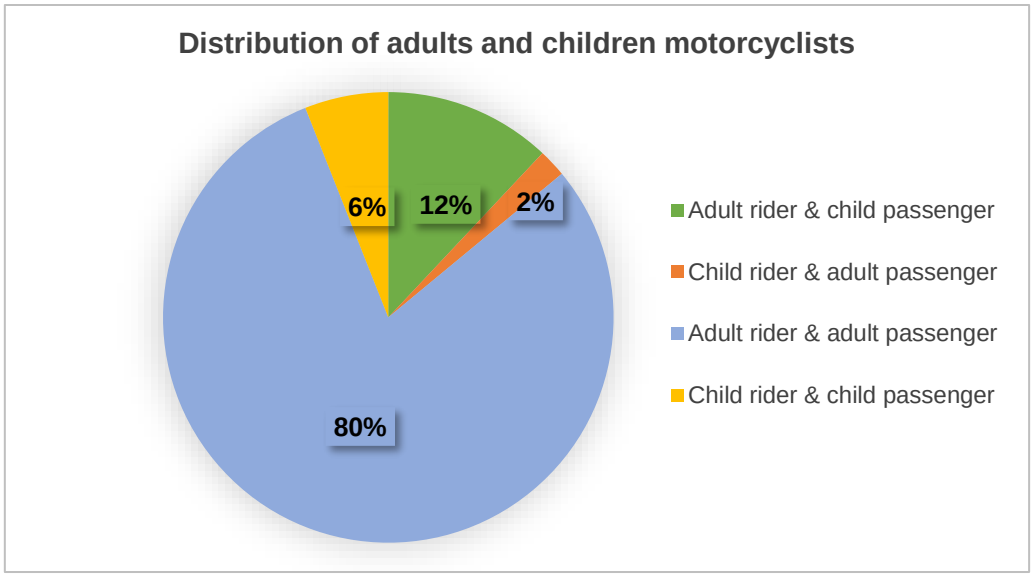


Figure 19: Distribution of motorcycle rider/passenger, adult/child pairs implicated in non-fatal accidents in Malaysia. (Zulkipli, Faudzi, & Syed Noh, 2016)

When there is more than one occupant on the motorcycle, children are found in 20% of the pairs of motorcycle riders or passengers. The rider is a child in 8% of the pairs, the passenger is a child in 18%. The pairs with only children as users of the motorcycle account for 6% of the cases.

3.9.2. Thailand

Passengers tend to be younger than the drivers. In Thailand, 14% of the motorcycle passengers were less than 10 years old, and about one third were between 10 and 19 years old (Carmai, Koetniyom, Sungduang, Abu Kassim, & Ahmad, 2018).

3.9.3. Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Myanmar, Philippines, Singapore, Viet Nam

No data on children as motorcycle users were found for these countries.

3.10. Representativity issue

The literature review aims to investigate the motorcycle accidents scenario occurring in the different countries of the ASEAN region. The results of the found articles are synthesised. They are compared to the results of the Thai and Malaysian database analysis. The literature review also helps to select the most relevant variables for the data study, providing background elements to compare countries and assess the representativeness of the available data. The review shows that most of the published information cover only two countries out ten, i.e. Malaysia and Thailand. Scarce data was found for Cambodia also. This raises the question whether the situation of these two or three countries allows to describe the whole ASEAN region. Furthermore, it should be kept in mind that Malaysia and Thailand may be representative of the ASEAN countries only regarding some characteristics. Thus, the answer to this question cannot be binary but would depend on the parameters considered.

Population density

First of all, Malaysia and Thailand represent 15% of the ASEAN population. Their density (person/km²) is less than the average density in the whole ASEAN region (98 and 132 versus 144 person/km²). The most populated country, Indonesia, shows a similar density (138) to the one in Thailand.

Network characteristics

When it comes to network characteristics, Malaysia shows a high proportion of paved road. That is very different from the situation in Cambodia and in Laos PDR for example. This distinction is also noticeable with the percentage of population living in urban area. Malaysia and Thailand exhibit very different situation from Cambodia, Myanmar, Viet Nam (lower rate of paved road), as well as Singapore and Brunei Darussalam (highly urbanized countries). This may lead to different motorcycle behaviour, not taken into account here.

Speed limits

Speed limits are quite similar for highway and rural area. There is some discrepancy in urban area, where Malaysia and Thailand present the highest allowed speed. This situation may permit to cover the most severe situation of the whole ASEAN area.

Fleet composition

Regarding the fleet composition, Malaysia and Thailand have similar proportions of motorcycle within the traffic (around 50%). The situation is very different in Singapore (15%, lowest percentage of motorcycle), Viet Nam, Indonesia, and Myanmar (more than 80% of motorcycles). Consequently, extreme traffic condition might not be covered by the available to date. It would have been interesting to explore the scenario for these extreme countries in term of fleet composition.

The characteristics of passenger cars fleet, such as mean age of the fleet has to be taken into account when describing the accidentology. Within the 10 countries of ASEAN, the categorisation of vehicles (SUV, small family car, executive car, …) and the safety systems fitment rate (ESC, EBA,…) might be different, which is worthy to be analysed

The percentage of motorcycle among the road fatalities

An important parameter to look at is the percentage of motorcycle users among the road fatalities. Malaysia and Thailand exhibit some of the highest proportion of motorcyclists among their fatalities. Thus, the available data relate to countries where motorcycle casualties represent the most striking issue.

Therefore, some countries show some specificity that may not be available in the data gathered for the literature review. The lack of data for Indonesia, Laos PDR, and Singapore do not allow to cover all different traffic situations. Otherwise the representativeness of the literature review would have been more significant.

3.11. Literature review conclusion

The main findings are:

- An overall lack of data for most of the ASEAN countries: Brunei Darussalam, Indonesia, Laos PDR, Myanmar, and Philippines. Then, the results are based on Thai and Malaysian articles. This raised the issue of the representativeness of the results.
- Angular/side impact scenario appear to be the most important crash configuration in fatal motorcycle accidents in Thailand and Malaysia. The data were not available for the other ASEAN countries
- Rear-end collision is the most frequent crash scenario in Bangkok according to an in-depth analysis of all injury severity motorcycle accidents. The second crash scenario involves a motorcycle facing a vehicle turning, overtaking or driving in the motorcycle lane.
- In the Thailand insurance database, angular scenarios include on the other hand, the cases where the other vehicle comes in the path of the motorcycle and the opposite cases where the motorcycle rides on the lane of the opposite vehicle.
- In Cambodia, head-on and right-angle/side-swipe account for about the same proportion of accidents (36% and 37%).
- Median collision speed for motorcycle is about 31 Kph. This value reaches 48 kph in fatal accidents.
- Passengers account for 11%-24% of fatalities in Thailand, Malaysia and Cambodia.
- Children are significant users of motorcycles either as riders or passengers (up to 14% in Thailand)

As a result of the literature review, many accident parameters, such as vehicle speed and impact angle, cannot be attributed to the various accident scenarios. The difference and specificity of fatal and severe accident could neither be analysed.

To illustrate, accident scenarios with motorcycles according to the needs of the other Work Packages of this project. An accident data study based on Malaysian and Thai data will be carried out.

4. Databases description

This section of the deliverable provides an overview of the two databases available in the project and a description of the methodology used to combine results from both databases in order to establish the most frequent accident scenarios.

4.1. Malaysian database

4.1.1. Quick overview of database background and design

The Malaysian accidents database is owned by Traffic Enforcement and Investigation Department of the Royal Malaysian Police, and provided to the designated project partners by MIROS (Malaysian Institute of Road Safety Research). This database is completed by the Police forces who gather all injury accidents across Malaysia and constitute the national accident database of Malaysia.

Table 7: Malaysian database: owner and provider

Country	Owner of the database	Provider of the database
		

This database is constituted of 91 variables distributed over three tables linked together by a unique number attributed to each accident. The three tables are described in the following section:

- A table with general information related to the accident: date, hour, number of vehicles involved, localisation, severity of the accident.
- A table with the driver information related to the drivers involved in the accidents. It describes the gender and the age of the driver, the status of his driving licence, the usage of a protective device, the driver errors, and the part of the body injured. It also includes data on the type of vehicle, the damage on the vehicle and the manoeuvre of the driver.
- A table with the injury information related to the injured occupants or pedestrians (not related to the driver: driver injury information is specified in the above described table). The table describes the age and sex of injured occupants, the use of the seat belt, the position in the vehicle, the level of injuries, the part of the body injured and action of the pedestrian.

4.1.2. Number of cases

MIROS provided CEESAR with accidents data for the three following years: 2016, 2017, 2018.

Among the complete Malaysian national database, a first selection has been made to select accidents involving at least one passenger car. The numbers are as follows, described for each year and representing a total of 5377 accidents:

Table 8: Number of accidents by year – Malaysian database

Year of accidents	Number of accidents with at least one passenger car
2016	1647
2017	1377
2018	2353
Total	**5377**

This sample represents accidents with at least one passenger car. Then a selection is applied as described in the Figure 20, to select only accidents that are in the scope of the OASIM project (one passenger car against one motorcycle).

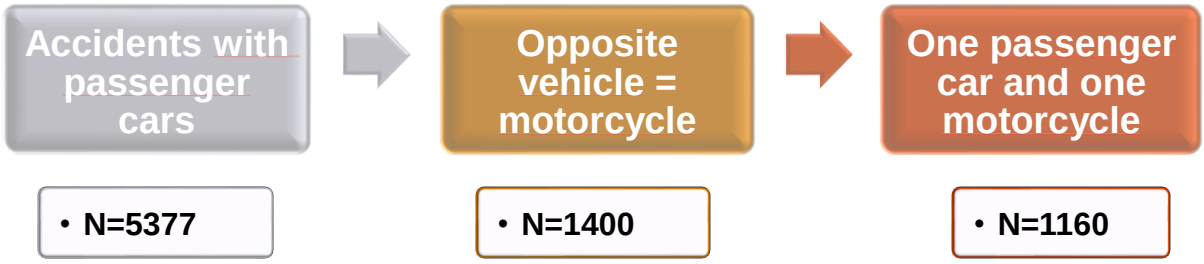


Figure 20: Selection of the Malaysian accident cases

The final comprises 1160 cases of accidents between one passenger car and one motorcycle.

4.1.3. Variable description

4.1.3.1. Accident information

The accident information table describes general characteristics of the accident and takes into account variables related to the infrastructure and to the road. Table 9 lists all variables contained in the accident information table.

Table 9: Accident information table, list of variables (Malaysian database)

Accident info	ID, month, Hour, Day_Of_Week, No_Veh_Involved, No_Veh_Damaged, No_Drivers_Killed, No_Drivers_Injured, No_Passengers_Killed, No_Passengers_Injured, No_Pedestrian_Killed, No_Pedestrian_Injured, Accident_Severity, Road_Surface_Type, Traffic_System, Road_Geometry, Quality_Of_Surface, Road_Condition, Lane_Marking, Hit_Run, Control_Type, Shoulder_Type, Road_Defect, Speed_Limit, Road_Surface_Condition, Collision_Type, Weather, Light_Condition, Road_Type, Location_type, Area_type, Animal_fault.

For the purpose of the study only the following variables listed in Table 10 could be used, the other one are not relevant in the scope of the project.

Table 10: Accident information table, variables, and values (Malaysian database)

No_Veh_Involved	Number of vehicles involved in the accident
Accident_Severity	Fatal, Severe, Slight, Damage
Speed_Limit	50, 70, 80, 90, 110, other
Light_Condition	Day, Dawn/Dusk, Dark with streetlight, Dark without streetlight

Road_Type	Expressway, Federal, State, Municipal, Other
Location_type	City, Urban, Built-up area, Rural
Road_Geometry	Straight, Bend, Roundabout, Cross junction, T/y junction, Staggered junction, Interchanges
Collision_Type	Head-on, Rear, Right Angle side, Angular, Side swipe, Forced, Hitting animal, Hitting object on road, Hitting object off road, Hitting pedestrian, Overturned, Out of control, Others

For information, "A staggered junction is where a minor road meets a major road, but unlike a crossroads where the minor road continues directly opposite the major road, the points that the minor road meet the major road are slightly offset (out of line) by a short distance." (https://www.drivingtesttips.biz/staggered-junction.html).

4.1.3.2. Driver information

The driver information of the Malaysian database gathered the variables listed in the table below:

Table 11: Driver information table, list of variables (Malaysian database)

Driver info	ID, c_Veh_Type, Veh_Ownership, Veh_Damage, Veh_Movement, Veh_Defect, Veh_Modification, Tyre_burst, Driver_sex, Driver_age, License_status, Driver_injury, Driver_belt_wearing, Driver_part_of_body_injured, Driver_errors, Driver_qualification, Drinking_drive, Driver_occupation, License_type.

The following variables could be used within this project:

Table 12: Driver table, variables, and their values (Malaysian database)

c_Veh_Type	Express bus, Stage bus, Factory bus, Minibus, Tour/excursion, School bus, 4-wheel drive, Special duty vehicle, Bullock cart, Lorry trailer, Rigid lorry (>2.5 tonne), Small lorry (<2.5 tonne), Motorcar, Motorbike>250cc, Motorbike<251cc, Taxi, Trishaw, Van, Hired car, Bicycle, Unknown
Veh_Damage	None, Front, Rear, Right, Left, Roof, Multi
Veh_Movement	Parked, Suddenly stopped, Diverging, Converging, Out of control, Right turn, Left turn, Overtaking, U-turn, Forward, Reverse, Others
Veh_Defect	Brakes, Broken windscreen, No light, Defective lamps, Steering, Old tyre, Rethread tyre, Bald tyre, Wiper, Excessive smoke, Not relevant
Driver_sex	Male, Female
Driver_age	In Year
Driver_injury	Fatal, Serious, Slight, Not injured
Driver_belt_wearing	Belt, No belt, Helmet, Turban, Helmet but unprotected, No helmet
Driver_errors	In/out, Negligent signalling, Overloading goods, Overloading passengers, Wrong parking, Drugs, Careless driving, Dangerous driving, Dangerous turning, Dangerous overtaking, Driving too close, Speeding, Traffic light violation, Other offences, Not at fault

4.1.3.3. Injury information

The table related to the injuries sustained by the different occupant is described in the Table 13.

Table 13: Injury information table, list of variables (Malaysian database)

Injury info	ID, Sex, Age, Injury, Part_of_Body_Injured, Passenger_Belt_Wearing, Passenger_position, Pedestrian_action, pedestrian_location, school_pupil, veh_code

The following variables and values could be used to describe the passenger information.

Table 14: Injury table, variables and their values (Malaysian database)

Sex	Male, Female
Age	In Year
Injury	Fatal, Serious, Slight, Not injured
Part_of_Body_Injured	Head, Neck, Chest, Arms, Back, Hip, Legs, Multi, None
Passenger_Belt_Wearing	Belt, No belt, Helmet, Turban, Helmet but unprotected, No helmet
Passenger_position	Front passenger, Rear Passenger, N/A

4.2. Thai database

4.2.1. Quick overview of database

The Thai database provided to CEESAR is an on-the-spot accidents study managed by Honda and Yamaha. It is carried out in different region of Thailand with an in-depth protocol.

Table 15: Thai database - owner and provider

Country	Owners and providers of the database
	HONDA YAMAHA Revs Your Heart

Sixteen provinces are covered by the study. This database is constituted of accidents where at least one motorcycle was involved. The opposite vehicle can be a passenger car, a lorry, a LGV (Light Goods Vehicle), or a pedestrian. The database also registers single motorcycle accidents.

The Thai database includes a relatively high number of severe accidents. About 30% of the accidents in this database resulted with at least one severely or one fatally injured occupant (KSI accidents).

4.2.2. Number of cases

The data provided to CEESAR is constituted of relatively recent accidents which occurred from 2016 to 2020. Figure 21 illustrates the percentage distribution of accidents by the year of the accident in the Thai database.

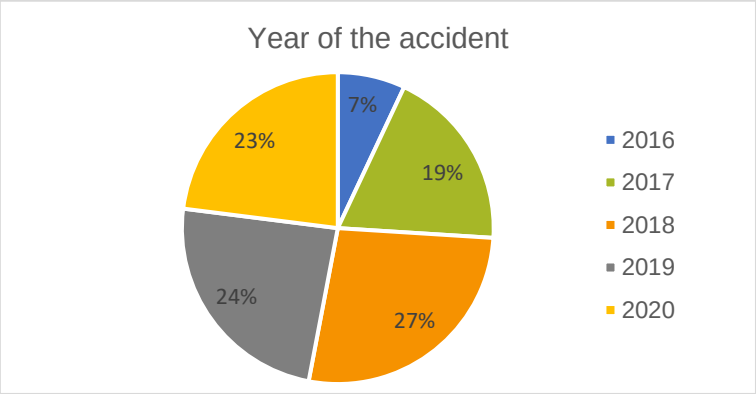


Figure 21: Thai in-depth database, distribution of the accidents by the year.

The database is constituted of 751 motorcycle accidents, 639 of them occurring against one passenger car or one pick-up.

There are more than 20 tables in the database, each table dealing with a specific topic of motorcycle accidents. Each accident is described with around 700 variables.

4.2.3. Variable description

4.2.3.1. Accident information

In this paragraph, the variables of the database will be described only briefly due to the confidential character of the data owned by Honda and Yamaha.

The information will be gathered in the same way as the Malaysian database (general information, driver and passenger, vehicle, and road information).

Table 16: Accident information (In-depth Thai database)

Accident information	Time & date of accident, Accident severity, Urban/rural, Weather, Luminosity, Intersection, accident pictogram, contributing factor related to the driver, contributing factor related to the vehicle.

4.2.3.2. Road information

All road information is explained through the description of the major road where the accident took place. The table below provides some variables available in the database regarding the road description.

Table 17: Road information (In-depth Thai database)

Road information	Road Category, Speed limit, State of road surface, Kind of road surface, Straight/Curve, Skid marks (length)

4.2.3.3. Driver information

Table 18 illustrates the variables which describe the driver of the passenger car or the motorcycle.

Table 18: Driver information (In-depth Thai database)

Driver information	Age and gender, Driving licence status, alcohol impairment, distraction, helmet usage, seat belt usage and type, airbag deployment and type, trip length, manoeuvre during the accident.

4.2.3.4. Vehicle information

Table 19 gathers some of the variables that were kept in this project for describing the vehicles and the collision.

Table 19: Vehicle and collision information (In-depth Thai database)

Vehicle information	Vehicle type, model, launch year, ABS fitment, type of impact, angle with the opposite vehicle, impact speed, initial speed.

4.3. Common variables

The goal of the WP1 accident data study within the OASIM project is to define the most relevant accident scenarios that happen between a passenger car and a motorcycle in the ASEAN region. These main scenarios should be representative of the whole ASEAN region. In order to achieve this objective, only two databases are available from two countries out of the ten countries that constitute the ASEAN region.

The Malaysian database is an extraction of cases involving only passenger cars made among the Malaysian national census. This database is then representative of the whole country and covers all injury severities without any specific selection. It has, in theory, a large number of accidents, described by less than 100 different variables.

On the other hand, the Thai database is an in-depth accident database. It focuses exclusively on motorcycle accidents and KSI accidents are overrepresented. The accidents are analysed in 16 provinces in the country. When compared to a national database, the number of cases seems to be relatively low. However, these cases are coded very precisely with more than 700 variables.

To work on data coming from two different sources, it is first compulsory to determine the variables that are common between the two databases. The table below summarises the common variables available in both databases.

Table 20: Common variables between the Malaysian and the Thai databases

Accident information	• Time & date of accident • Collision type/accident configuration • Accident severity • Urban/rural • Weather • Luminosity • Intersection, • Contributing factor related to the driver • Contributing factor related to the vehicle
Road information	• Road category • Speed limit • State of road surface • Kind of road surface • Straight/Curve
Vehicle information	• Vehicle type • Type of impact

Driver information	• Age and gender • Driving licence status • Alcohol impairment • Manoeuvre at the crash • Seat belt/helmet usage

The values within the variables might not be the same in each database, but they can be compared using a new definition allowing to compile them. For example, the accident severity is coded in both databases with those different values:

Table 21: Comparison of the codification of the accident severity in the two databases

Accident severity as coded in the Thai database	Accident severity as coded in the Malaysian database
Minor = the most severely injured occupant in the accident sustained an MAIS 1 injury	**Slight** = the most severely injured occupant in the accident sustained a slight injury
Moderate = the most severely injured occupant in the accident sustained an MAIS 2 injury	
Serious = the most severely injured occupant in the accident sustained an MAIS 3 injury	**Severe** = the most severely injured occupant in the accident sustained a severe injury
Severe = the most severely injured occupant in the accident sustained an MAIS 4 injury	
Critical = the most severely injured occupant in the accident sustained an MAIS 5 injury	
Maximal = the most severely injured occupant in the accident sustained an MAIS 6 injury	**Fatal** = the most severely injured occupant in the accident sustained a fatal injury
Fatal = the most severely injured occupant in the accident sustained a fatal injury (whatever the MAIS severity)	
PDO = Personal Damage Only accident. No injured occupant in the accident	**Damage** = damage only to the vehicle, no injured occupant in the accident

The more detailed categories can be recoded in a simpler way to match the second encoding system. For example, the “minor” and “moderate” injury categories of the Thai database are grouped and are equivalent to the “slight” category of the second database.

4.4. Methodology to merge the Malaysian and the Thai databases

4.4.1. Context

Two different databases were made available to CEESAR within the project. These databases are created with different inclusion processes and different selection criteria:

- The Malaysian database is a yearly national database that gathers all the accidents reported by police in Malaysia. This database is considered to be representative of the accidents in Malaysia.
- The Thai database is an in-depth accident analysis database. It is constituted by cases analysed throughout 16 provinces of Thailand. There is a selection of the cases to be included in database, based on the type of vehicle and on the severity of the accident: this database focuses mainly on severe accidents including only accidents where at least one motorcycle was involved.

As there is one national database and one in-depth database, with different characteristics, the addition of all the cases in one single database is not possible.

4.4.2. Clustering

To define motorcycle accidents scenarios, a clustering analysis based on the Malaysian data was firstly planned. The clusters would have been then described in detail with the in-depth data coming from Thailand.
The clustering methodology provides groups of accidents (clusters) which contains accidents with comparable characteristics. Accidents from separate clusters present dissimilar attributes. The clusters are built with the selected variables (selection of variables done by the data analyst) allowing the definition of accident scenarios. This methodology provides several results with various clusters based on the utilisation of a set of variables among the proposed variables. Statistical indicators help to choose the most adequate clustering. The figure below gives an illustration of the possible variables used in the clustering and the process of the method.

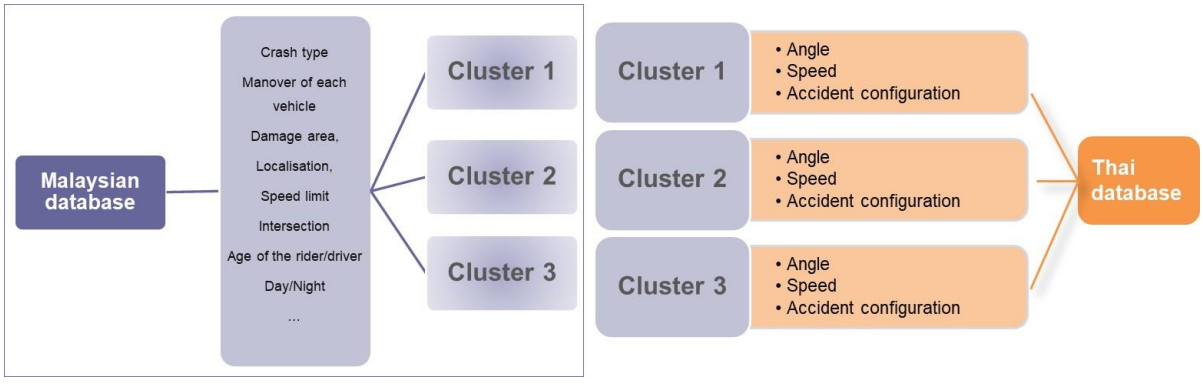


Figure 22: Illustration of the clustering process on the Malaysian database and the description of scenarios with the Thai database

Finally, this methodology has not been used because the Malaysian database structure did not allow to have all the needed information.

4.4.3. Malaysian database specificity

Manoeuvre and damage on both vehicles are the most valuable information to describe the scenarios, as they allow to give a representation of the accident configuration and the relative movement of the two vehicles just before impact.

The Malaysian database has the characteristic of recording the information relative to the driver and to the vehicle only if there were at least one injured occupant in the vehicle. However, accidents between passenger cars and motorcycles produce injuries for the riders/passengers of the motorcycles while in most of the cases, the occupants of the passenger cars don't sustain any injury. Thus, all the information about the latter occupants is then not recorded in the database.
The figure below provides the number of accidents in the Malaysian database with information on both motorcycles and passenger cars and the number of accidents with only the motorcycle information.

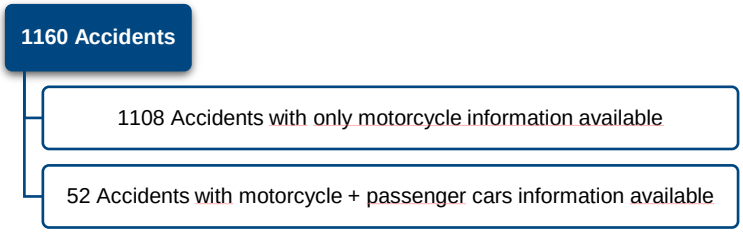


Figure 23: Driver and passenger car information availability in the Malaysian sample

Eventually, the manoeuvres and damages are available for both motorcycle and passenger car in 52 accidents among 1160. In this context, due to missing data, the clustering analysis is not relevant anymore to determine motorcycle accident scenarios.

4.4.4. Alternative proposals

This paragraph gives an overview of a method that was proposed in order to increase the number of Malaysian accidents to take into account in this study. An analysis was carried out to explore the possibility of retrieving relevant passenger car information, based on the available data on motorcycle manoeuvre and type of collision.

4.4.4.1. Providing additional data

To increase the proportion of car driver data availability, the accident description summary of some database's accidents has been shared by MIROS. These summaries were written by the Police forces and describe the unfolding of the accident. However, its translation from Malay to English to get the information on the car damage and car driver manoeuvre allows gaining only about 50 cases. A final sample of 106 accidents with the complete information was identified among a total of 1160 accidents.

4.4.4.2. Crossing available variables

In the Malaysian database, the collision type, the motorcycle manoeuvre, and the impact point on the motorcycle are known for all cases. A table was created by crossing together these variables and those related to the passenger car when available. An attempt was made to establish the scenarios by analysing each of the combination of those variables. The table hereafter gives an overview of the main observed combinations.

Table 22: Main combinations between collision type, manoeuvre, and damage on the vehicles

Collision Type	Motorcycle manoeuvre	Passenger car manoeuvre	Motorcycle damage	Passenger car damage	Freq.
Angular	Forward	Unknown	Front	Unknown	159
Head-on	Forward	Unknown	Front	Unknown	87
Rear	Forward	Unknown	Front	Unknown	55

The first combination may represent the accident configurations illustrated in the figure bellow.

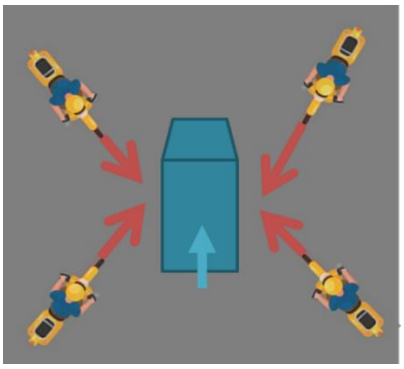


Figure 24: Possible accident scenarios with angular collision, covered by the main combination of known variables (Malaysian database)

These accident scenarios are compatible with the first line of variables combination of Table 22, but there is no way to determine the proportion of each of them. Besides, strong assumptions must be made on the manoeuvre and on the impact point on the passenger car. It appears that dealing with many unknown values leads to too much uncertainty.

Due to this uncertainty and all the needed assumptions, this method of determining motorcycle accident scenario was abandoned.

Therefore, the sample size remains at 1160 accidents between one passenger car and one motorcycle, among them only 106 have the information needed from both vehicles.

4.4.5. Proposed methodology

This paragraph describes the methodology that is proposed to determine the main passenger car to motorcycle accidents scenarios in the ASEAN countries.

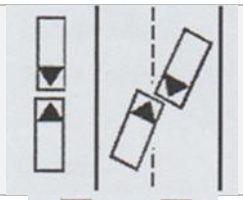
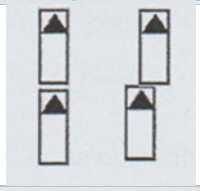
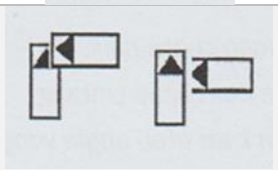
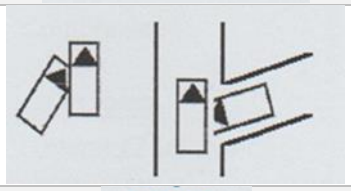
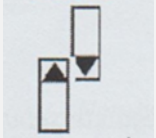
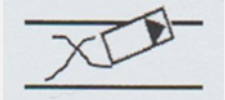
Collision type, motorcycle damage and manoeuvre are available in both the Malaysian and the Thai databases. Thus, accident scenarios could be characterised by crossing these three parameters. The same process is applied on the Malaysian data and on the Thai data. It allows to have the same accident scenarios definition on the two databases. The distributions of the accident scenarios built according to the collision type, the manoeuvre, and damage on the motorcycle, observed on the Malaysian and Thai databases will be compared. A ranking of the most frequent scenario for all injury accidents and for KSI accidents will be used to determine the most frequent passenger car to motorcycle accident scenarios.

In the following, the definition of the accident scenarios will be described for the Malaysian database and for the Thai data. Then, the distributions of accident scenarios will be compared between both databases. Finally, the variables used to describe the main scenarios will be listed.

4.4.5.1. Malaysian database

The distribution of the collision type, motorcycle damage and manoeuvre observed in the Malaysian database are provided bellow. The collision type is known for all 1160 accidents. The distribution and generic illustration of the collision are described in the following table. The complete illustration of the collision type is provided in Annex 2.

Table 23: Distribution of the collision type (Malaysian database)

Collision Type		Frequency	%
Head-on		326	28%
Rear		183	16%
Right Angle side		59	5%
Angular		460	40%
Side swipe		105	9%
Hitting object on road		2	<0,2%
Hitting object off road		1	<0,1%
Hitting pedestrian		1	<0,1%
Out of control		23	2%
Total		1160	100%

The vehicle damage distribution related to the motorcycle and the passenger car is illustrated in the following table:

Table 24: Distribution of the damage observed on the motorcycle and the passenger car (Malaysian database)

	Motorcycle damage		Car damage	
	Frequency	**%**	**Frequency**	**%**
Unknown	0	0%	1057	**91%**
None	9	0,8%	0	0%
Front	651	**56%**	51	**4,4%**
Rear	76	7%	4	0,3%
Right	113	**10%**	23	2%
Left	76	6%	12	1%
Roof	1	0,1%	0	0%
Multi	234	**20%**	13	1%
Total	1160	100	1160	100

This database records the manoeuvre of the vehicle. Its distribution is presented below:

Table 25: Distribution of the manoeuvre of the motorcycle and the car (Malaysian database)

	Motorcycle movement		Car movement	
	Frequency	**%**	**Frequency**	**%**
Unknown	0	0%	1053	**91%**
Parked	11	1%	0	0%
Suddenly stopped	30	3%	1	0,1%
Diverging	45	4%	1	0,1%
Converging	59	5%	5	0,4%
Out of control	11	1%	2	0,2%
Right turn	76	**6%**	22	2%
Left turn	22	2%	3	0,3%
Overtaking	13	1%	2	0,2%
U turn	16	1%	11	1%
Forward	625	**54%**	43	**4%**
Reverse	1	0,1%	0	0%
Others	251	**22%**	17	1%
Total	1160	100%	1160	100%

The collision type can be detailed with some information on the motorcycle damage. For example, the rear-end collision type may be divided between the cases where the motorcycle is hit at the rear and the cases where the front of the motorcycle collides with the rear of the car. The movement of the motorcycle can also be used to better characterise the collision type, for instance the angular collision: the cases where the motorcycle is turning, diverging or converging (thus it is changing lane) will be mentioned.

The following passenger car-to-motorcycle accident scenarios are then established:

Table 26: Description of the accident scenario (Malaysian database)

Accident scenario	Frequency	%
Angular: Motorcycle with a frontal impact	238	**21%**
Angular: Motorcycle with a lateral impact	55	5%
Angular: Motorcycle turning-diverging-converging with a frontal impact	34	3%
Angular: Motorcycle turning-diverging-converging with a lateral impact	42	4%
Angular: Not further specified	91	**8%**
Head-on	326	**28%**
Loss of control: For the motorcycle	4	0,3%
Loss of control: Not further specified	19	1%
Rear-end: Motorcycle with a rear impact	52	5%
Rear-end: Motorcycle with a frontal impact	89	**8%**
Rear-end: Not further specified	42	3%
Right angle: Motorcycle with a frontal impact	38	3%
Right angle: Motorcycle with a lateral impact	12	1%
Right angle: Not further specified	9	0,8%
Side swipe	105	**9%**
Other	4	0,3%
Total	1160	100%

4.4.5.2. Thai database

The information coded in the Thai database allows to build a comparable accident scenario (as in Table 26).

Although, the accident type codification in the Thai database is sometimes different compared to the Malaysian database, it describes groups of accidents that are relevant to build the accident scenarios. The accident type distribution in the Thai database is described in Table 27. Annex 3 provides more details about the accident type.

Table 27: Distribution of the accident type (Thai database)

Accident Type		Frequency	%
Same Trafic Way, same direction	Rear-end	142	**22%**
	Forward Impact	8	1%
	Sideswipe Angle	54	8%
Same Trafic Way, opposite direction	Forward Impact	26	4%
	Sideswipe Angle	12	2%
	Head-On	26	4%
Same Trafic Way, vehicle turning	Turn Across Path	224	**35%**
	Turn Into Path	86	**13%**
Intersecting Path	Straight Paths	53	8%
Other	Backing	7	1%
Unknown	Unknown	1	0%
Total		639	100%

Some Thai accident types can be directly linked to the Malaysian collision types. For instance, the rear-end collisions have the same definition in both databases. The “intersecting path” category of the Thai database is equivalent to “right-angle side” collision type of the Malaysian database.

The type of impact is also used to identify all head-on collisions. The distribution of the damage location for the motorcycle and the passenger car are presented below:

Table 28: Distribution of the damage location for the motorcycle and the passenger car (Thai database)

	Motorcycle		**Passenger car**	
Damage location	Frequency	%	Frequency	%
Frontal	312	49%	232	36%
Lateral left side	116	18%	155	24%
lateral right side	153	24%	143	22%
Rear	56	9%	107	17%
Unknown	2	0%	2	0%
Total	639	100%	639	100%

The manoeuvre described in the Thai database allows the identification of the turning, converging and diverging movement. The following examples give an illustration of some turning manoeuvre.

Figure 25: Example of turning scenario (vehicle in position 46 and 48) (Thai database).

By merging the accident type, motorcycle damage and manoeuvre, a similar accident scenario is defined. It is built in the same way as in the Malaysian database. The accident scenario distribution is illustrated in Table 29.

Table 29: Description of the accident scenarios (Thai database)

Accident scenario	Frequency	%
Angular: Motorcycle with a frontal impact	127	20%
Angular: Motorcycle with a lateral impact	102	16%
Angular: Motorcycle turning-diverging-converging with a frontal impact	10	2%
Angular: Motorcycle turning-diverging-converging with a lateral impact	62	10%
Head-on	66	10%
Loss of control: for the motorcycle	5	1%
Loss of control: for the passenger car	2	0,3%
Rear-end: Motorcycle with a rear impact	54	8%
Rear-end: Motorcycle with a frontal impact	96	15%
Right angle: Motorcycle with a frontal impact	22	3%
Right angle: Motorcycle with a lateral impact	31	5%
Side swipe	54	8%
Other	8	1%
Total	639	100%

4.4.5.3. Comparison of the distributions – selection of the relevant scenarios

In this part, accident scenarios from the Malaysian and the Thai databases built according to the accident type, manoeuvre and damage on the motorcycle are compared.

Comparison of all injury accidents (all severity)

The top 6 of the most common accident situations in Malaysia and in Thailand are identified. The following tables describe the 6 most frequent scenarios of accidents of all severity in both countries.

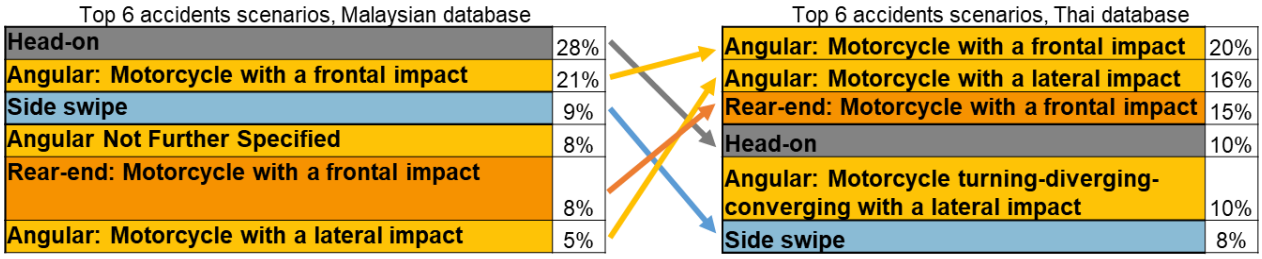


Figure 26: Top 6 accident scenarios from Malaysian and Thai databases

The top 6 represents 78% of all accidents from the Malaysian database, and 79% of all accidents of the Thai database.

Although the percentage might not be the same, it must be highlighted that 5 out 6 of the scenarios are identical in Malaysia and Thailand. Head-on and angular scenarios are the most frequent accident configurations, when looking at accidents of all severity.

Comparison of KSI accidents

The second comparison focuses on accidents with at least one severely injured occupant. The comparison is described in the following figure:

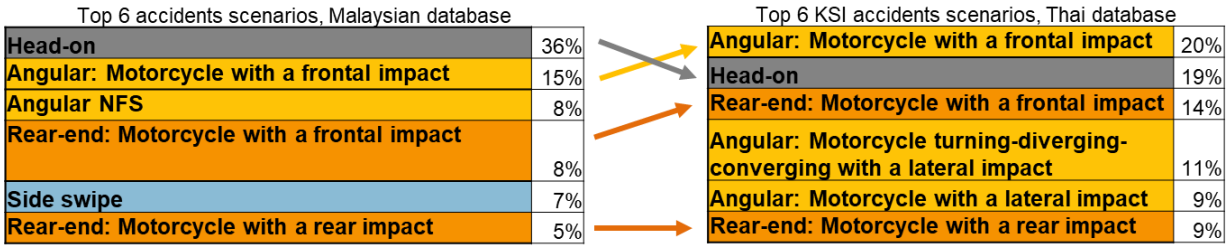


Figure 27: Top 6 KSI accident scenarios from Malaysian and Thai databases

The top 6 of the KSI accidents stands for 80% of the KSI accidents in Malaysia and 82% of the KSI accidents in the Thai database.

The two first KSI scenarios (Head-on and angular with a frontal impact for the motorcycle) are identical in the Malaysian and in the Thai databases. Angular scenarios are representing 40% of the top 6 in the Thai database.

The rear end scenario with a rear impact on the motorcycle is to be taken account when focusing on KSI accidents.

Selection of passenger car to motorcycle accidents scenario

It has to be noticed that the rear-end scenario with a frontal impact for the motorcycle is not relevant for the purpose of the project as ASEAN NCAP aims to test cars equipped with active safety systems.

The following table proposes a summary of the configuration to be taken into account for passenger car to motorcycle accidents in ASEAN region, based on the results observed in Malaysia and Thailand:

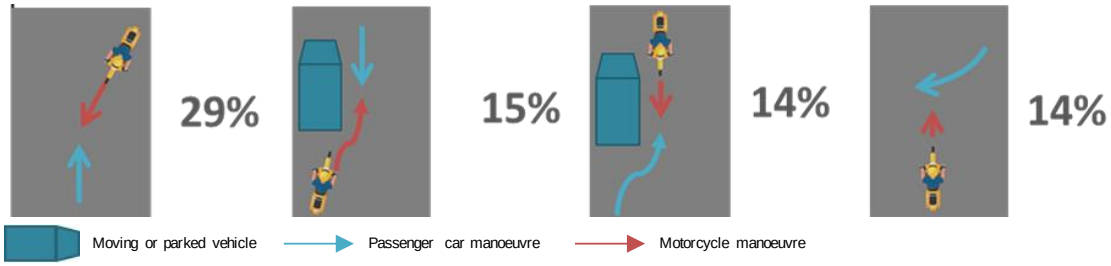
Table 30: Selection of passenger car to motorcycle accident scenarios

⇨ **Head-on**	MC = Motorcycle
⇨ **Angular scenario with frontal impact for the MC**	
⇨ **Angular scenario with lateral impact for the MC**	
⇨ **Rear end collision rear impact for the MC**	

Those scenarios represent 60% of the KSI cases in the Malaysian database and 57% in the Thai database.

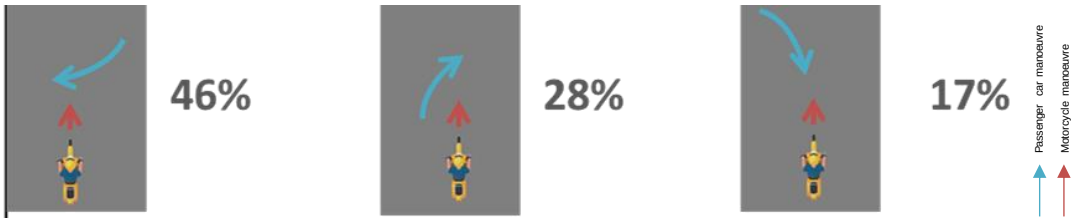
An analysis of the Thai database provided further details on the exact configurations within each scenario. The percentages of the more frequent configurations are given. The less frequent configurations within each scenario are not presented here, and they will be provided in the deliverable D1.2.

- The <u>head-on scenario</u> is distributed as follows,



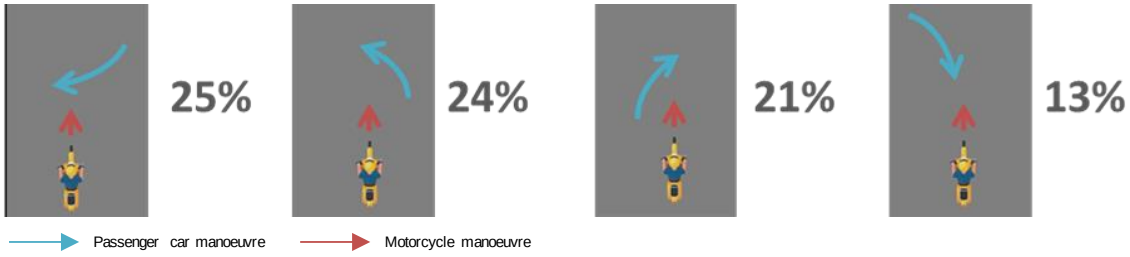
Those four configurations represent 72% of the head-on scenario. The remaining configurations will be described in the D1.2 deliverable.

- The <u>angular scenario with frontal impact for the motorcycle</u> is distributed as follows:



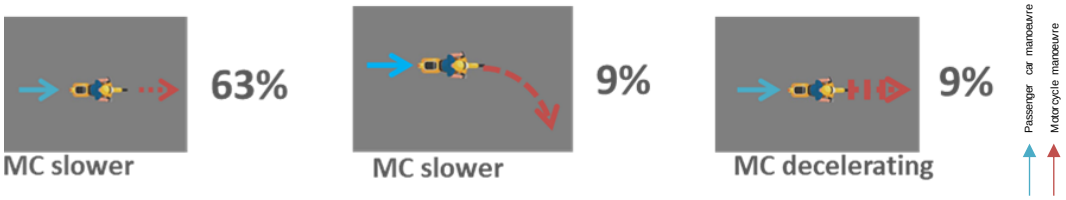
Those three configurations represent 91% of the angular scenario with frontal impact for the motorcycle. The remaining configuration will be described in the D1.2 deliverable.

- The angular scenario with lateral impact for the motorcycle is distributed as follows:



Those four configurations represent 83% of the angular scenario with lateral impact for the motorcycle. The remaining percentage will be described in the D1.2 deliverable.

- The rear-end scenario is distributed as follows:



Those three configurations represent 81% of the rear end scenario with a rear impact for the motorcycle. The remaining percentage will be described in the D1.2 deliverable.

4.4.6. Proposed variables to describe the accident scenarios

The four scenarios need to be described more precisely in order to be fully useful for the next steps of the project. For that purpose, the in-depth Thai database is analysed to provide detailled information on each scenario. The following tables provide the list of variables that could be used to describe the scenarios. Some variables are related to the accidents (Table 31), and some other are related to the collision itself (Table 32).

Table 31: List of accident variables to describe the relevant scenarios

Configuration: out of intersection/in intersection (type of junction)
Category of road and number of lanes
Lane marking
Straight road, bend
Slope (%)

Visibility obstruction and type of obstruction
Weather conditions
Light condition
Speed limit
ABS fitment on the passenger car

Table 32: List of collision variables to describe the relevant scenarios

Impact angle
Initial speed (for the passenger car and the motorcycle)
Impact speed (for the passenger car and the motorcycle)
Initial relative velocity

The relevant variables are fully explained in Annex 4.

Thus, a complete description of the relevant scenario will be given according to the variables available in the in-depth Thai database. The lane marking will be provided through the Malaysian database.

Some data, as the radius of the curve, the lane width, the traffic regulation would have been interesting to describe the scene of the accident, but they are available in none of the databases. In the same way, overlap and deceleration would have been important for the collision description, but they are not registered. Deceleration might be studied with skid marks

The results of the description of the four scenarios are provided in the D1.2 deliverable.

5. Conclusion

A literature review highlighted the context of road traffic in the ASEAN countries and some critical accident situations between one motorcycle and one passenger car. It also raised the issue of the lack of accident dataset and information in those countries as the literature review was mostly based on five countries: Cambodia, Malaysia, Singapore, Thailand, and Vietnam. The findings shows that angular/side impact scenarios appear to be the most important crash configurations in fatal motorcycle accidents in Thailand (27,5% according to an analysis based on 2000-2009 accident data) and Malaysia (30% of cases from a 2013 study focusing in motorcycle accidents involving children). In the Thailand insurance database, angular scenarios include the cases where the other vehicle drives into the path of the motorcycle and where the motorcycle drives into the lane of the opposite vehicle. Then, specifically in Bangkok, rear-end collision is the most frequent crash scenario (14,5%) according to an in-depth accident study. The second one involves a motorcycle facing a turning vehicle (7,5%), or a vehicle overtaking another vehicle or driving in the motorcycle lane (7%). In Cambodia, head-on and right-angle/side-swipe accidents are predominant and account for about the same proportion of accidents (36% and 37%). Concerning the motorcycle users, passengers account for 11% to 24% of fatalities in Thailand, Malaysia, and Cambodia.

An analysis of the accidents between motorcycles and passenger cars in ASEAN countries has been conducted based on two datasets from Thailand and Malaysia. At first, the method defined to compile and analyse the information from two different databases was to use a clustering method. This method provides groups of accidents (clusters) which contains accidents with comparable characteristics. Statistical indicators would then help to choose the most adequate clustering. However, this method could not be applied due to missing information about passenger car's manoeuvre for most of the accidents from the Malaysian database. Then, the method applied for the analysis is to characterise the accident scenario by crossing three parameters: collision type, motorcycle damage and manoeuvre.

Four main categories of situations have been identified as the most frequent motorcycle accident scenarios in both countries: *head-on, angular with frontal impact on the motorcycle, angular with lateral impact on the motorcycle, read-end accidents*. It is worth nothing that loss of control accidents and read-end collisions where the motorcycle collide with the passenger car, have not been taken into account within the analysis. Focusing on KSI accidents, the first two scenarios, *head-on* and a*ngular with a frontal impact on the motorcycle*, are identically distributed in the Malaysian and in the Thai databases. Head-on scenarios, which correspond to situations with frontal impact on both vehicles travelling from opposite directions, accounts respectively for 36% and 20% of the accidents for each country. Angular accident scenarios with a frontal impact on the motorcycle cases accounts also for 15% and 19%. Afterwards, angular scenarios with lateral impact on the motorcycle represent the third most common situation, with 16% of all the accident in Thailand. Finally, the fourth most common situation is the rear-end collision with either the motorcycle driving forward or turning, at slower speed than the passenger car or decelerating in front of it.

Within the project these main accident situations will be further analysed. The main parameters to be studied are described in this report such as road configuration, weather condition, speeds, impact points and angle. Therefore, the most common situations and their parameters should be used to select test scenarios for future ADAS systems to avoid help avoid them, or at least, reduce their consequences.

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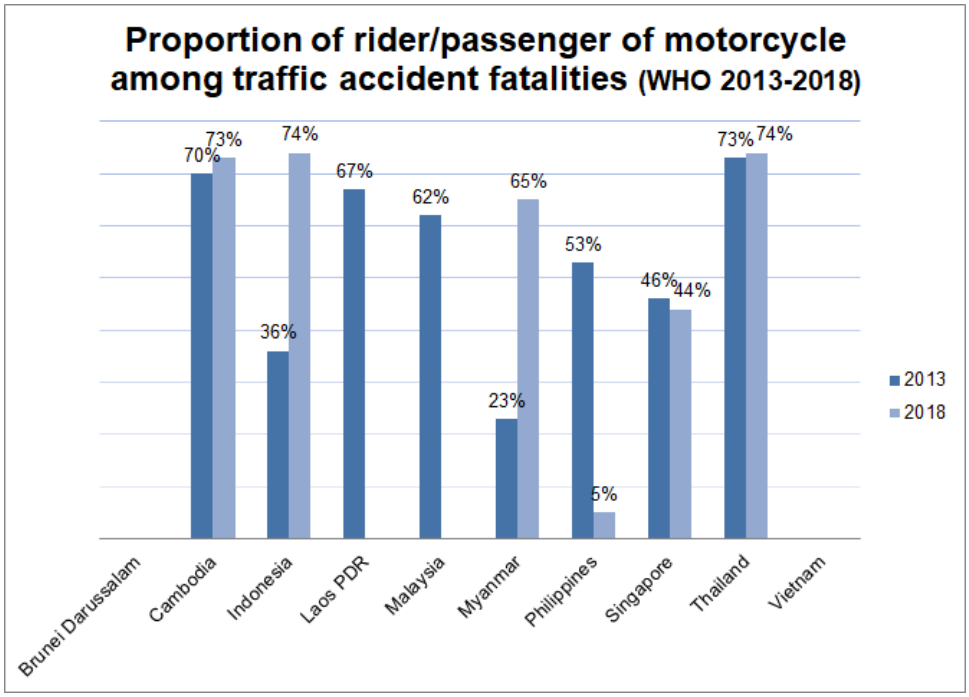
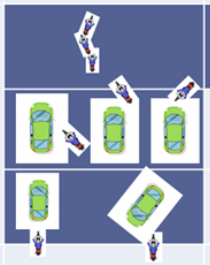
7. Annex 1 – Literature Review additional table and sum-up tables

- Additional table



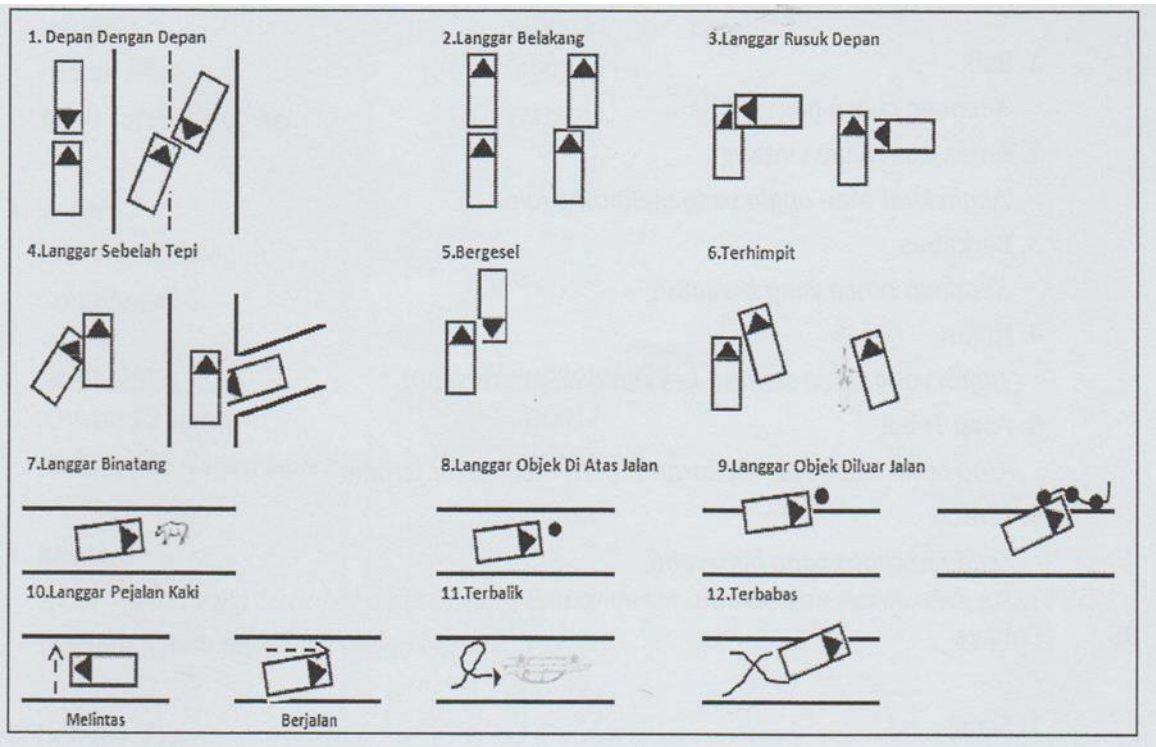
- Sum-up tables

ASEAN country	% of ASEAN population	Percentage of the population living in urban area	Percentage of paved road	Nb of registered MC or 3 wheelers per 1 000 pop	% of 2/3 wheelers among vehicle fleet	Motor vehicle per km of road	% of Mc among traffic fatalities
Brunei Darussalam	<1%	predominantly urban	93%	NA	NA	91	NA
Cambodia	2%	20%	11%	137	72%	6	70%
Indonesia	41%	52%	90%	345	82%	235	36%
Laos PDR	1%	64%	18%	166	77%	-	67%
Malaysia	5%	73%	81%	373	46%	70	62%
Myanmar	8%	30%	Express way = 587 km	70	84%	9	23%
Philippines	16%	45%	86%	43	58%	28	53%
Singapore	1%	predominantly urban	100%	27	15%	278	46%
Thailand	10%	48%	Express way = 450 km	286	55%	50	73%
Viet Nam	15%	32%	-	422	93%	7	NA

	All accident Scenarios	Fatal accident Scenarios	Severe accidents Scenario	Type of collision
Brunei Darussalam				
Cambodia				Head on, side, rear-end, side swipe
Indonesia				
Laos PDR				
Malaysia				
				Side impact
Myanmar				
Philippines				
Singapore				
Thailand				
Viet Nam				

8. Annex 2 – Collision type definition in the Malaysian database

Illustration of the collision type in the Malaysian database.



The values of the codification are:

1=Head-on

2=Rear

3=Right Angle side

4=Angular

5=Side swipe

6=Forced

7=Hitting animal

8=Hitting object on road

9=Hitting object off road

10=Hitting pedestrian

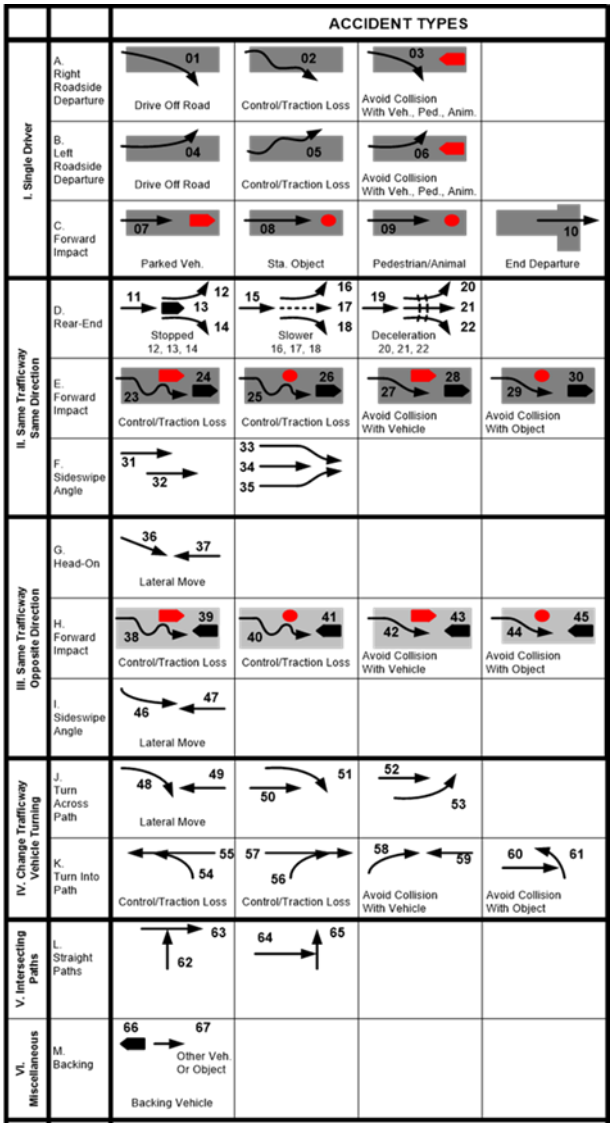
11=Overturned

12=Out of control

13=Others

9. Annex 3 – Accident type definition in the Thai database.

Illustration of the accident type in the Thai database.



10. Annex 4 – Definition of database variables

Definition of the variables describing the scene of the accident (all variables are from the Thai database, except the lane marking which comes from the Malaysian database):

- **Configuration: out of intersection/in intersection (type of junction).** *The variable indicates whether the accident occurred at intersection or not. In case of intersection, the type of junction is detailed. The value are as follows:*
  - *Out of intersection*
  - *Intersection: Diverging lane*
  - *Intersection: 3-leg skewed*
  - *Intersection: Alley*
  - *Intersection: Driveway*
  - *Intersection: 4-leg intersection*
  - *Intersection: 3-leg intersection*
  - *Intersection: 5-leg or more intersection*
  - *Intersection: Interchange area*
  - *Pedestrian crossing*
  - *Merging lane*
  - *Diverging lane*
  - *Roundabout*
  - *Railway crossing*

- **Category of road and number of lanes.** *The variable indicates the type of environment and the number of lanes of the road at the scene of accident. The value are as follows:*
  - *Expressway*
  - *Highway*
  - *City street*
  - *Residential street*
  - *Local road*

- **Lane marking.** *The variable indicates the type of lane marking on the road at the accident scene. The value are as follows:*
  - *Single*
  - *Double*

- *One way*
- *Divider*

- **Straight road, bend.** *The variable indicates whether the accident occurred on a straight part of the road or in a curve. The characteristic of the curve is also described. The values are as follows:*
  - *Straight no curve*
  - *Regular curve*
  - *Sharp curve*
  - *S-curve*

- **Slope.** *The variable indicates the percentage of slope observed on the portion of the road where the accident occurred. The given number represents the percentage value.*

- **Weather conditions.** *The variable indicates the meteorological conditions when the accident occurred. The values are as follows:*
  - *Clear*
  - *Cloudy*
  - *Rainy*
  - *Foggy*

- **Light condition.** *The variable indicates the luminosity condition at the time of the accident. The values are as follows:*
  - *Daylight*
  - *Dark with streetlight*
  - *Dark without streetlight*

Speed limit. *The variable indicates the value of the speed limit of the road where the accident occurred. The values range from 30 kph to 130 kph with a step of 10 kph.*

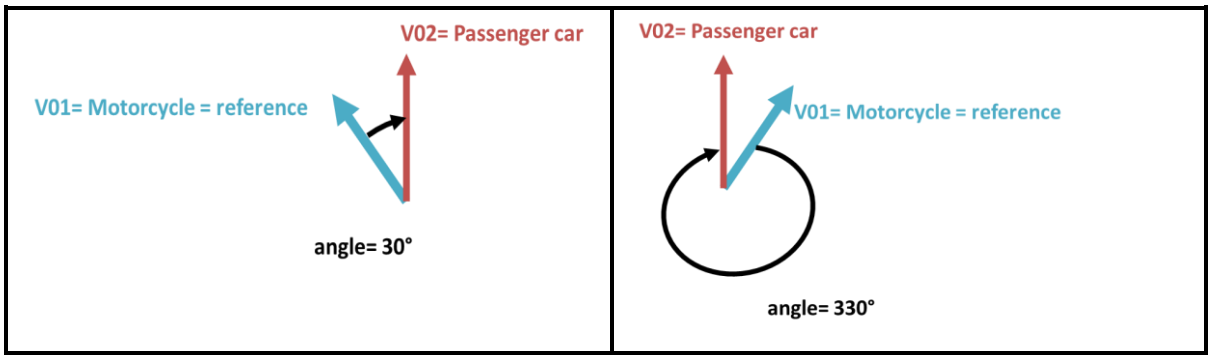
- **Visibility obstruction and type of obstruction.** *The variable indicates whether the view of the driver was blocked or not, and it describes what was the type of view obstruction. There can be a combination of the view obstructions, the values are as follows:*
  - *Clear: no obstruction*

- *Obstructed by road curvature*
- *Obstructed by roadway grade*
- *Obstructed by roadside objects*
- *Other vehicle in blind spot of mirror*
- *Obstructed by parked vehicles*
- *Obstructed by vehicle in front*
- *Other type of view obstruction*

- **ABS fitment on the car.** *The variable indicates if the* passenger *car involved in the accident was fitted with ABS or not. The values are as follows:*
  - *Yes, ABS was fitted on the car*
  - *No, ABS was not fitted on the car*

Definition of the variables describing the scene of the accident (all variables are from the Thai database):

- **Impact angle.** *The variable describes the angle made between the car and the motorcycle at the crash point. The angle is calculated clockwise, related to the motorcycle direction, which is the reference. The following figures give an illustration of some angle determination*



- **Initial speed.** *The variable gives the speed of the vehicle in the travelling condition, just before the event leading to the crash occurred. It can be a null value if the vehicle was stopped. The value is coded in kph.*

- **Impact speed.** *The variable gives the speed of the vehicle at the moment of the crash. It can be a null value if the vehicle was stopped. The value is coded in kph.*

- **Initial relative velocity.** *The variable gives the value of the difference between the initial speed of the car and the initial speed of the motorcycle. The value is coded in kph.*