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ATRANS
ASIAN TRANSPORTATION RESEARCH SOCIETY

In-depth Analysis of Black Spot Characteristics in Thailand from ATRANS Safety Map Applica

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List of Abbreviations and Acronyms

ATRANS	Asian Transportation Research Society
DOH	Department of Highways
DRR	Department of Rural Roads
MOPH	Ministry of Public Health
MOT	Ministry of Transport
OTP	Office of Transport and Traffic Policy and Planning
RSWG	Road Safety Prevention Working Groups
RTP	Royal Thai Police
RVP	Road Victim Protection Co., Ltd.
WHO	World Health Organization

CHAPTER I INTRODUCTION

1.1 Rationale

Road crash has been a pressing problem causing fatalities and injuries to Thai citizens for many decades. According to the World Health Organization (WHO) Global Status Report in the year 2015, Thailand was ranked the second highest fatality rate worldwide. It was estimated that Thailand has a road traffic fatality rate of 36.2 persons per 100,000 populations (WHO, 2015).

Recently, ATRANS launched a 4-year common research project, named development of compiled road safety data and analysis for safety research (ATRANS, 2018), to tackle the road safety problem in Thailand. The research highlighted on the development and implementation of road safety map application, briefly called ATRANS Safety Map, in order to collect the common data of crash and risk locations and to identify hazardous (black spot) locations on the road networks in Thailand. The project was divided into four phases including 1) review of current practices (the fiscal year 2014); 2) development and implementation (the fiscal year 2015); 3) evaluation process (the fiscal year 2016); and 4) revision process (the fiscal year 2017). One of the potential outcomes of the previous project is that the concerned authorities in local areas (e.g. Phuket, Songkhla, Suphanburi) can use the ATRANS Safety Map as a supplement tool to systematically report the crash and risk locations and to simply perceive the road safety issues in their community.

However, there were some further research gaps need to be investigated, for examples:

- In-depth analysis of hazardous characteristics;
- The relationship between hazardous locations and risk locations;
- Prioritization of hazardous and risk locations.

1.2 Objectives

This research aims at extending the development of ATRANS Safety Map application and applying the application for further investigations of crash and risk locations.

Four specific objectives are listed as follows:

1) To investigate the relationship between crash and risk locations;
2) To develop hazardous (black spot) location ranking system;
3) To analyze the detailed characteristics of the top hazardous locations in the study areas;
4) To design and propose road safety measures in the study areas.

1.3 Scope of the research

The scope and some assumptions made in this research can be explained as follows.

- **Study areas**

At a national level, the crash and risk location data were collected across the country where the data are available. The data were analyzed at the macroscopic level. At a local level, the crash and risk location data in potential areas (e.g. Phuket, Songkhla) were collected. With a high number of detailed crash data reported, the characteristics of crash locations were analyzed and investigated.

- **Data**
  - Crash data were collected from primary sources, e.g., police, rescue team, and Road Safety Prevention Working Groups and secondary sources, e.g., official news, JS100 webpage.
  - Risk location data were reported by any road users including pedestrian, bicyclist, motorcyclist, and car driver.
  - Both data of crash and risk locations reported to the database of ATRANS Safety Map were verified by database administrators and local experts in the collaborative study areas.

- **Identification of hazardous locations**
  - Hazardous (black spot) locations were identified applying the accident costing approach.
  - This research applied the cost of each crash by severities (death, serious injury, slight injury, and property damage only) from the recent studies commonly used in Thailand.

CHAPTER 2 LITERATURE REVIEW

2.1 Some definitions

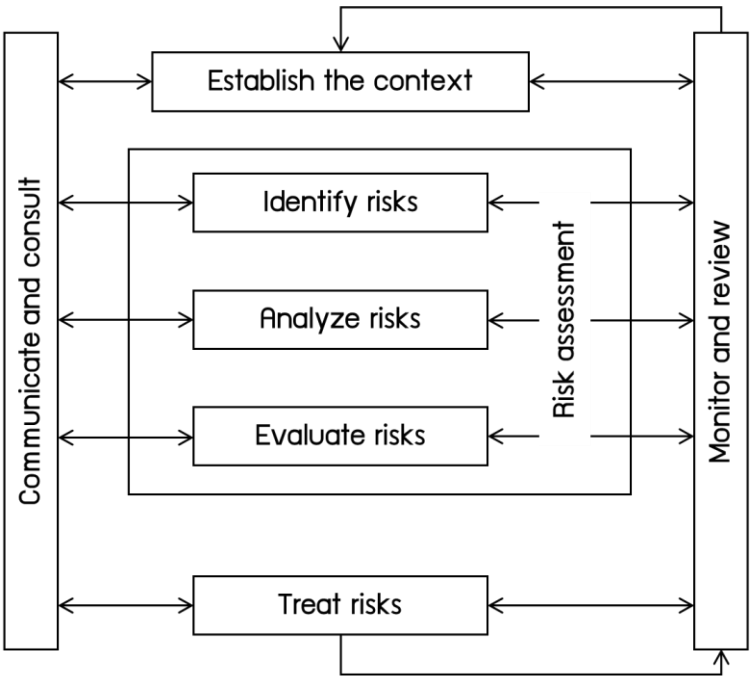
Some definitions and terms mainly used in this research are explained as follows (Austroads, 2004 and 2006):

- **Crash**: A crash is a rare, random, multifactor event preceded by a situation in which one or more persons failed to cope with their environment.
- **Crash severity:** The most severely injured casualty occurring as a result of a crash.
  - *Fatal*: A death occurring as the result of injuries sustained in a road crash within 30 days of the crash.
  - *Serious*: Injury (fracture, concussion, severe cuts or other injuries) requiring medical treatment or removal to and retention in hospital.
  - *Minor*: Injury which is not 'serious' but requires first aid, or which causes discomfort or pain to the person injured.
  - *Non-injury*: Property damage only (PDO).
- **DCA**: Definition for Coding Accidents
- **Frequency**: Commonly applied to accidents to mean 'number per year'.
- **Rate**: Number of accidents per unit of exposure. For example, a number of accidents per million vehicle kilometers traveled.
- **Location**: A single site (either an intersection or a point along a road), a route (length of road), or an area covering a number of roads. In connection with 'mass action programs' it also means a multitude of locations across a road network which have a common hazardous feature.
- **Crash location**: A location where a limited range of crash types occurs repeatedly, suggesting that there are common causes, rather than the crashes being the result of mere chance.
- **Crash cluster**: A number of crashes at one location that may be of the same or related crash type.
- **Black spot**: Now replaced by the term 'crash location' or 'crash cluster'.

2.2 Crash risk assessment and management on road network

Austroad (2004) and Austroad (2006) introduced the concepts of risk assessment and risk management on the road network. The risk can be defined as the chance of something happening that will have an impact upon objectives. The risk often refers to an event, the likelihood of it occurring, and the consequences resulting from it should it occur.

Risk management in road authorities could be seen as managing internal and external influences to maximize positive outcomes, including safety, legal liability, public opinion, and budgets. Minimizing the potential for damage (human, financial or image), loss, injury, or death should also be taken into account. In addition, the risk management process, which is defined as the systematic application of management policies, procedures and practices to the tasks of communicating, establishing the context, identifying, analyzing, evaluating, treating, monitoring and reviewing risk, can be illustrated in Figure 1.



Source: Austroads (2004)

Figure 1. Risk management process

Each step can be comprehensively explained as follows (Austroads, 2004).

- **Establish the context**

Establishing the context is important to gain an appreciation of all factors which might influence the ability to meet the intended outcomes. It includes defining the goals and objectives, and the scope or range of activities which the management process should cover. These include road trauma levels/crash types/crash costs, the legal context, and liability, and public opinion. In addition, there is a need to develop some criteria against which the risk is to be evaluated. This includes assessing the needs for treatment based on financial, social, legal or other criteria.

- **Identify risks**

Identifying risks involves the identification of risks to be managed, and a systematic approach is required to ensure that all relevant risks are identified for inclusion in the later analysis. Various tools including the Haddon Matrix can be applied in this identification task. Risks that are under the control of the organization should be identified, as well as those that are not. Consultation with internal and external stakeholders is important in identifying all relevant risks.

- **Analyze risks**

An analysis of risks requires an understanding of the level of risk so that decisions can be made about how or whether to treat the risk. This involves assessing issues such as the consequences and likelihood of an event, including the magnitude of consequences should the event occur. Analysis of events can be quantitative (e.g., analysis of historical data), semi-quantitative or qualitative (e.g., expert judgment). Communication and consultation with relevant stakeholders are required as part of this process.

- **Evaluate risks**

Evaluation of risks is required in order to select those risks that require treatment and to prioritize them. Given a finite level of resources, it is usually not possible to treat all potential risks. It is important to prioritize risks in order to produce the maximum benefit from the limited available resources (e.g. budget). It is also important to communicate and consult with all relevant stakeholders during the prioritization task.

- **Treat risks**

Once an assessment of the risks has been undertaken, and those risks that need to be treated have been identified, it is then necessary to assess available options for the treatment of those risks. A treatment plan should be produced including details of how the risks will be treated, who will be responsible, and what the expected outcomes are. Close communication and consultation with stakeholders are required when treating risk.

- **Monitor and review**

Ongoing monitoring and review are required throughout the risk management process. This is to ensure that progress is being made against the treatment plan and that continual improvement can be made. For example, it is important that the effectiveness of treatments is monitored so that this information can be included in the future selection of appropriate treatments. It is also important to evaluate the influence of changing internal and external factors in this process.

2.3 Risk analysis

a. Sources of risk data

Once all sources of risk have been identified, there is a need to collect information on each of these to determine the level of risk. There are a number of sources of information that can be used, these include:

- crash databases
- hospital or insurance data
- pro-active assessments of safety (e.g., road safety audit findings, and network level assessments)
- information from asset management and road maintenance
- road inventory data
- traffic volume, speed and vehicle classification data
- enforcement data
- monitoring data
- legal precedents
- public opinion surveys
- media monitoring.

Good quality information is important in order to make informed decisions about the current level of risk. However, there are often deficiencies in the available data due to factors such as constraints in data collection systems and errors in the database, including an incorrect recording of the location where crashes occurred. Crash databases are comprehensive in the collection and recording of crashes involving fatalities, but those involving lower severities often go unreported or are inaccurate in terms of location and orientation of vehicle movements. In some instances, the data collected may be based on subjective judgment. It is therefore important to know how much reliability can be placed on data to enable informed decision making and to work towards improvement where deficiencies are identified. These limitations can have direct implications for the successful management of risk. For example, crashes attributed to the wrong location may direct funds to the wrong site, and lead to the problem not being addressed.

b. Analysis methods

- Quantitative approaches

When assessing the risks for road trauma, blackspot analysis is typically used to identify locations with high levels of risk. Blackspot sites, lengths of road or areas with crashes over a minimum number per year are selected for inclusion in the analysis. A list of sites is produced which forms a 'short-list' for a more in-depth assessment and consideration for treatment.

A simple analysis of crash numbers gives no indication of the severity of the crashes involved, so often the crash or social cost is used. In addition, crash risk analysis can be undertaken by including a measure of vehicle volume to crash information. This provides a level of crash risk by vehicle volume (e.g., crashes per million vehicle kilometers traveled or vkt) to identify routes, areas or crash types that fall above the average expected. Similarly, pattern analysis can be undertaken to identify common crash types for treatment (e.g., drink drive, speed, fatigue, and run-off-road crashes). Crash costs can also be included in this type of analysis to indicate severity.

- Qualitative and semi-qualitative analysis

In some situations, there may be a lack of objective data with which to make a quantitative assessment of risk. There are various models of qualitative risk assessment that are of relevance to road safety. These include:

  - risk classification
  - fault and success trees
  - cause-consequence diagrams

c. Evaluating and prioritizing risks

Given limitations on budgets, it is important to determine which interventions will produce the greatest savings in casualty numbers and severity. There are several sources of information relating to risk, including blackspot analysis, information from pro-active approaches (such as road safety audit), maintenance programs and public feedback. Each of these sources needs to be used in the process of prioritization for later treatment.

- Evaluation based on historical data

The most commonly applied technique to evaluate existing crash locations is to assess historical trends in data (e.g. blackspot analysis). This involves comparison with existing crash numbers (or crash rates, or the social cost of these crashes) over the network. However, the evaluation also requires knowledge of expected reductions at the locations if they are treated. Predicted reductions in crashes from proposed treatments are calculated to provide input to a benefit-cost analysis at each site. Sites can then be compared, and the most economically advantageous set of sites and interventions programmed for remedial work.

- Evaluation where there is little historical data

In the case of risks identified through pro-active assessment (such as network-level assessments of risk, or road safety audit), or with sites and treatments suggested by elected members or the public, there is often little crash data to help with prioritization. Because of this, a prediction about future crashes is difficult. However, given that the majority of crashes on the road network fall outside what would normally be defined as blackspots, there is a need to address such locations in order to reduce overall road trauma.

- Comparison between risk types

It is much more difficult to prioritize risks across a variety of data sources, for instance, blackspot sites and recommendations from road safety audit.

In Australia, the Department of Transport and Regional Services (DOTARS, 2005) suggests that recognition needs to be given to both blackspot and pro-active approaches. For example, up to 20% of program funds may be used to treat sites where road traffic engineers have completed a "Road Safety Audit" and found that remedial work is necessary. This allows an opportunity for proactive safety works to be undertaken before casualties occur. In addition, in some locations, there are fewer blackspots, and crashes are more scattered across the network. In such locations, a higher proportion of funding on proactive safety works may be appropriate.

d. Treatment of risk

There are multiple causes of crashes. As a result, there are multiple ways in which these causes can be treated. Selection of treatments should be based on sound evidence, as measures that may appear to be potentially effective to the casual observer may have little impact on safety or, in the worst case, may actually lead to increased risk.

For the treatment of risks associated with adverse public opinion, there is a need to formulate relevant strategies, and this can be done in association with public relations personnel.

When treating the risk associated with road trauma, there are a number of ways that authorities can decrease the level of risk. These include:

- reduction of exposure to the risk
- reduction in the likelihood of a crash (including the concept of a 'no surprises' environment)
- reduction in severity (e.g. creating a more forgiving road environment).

In terms of solutions to the risk related to exposure and consequences, remedial treatments could be viewed as:

- elimination - remove the hazard
- substitution - use a safer option
- engineering controls - in terms of design modifications
- isolation - where the hazard is removed from the direct influence
- administrative controls - including educational initiatives, speed limits, licensing, drink driving laws, or
- personal protective equipment – for example, vehicle improvements (air-bags, electronic stability control, etc.).

The Haddon Matrix and Safe System may also be applied to formulate countermeasures based on human, vehicle, and road related issues (including speed), and how these can influence safety before, during and after a crash.

e. Monitor and review

Ongoing monitoring and review at all stages of the risk management process are required to ensure that the treatment plan is being met when implementing treatments and that lessons learned from the process are recorded and included in future risk management. Measures may have both positive and negative consequences, and it is important to assess these to help refine future treatment options and to minimize any negative factors. Monitoring is not only a useful source of information within the authority for use at a later date but is also potentially useful for other authorities. It is also important to recognize the impact of changes in an organizational context (either in relation to internal or external factors), for instance in levels of funding, legislation or overall strategic policy. Treatment plans will need to be reviewed and altered where appropriate as the result of such changes.

2.4 Treatment of crash locations

a. Approaches to improve road safety of crash locations

Austroads (2016) provided the guideline to treat crash locations. Several approaches can be applied to improve the road safety of the crash locations. These are, for example:

- Countermeasure approach and the role of infrastructure

There are many possible countermeasures that could be applied to a particular safety problem including various engineering treatments (ranging in cost), speed management options, application of new technology or training and education. Packages of treatments are often the most effective way to address road safety risk.

Although the role of human error in road crashes is substantial, road infrastructure has a significant role to play in reducing the severity of a crash. For these reasons, improvements to infrastructure can contribute substantially to reductions in death and serious injury.

- Safe system approach

The safe system approach recognizes that humans are fallible and will continue to make mistakes on the roads. Additionally, humans can only withstand limited amounts of kinetic energy exchange when a crash occurs before death or serious injuries result. Thus, appropriate infrastructure is required to take into account road user vulnerabilities and fallibilities in order to avoid death or serious injury should a crash occur.

The approach implies a shared responsibility for addressing fatal and serious crash outcomes. Road managers have a significant role in addressing these outcomes. It is not acceptable to blame the road user for a crash outcome when there are infrastructure solutions that may be applied to help reduce this risk.

- Crash risk

As risk is the product of three elements: probability, exposure, and severity, a road safety strategy must address all three elements. For a road agency, measures to reduce the risk of a crash may include, for example:

  - Influencing the probability of a crash
    - applying sound traffic engineering and road safety engineering techniques through the audit of new road designs and the treatment of known crash sites
    - modifying road user behavior by appropriate design elements
    - using well-targeted education and enforcement programs
    - applying appropriate speed management.
  - Influencing the exposure to a crash
    - providing alternative safer routes for vulnerable road users
    - promoting safer forms of transport.
  - Influencing the severity of a crash
    - providing a more forgiving roadside environment (e.g. safety barriers)
    - providing appropriate speed management
    - providing good access for emergency services to reach crash sites.

b. Process of crash location treatment

The process of crash location treatment can be illustrated in Figure 2. Following Austroads (2006), the details of each step can briefly explain as follows:

- Decide on the criteria for listing crash locations

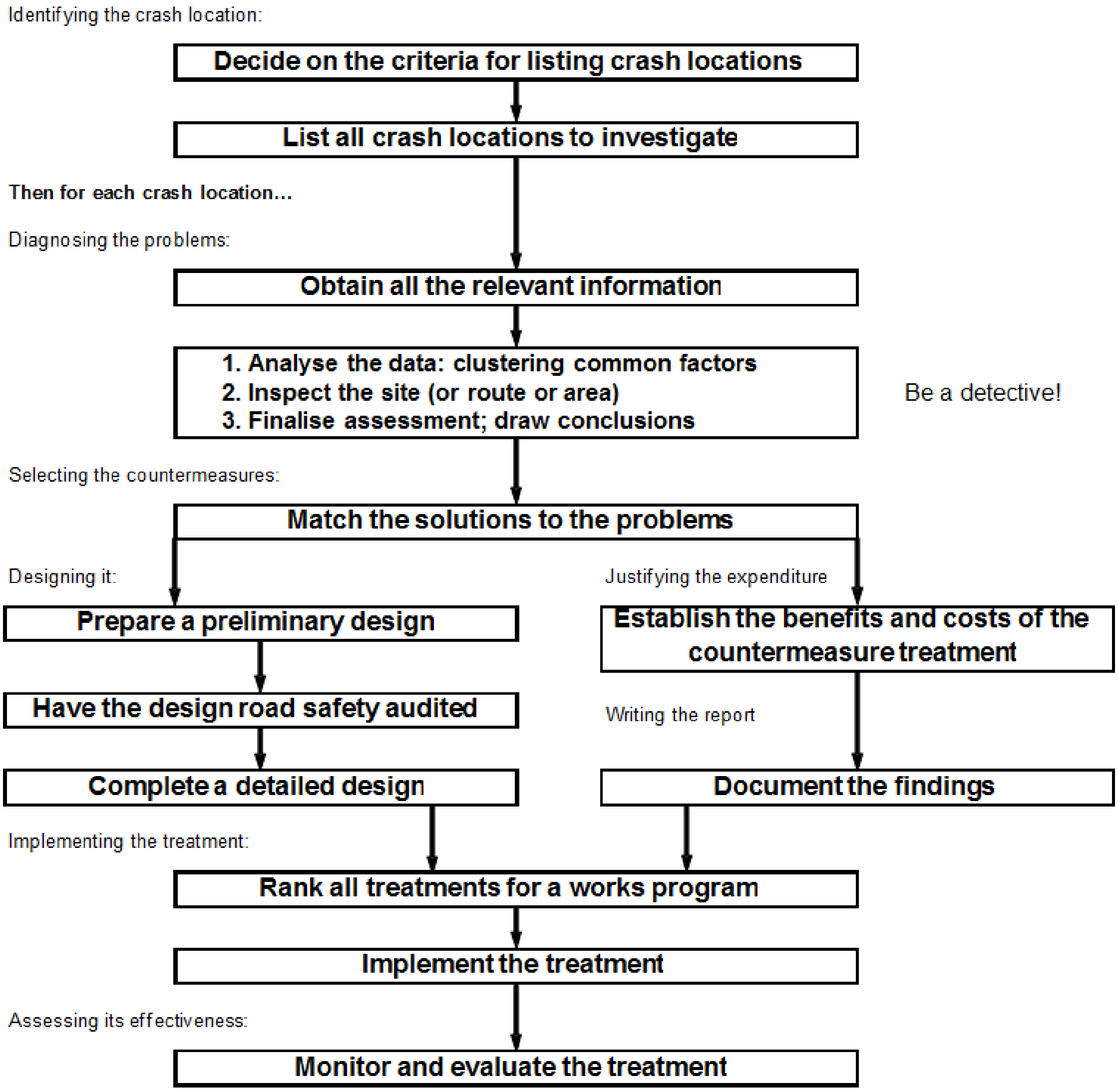
Define the physical limits of individual locations, so that sections with similar characteristics are considered together. Decide on the time period over which crash patterns are to be investigated. All sites need to be compared using an agreed selection criterion. The preferred criterion is ‘cost of crashes by crash type’ rather than a number of or rate of crashes. If necessary, select a crash threshold, above which locations will be considered for inclusion as crash locations.

- List all crash locations to investigate

Examine the information in the crash database to identify locations which meet the definition of crash location. Establish the cost of crashes at each location, over the agreed time period. Make a list of all the locations which meet the minimum cost threshold selected. Ensure that locations are sensibly defined so that no location worthy of investigation is missed through being subdivided into the data. Plan ahead for later monitoring.

- Obtain all the relevant information

Obtain the crash data for the location. Be aware of the limitations on the availability and accuracy of crash data. Obtain other information such as traffic volumes, recent changes in the road network or traffic generating land uses, and any documented concerns about safety at the location.



Source: Austroads (2006)

Figure 2. Risk management process

- Diagnose the problems
  This is a three-step process, including:
  - analyze the crash data (including crash rates and densities) for any clustering by common crash types or factors such as common approach legs, common weather or daylight, common age of those involved, etc. Construct a factor matrix and draw a collision diagram.
  - inspect the site from the perspective of the involved road users, as well as undertaking a close-up examination of the site's features and its users' behavior.
  - Make any other investigations, then draw conclusions about the likely causes of crashes for which there are common factors. There may be other types of contributing factors (e.g. speeding), but focus on what it is about the road or traffic environment which is leading to crashes.

- Select the countermeasures

Match the solutions to the problems. The key to the selection of countermeasures is to concentrate on the particular crash types which have been identified in the diagnosis phase and which are amenable to treatment with road or traffic engineering measures. Select the countermeasure(s) and take account of the crash modification factors for each countermeasure.

- Prepare a preliminary design

A preliminary design is required so that its practicality can be confirmed and the cost of the remedial treatment can be estimated. This design then needs to be road safety audited. Prior to implementing the project, the design needs to be finalized, taking account of any audit recommendations.

- Establish the benefits and costs

Undertake an economic appraisal. Establish the costs (i.e. the initial design and construction costs only) and the benefits (i.e. reductions in crash costs by crash type). Decide whether to use net present value (NPV) or benefit/cost ratio (BCR). Conduct sensitivity testing.

- Document the findings

Draw together the documentation which has been undertaken through the previous steps and set it out in a format which allows this project to be assessed against other potentially worthy crash countermeasure projects.

- If there are several locations to treat - rank all treatments

Compare all projects' NPV or BCR. An alternative 'goals achievement approach' can be used, whereby projects are ranked but no attempt is made to assess their economic benefits against their costs.

- Implement the treatment

Once the countermeasure treatment has obtained funding it can be installed. It is important that the design is being implemented accords with the results of the crash investigation. During the implementation phase, traffic safety will continue to be important. Once the works have been completed, the project should be the subject of a pre-opening road safety audit.

- Monitor the treatment and evaluate its effectiveness

Monitoring is the systematic collection of data about the performance of road safety treatments after their implementation. Evaluation is the statistical analysis of that data to assess the extent to which the treatment (or a wider treatment program) has met crash reduction objectives. These tasks are important to ascertain the positive and negative effects of treatment and thus improve the accuracy and confidence of predictions of that treatment's effectiveness in subsequent applications. It may take a number of years to collect sufficient data.

c. Countermeasure selection and design

The aim of countermeasure development is to (Austroads, 2006):

- select countermeasures which have been demonstrated to be effective in reducing the incidence and/or severity of target crash types,
- check that adopted countermeasures do not have undesirable consequences, either in safety terms (e.g. lead to an increase in the number or severity of another crash type) or in traffic efficiency or environmental terms,
- be cost-effective (i.e. maximize the benefits from the whole program),
- be efficient (i.e. produce benefits which outweigh the costs).

There are several criteria for countermeasure selection, including (Ogden, 1996; Austroads, 2006):

- Technical feasibility: can the countermeasure provide an answer to the safety problems which have been diagnosed and does it have a technical basis for success?
- Economic efficiency: is the countermeasure likely to be cost-effective and will it produce benefits to exceed its costs?
- Affordability: can it be accommodated within the program budget; if not, should it be deferred, or should a cheaper, perhaps interim solution be adopted?
- Acceptability: does the countermeasure clearly target the identified problem and will it be readily understandable by the community?
- Practicability: is there likely to be a problem of non-compliance, or can the measure work without unreasonable enforcement effort?

- Political and institutional acceptability: is the countermeasure likely to attract political support and will it be supported by the organization responsible for its installation and ongoing management?
- Legal conformity: is the countermeasure a legal device, or will users be breaking any law by using it in the way intended?
- Compatibility: is the countermeasure compatible and consistent with other strategies, either in the same locality or which have been applied in similar situations elsewhere?

2.5 Crash and road data

Austroads (2006) explained that comprehensive and accurate crash and road data could enable

- crash locations to be accurately determined,
- events associated with crashes to be identified,
- identification of crash contribution and severity factors,
- identification of common factors across a number of crashes,
- all crashes at one location or several crashes with common factors to be identified,
- crash sites to be ranked.

In recent years, several technologies, especially the computer-based technology, have been developed and available for crash data collection. Some of them are, for example (Austroads, 2006):

- To improve the accuracy of location information

Global positioning systems (GPS) or satellite navigation systems are being used by most authorities for accurate determination of a crash location. The person attending the crash scene uses the system instead of, or as well as, documenting the location in traditional terms (e.g. ABC Road, xx meters N/S/E/W of XYZ Street). This method has great potential in rural areas where the recording of the distance and direction to identifiable features can be subject to significant error.

Most active authorities rather use a geographical information system (GIS) or digital mapping to record crash locations. This permits crash data to be incorporated within a relational database, allowing crash sites to be overlaid on plans showing other geographical information such as highway features, traffic flows, intersection layouts and land uses.

New technology makes the initial collection and assessment of safety-related data easier and more useful. As an example, in Main Roads Western Australia, the crash investigation team has recently begun using video to assist in fatal and serious crash investigations. The video camera used records of GPS information and has a viewer that overlays all route information on the video display. This assists in the completion of initial crash investigations.

- To improve the accuracy and completeness of crash data

Menu-driven crash data capture programs can be used with laptop computers or tablets by police attending a crash to ensure that all desired information is collected at the site. These programs can include in-built logic and consistency checks on the data as it is entered.

Crash report forms can be arranged so that the information can be scanned into the database, to minimize costs and to reduce the opportunity for coding errors.

However, there are some issues related to the limitations and accuracy of crash data, which include (Austroads, 2006):

- Under-reporting of crash data
- Systematic reporting bias
- Random reporting bias
- Subjective bias
- Reporting errors
- Coding errors
- Location errors
- Discontinuities over time
- Responding delays
- Masked or hidden problems

2.6 Accident costing in Thailand

From the literature, several studies have been conducted on the estimation of road accident costs in Thailand. However, a few studies have been used for the reference. The literature mentioned in this report is those mainly cited or referred by various official reports and studies.

Based on the human capital approach, DOH (2007) revealed that the economic losses per dead, seriously injured, slightly injured, and property damage crash were 5,315,556 Baht, 147,023 Baht, 34,761 Baht, and 45,898 Baht, respectively. These average unit costs can be summarized in Table 1.

Table 1. The average unit cost by severity

Severity	Average unit cost (Baht)	Ratio
Fatality*	5,315,556	152.92
Disability*	6,167,061	177.41
Serious injury*	147,023	4.23
Slight injury*	34,761	1.00
Property Damage Only (PDO)**	45,898	1.32

Note: * Baht per a casualty; ** Baht per a crash
Source: DOH (2007)

However, the costs estimated from the human capital approach were too low compared to other methods for accident costing and should be used as the minimum reference for the value of life (Haight, 1994). Recently, Ongkittikul and Jaensirisak (2018) applied the contingent valuation method to assess the traffic accident costs of the people in Saraburi province. It was found that the median values of death and serious injury were approximately 10 and 3 million baht, respectively. It can be implied that the unit cost per fatality is approximately 3.33 higher than the cost per a serious injury.

CHAPTER 3 METHODOLOGY

3.1 Research framework

The research framework can be summarized as illustrated in Figure 3. The details of each step are explained in the following sections.

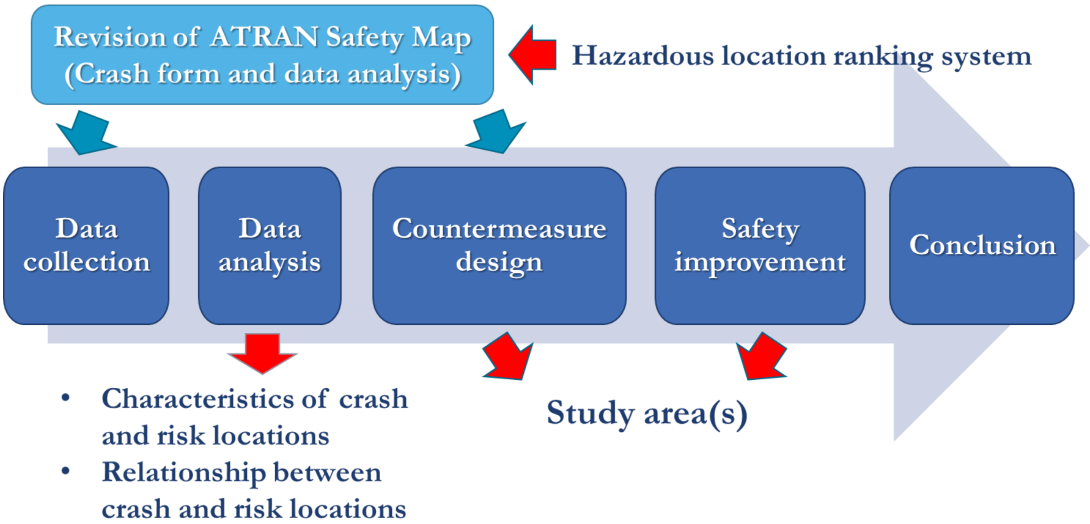


Figure 3. Research framework

3.2 Revision of ATRANS Safety Map application

The ATRANS Safety Map application developed in the previous research project had been revised in order to collect the common data of crash and risk locations as many as possible.

This research applied some features of the in-depth crash data collection form, recently developed by the Office of Transport and Traffic Policy and Planning (OTP, 2018).

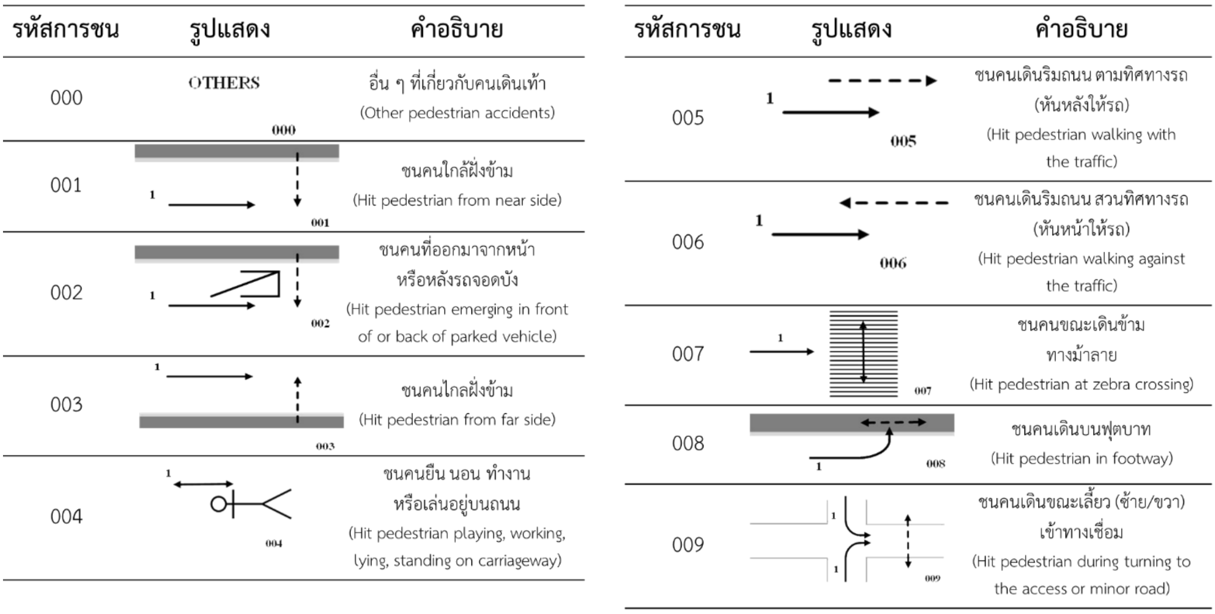
Some revisions of the online data collection form include:

- Crash data
    - Driver(s), rider(s), and victim(s)
        - The details of the gender and age of each casualty were considered.
    - Pedestrian(s)
        - The details of pedestrian(s), who is a vulnerable road user, were included.
    - Vehicle(s) involved
        - The motorcycle and big bike (engine higher than 400 cc.) were separated.
        - Private van and public van were classified into different groups.
        - Single-deck bus and double-deck bus were separated.
    - Road and environment data
        - Type of road was classified by its owner and function (expressway, DOH, DRR, urban road, local road, alley road, private road)
        - Crash location was identified based on the road locations, including
            - Midblock (straight, left-turning curve, right-turning curve, s-curve, sharp curve, broken back curve)
            - Intersection (T, Y, 4-leg, more than 4-leg, roundabout, rail-road at grade crossing)
            - U-turn (at midblock, at the intersection)
            - Pedestrian crossing (at midblock, at the intersection)
        - Details of vertical curved were considered (Level, downgrade, upgrade, top of the crest curve, bottom of the sag curve)
        - Road status (in normal service, renovation of the old road, construction for a new road)

- Road surface (concrete, asphaltic concrete, macadamized road, unpaved)
- A condition of the road surface (smooth, rough, slippery)
- Characteristic of the road surface (dry, moist, wet)
- Brightness during the night time (normal, no lighting)
- Weather (clear sky, sunny, windy, hot weather, cold weather, moisture air, dry air, light rain, torrential rain, smoke/dust, crash data)

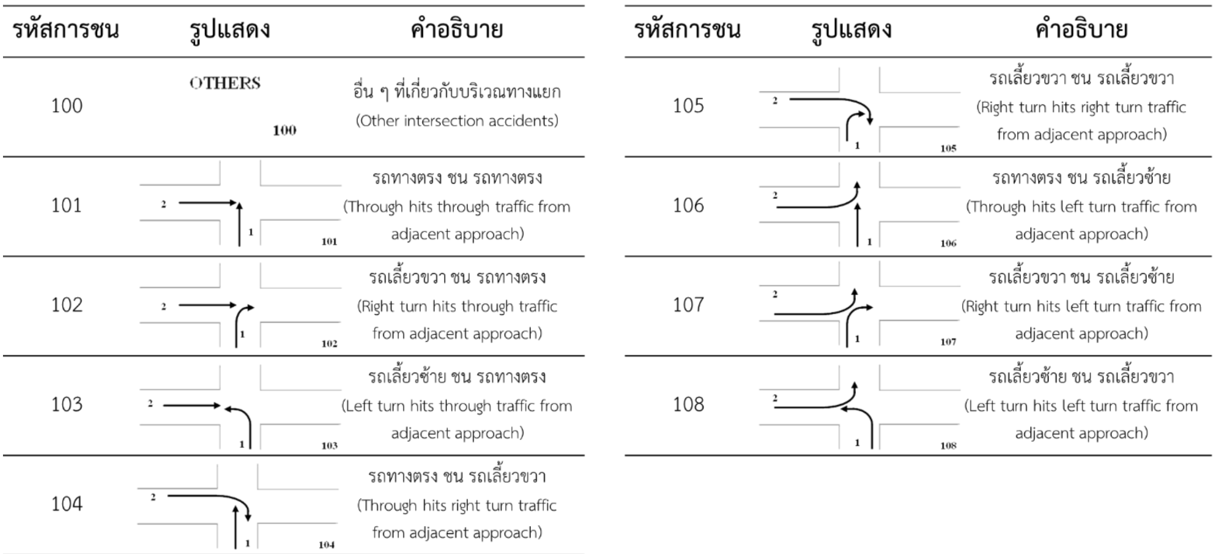
o Collision diagrams

- The collision diagrams were adapted from the DOH and the OTP (see OTP, 2018 for details). The summaries of collision diagrams for each crash type are illustrated from Figure 4 to Figure 13.



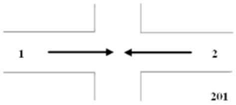
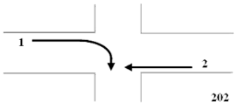
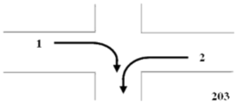
รหัสการชน	รูปแสดง	คำอธิบาย
000	OTHERS 000	อื่น ๆ ที่เกี่ยวกับคนเดินเท้า (Other pedestrian accidents)
001	1 001	ชนคนใกล้ฝั่งข้าม (Hit pedestrian from near side)
002	1 002	ชนคนที่ออกมาจากหน้าหรือหลังรถจอดบัง (Hit pedestrian emerging in front of or back of parked vehicle)
003	1 003	ชนคนไกลฝั่งข้าม (Hit pedestrian from far side)
004	1 004	ชนคนยืน นอน ทำงาน หรือเล่นอยู่บนถนน (Hit pedestrian playing, working, lying, standing on carriageway)
005	1 005	ชนคนเดินริมถนน ตามทิศทางรถ (หันหลังให้รถ) (Hit pedestrian walking with the traffic)
006	1 006	ชนคนเดินริมถนน สวนทิศทางรถ (หันหน้าให้รถ) (Hit pedestrian walking against the traffic)
007	1 007	ชนคนขณะเดินข้ามทางม้าลาย (Hit pedestrian at zebra crossing)
008	1 008	ชนคนเดินบนฟุตบาท (Hit pedestrian in footway)
009	1 1 009	ชนคนเดินขณะเลี้ยว (ซ้าย/ขวา) เข้าทางเชื่อม (Hit pedestrian during turning to the access or minor road)

Figure 4. Collision diagrams for pedestrain



รหัสการชน	รูปแสดง	คำอธิบาย
100	OTHERS 100	อื่น ๆ ที่เกี่ยวกับบริเวณทางแยก (Other intersection accidents)
101	2 1 101	รถทางตรง ชน รถทางตรง (Through hits through traffic from adjacent approach)
102	2 1 102	รถเลี้ยวขวา ชน รถทางตรง (Right turn hits through traffic from adjacent approach)
103	2 1 103	รถเลี้ยวซ้าย ชน รถทางตรง (Left turn hits through traffic from adjacent approach)
104	2 1 104	รถทางตรง ชน รถเลี้ยวขวา (Through hits right turn traffic from adjacent approach)
105	2 1 105	รถเลี้ยวขวา ชน รถเลี้ยวขวา (Right turn hits right turn traffic from adjacent approach)
106	2 1 106	รถทางตรง ชน รถเลี้ยวซ้าย (Through hits left turn traffic from adjacent approach)
107	2 1 107	รถเลี้ยวขวา ชน รถเลี้ยวซ้าย (Right turn hits left turn traffic from adjacent approach)
108	2 1 108	รถเลี้ยวซ้าย ชน รถเลี้ยวขวา (Left turn hits left turn traffic from adjacent approach)

Figure 5. Collision diagrams for the intersection vehicle from adjacent approaches

รหัสการชน	รูปแสดง	คำอธิบาย
200	OTHERS 200	อื่น ๆ ที่เกี่ยวกับการชนในทิศทางตรงข้าม บนถนนสายเดียวกัน (Other opposite direction accidents)
201		ชนประสานงา (Head on)
202		รถเลี้ยวขวาชนรถทางตรง บนถนนสายเดียวกัน (Right turn hits through traffic)
203		รถเลี้ยวขวาชนรถทางซ้าย บนถนนสายเดียวกัน (Right turn hits left turn traffic)

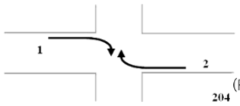
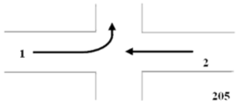
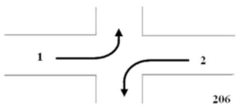
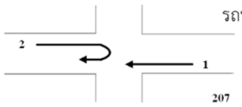
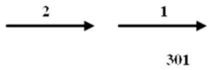
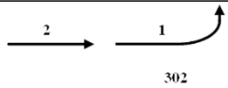
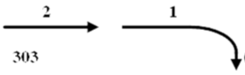
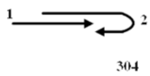
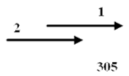
รหัสการชน	รูปแสดง	คำอธิบาย
204		รถเลี้ยวขวาชนรถทางขวา บนถนนสายเดียวกัน (Right turn hits right turn traffic)
205		รถเลี้ยวซ้ายชนรถทางตรง บนถนนสายเดียวกัน (Left turn hits through traffic)
206		รถเลี้ยวซ้ายชนรถทางซ้าย บนถนนสายเดียวกัน (Left turn hits left turn traffic)
207		รถทางตรงชนรถที่กำลังเลี้ยวกลับรถ บนถนนสายเดียวกัน (Through hits U-turn traffic)

Figure 6. Collision diagrams for the vehicle from the opposite direction

รหัสการชน	รูปแสดง	คำอธิบาย
300	OTHERS 300	อื่น ๆ ที่เกี่ยวกับการชนในทิศทางเดียวกัน (Other one direction accidents)
301		ชนท้าย (Rear end in the same lane)
302		ถูกชนท้ายขณะเลี้ยวซ้าย (Rear end during left turn)
303		ถูกชนท้ายขณะเลี้ยวขวา (Rear end during right turn)
304		ถูกชนท้ายขณะเลี้ยวกลับรถ (Rear end during U-turn)
305		รถที่วิ่งคู่กันมาเฉี่ยวชนกัน (Side swipe in parallel lane)

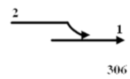
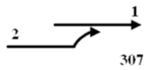
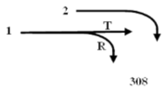
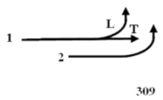
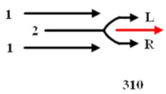
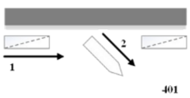
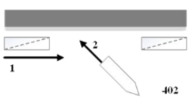
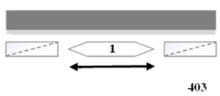
รหัสการชน	รูปแสดง	คำอธิบาย
306		ถูกชนจากกรณีที่เปลี่ยนช่องทางขวา (Hit by vehicle changing lane to the right)
307		ถูกชนจากกรณีที่เปลี่ยนช่องทางซ้าย (Hit by vehicle changing lane to the left)
308		รถทางตรง (หรือเลี้ยวขวา) ชนกับรถเลี้ยวขวา (จากทิศทางเดียวกัน) (Vehicle making through or right hit by another vehicle making right turn)
309		รถทางตรง (หรือเลี้ยวซ้าย) ชนกับรถเลี้ยวซ้าย (จากทิศทางเดียวกัน) (Vehicle making through or left hit by another vehicle making left turn)
310		ชนรถที่กำลังเปลี่ยนช่องจราจร (Hit vehicle pulling out)

Figure 7. Collision diagrams for the vehicle from one direction

รหัสการชน	รูปแสดง	คำอธิบาย
400	OTHERS 400	อื่น ๆ ที่เกี่ยวกับความบกพร่องของผู้ขับขี่ (Other maneuvering accidents)
401		ชนรถที่กำลังออกจากที่จอด (Hit with vehicle leaving the parking)
402		ชนรถที่กำลังจะเข้าที่จอด (Hit with vehicle entering the parking)
403		ชนรถจอดขณะเข้าทางจอด หรือจะออก (Hit during parking)

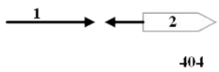
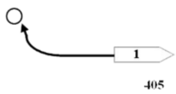
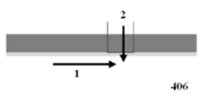
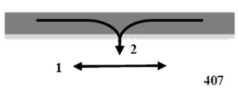
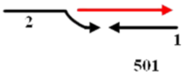
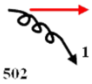
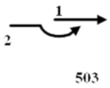
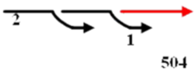
รหัสการชน	รูปแสดง	คำอธิบาย
404		ชนรถที่กำลังถอยหลัง (Hit with reversing vehicle)
405		ถอยหลังชนสิ่งกีดขวาง (Hit fixed object during reversing)
406		ชนรถที่กำลังออกจากทางเชื่อมถนนสายย่อย (Hit vehicle leaving driveway)
407		ชนรถที่กำลังลงมาจากทางเท้า (Hit vehicle from footway)

Figure 8. Collision diagrams for the mistake maneuvering

รหัสการชน	รูปแสดง	คำอธิบาย
500	OTHERS 500	อื่น ๆ ที่เกี่ยวกับการแซง (Other overtaking accidents)
501		ชนกับรถที่หักแซงขึ้นมาในทิศทางตรงข้าม (ประสานงา) (Head on with overtaking vehicle)
502		แซงขึ้นมาแล้วเสียหลักแฉลบออก (Out of control during overtaking)
503		แซงไม่พ้น หักชนรถที่ถูกแซง (Hit by overtaking vehicle during going straight)
504		เบียดแซงออกมาถูกรถที่วิ่งมาชน (Rear end by overtaking vehicle during pulling out)

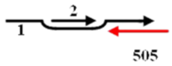
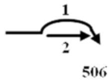
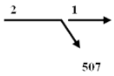
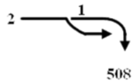
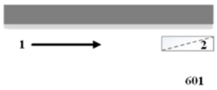
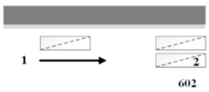
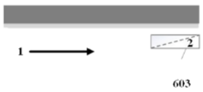
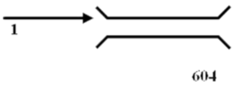
รหัสการชน	รูปแสดง	คำอธิบาย
505		ถูกชนเพราะหลบรถที่วิ่งทิศตรงข้าม (Rear end during cutting in)
506		ถูกชนเพราะแซงซ้ายแล้วเบียดเข้าช่องจราจร (Rear end during overtaking to the left)
507		ถูกรถที่กำลังแซงชนท้าย (Rear end by pulling out vehicle)
508		แซงขวาชนกับรถเลี้ยวขวา (Hit by overtaking vehicle during right turn)

Figure 9. Collision diagrams for the overtaking

รหัสการชน	รูปแสดง	คำอธิบาย
600	OTHERS 600	อื่น ๆ ที่เกี่ยวกับการบนทาง (Other on path accidents)
601		ชนรถที่จอดอยู่ (จอดคันเดียว) (Hit parked vehicle)
602		ชนรถที่จอดซ้อนคัน (Hit double parked vehicle)
603		ชนกับประตูที่เปิดอยู่ (Hit car door)
604		ชนสิ่งก่อสร้างถาวร เช่น สะพาน ราวเหล็ก (Hit permanent obstruction)

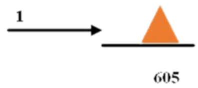
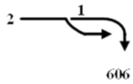
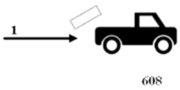
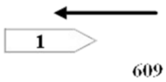
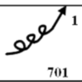
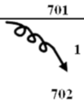
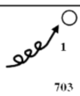
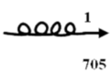
รหัสการชน	รูปแสดง	คำอธิบาย
605		ชนวัสดุงานทางหรือวัสดุอื่นซึ่งกองอยู่ชั่วคราว (Hit temporary roadwork or other objects)
606		ชนรถที่เกิดอุบัติเหตุหรือจอดเสียอยู่บนทาง (Hit broken down or accidents vehicle)
607		ชนสัตว์ (Hit the animal)
608		อุบัติเหตุจากสิ่งของบรรทุกตกหล่น หรือยื่นออกนอกตัวรถ (Hit the falling object from loading vehicle ahead)
609		ชนรถที่วิ่งสวนทางแบบผิดกฎหมาย (ย้อนศร) (Hit opposing vehicle driving illegally)

Figure 10. Collision diagrams for the crash on a path

รหัสการชน	รูปแสดง	คำอธิบาย
700	OTHERS 700	อื่น ๆ ที่เกี่ยวกับนอกทางบนทางตรง (Other off carriageway accidents on the straight)
701		เสียหลักตกถนนทางด้านซ้าย (Off carriageway to the left)
702		เสียหลักตกถนนทางด้านขวา (Off carriageway to the right)
703		เสียหลักตกถนนทางด้านซ้าย ชนถาวรวัตถุ (Off carriageway to the left and hit the fixed object)
704		เสียหลักตกถนนทางด้านขวา ชนถาวรวัตถุ (Off carriageway to the right and hit the fixed object)
705		เสียหลัก ไปอยู่ในช่องจราจรอื่น ๆ (Out of control on carriageway)

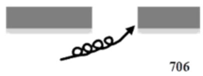
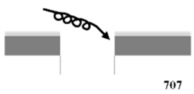
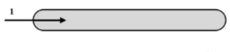
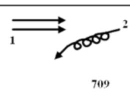
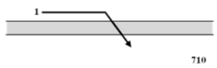
รหัสการชน	รูปแสดง	คำอธิบาย
706		แฉลบเสียหลักตกถนนบนทางตรงขณะเลี้ยวซ้ายเข้าทางเชื่อม (Off carriageway at the access on left side during left turn)
707		แฉลบเสียหลักตกถนนบนทางตรง ขณะเลี้ยวขวาเข้าทางเชื่อม (Off carriageway at the access on left side during right turn)
708		ชนเกาะกลางถนน รวมถึงเสาไฟ ฯลฯ (Mounts the traffic island)
709		เสียหลักตกถนนเนื่องจากหลบรถในทิศทางตรงข้ามวิ่งคู่กันมา (Off carriageway due to opposing traffic)
710		เสียหลักแล้วปีนข้ามเกาะกลางถนน (Off carriageway and across median)

Figure 11. Collision diagrams for the crash off the path on a straight section

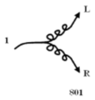
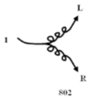
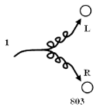
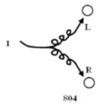
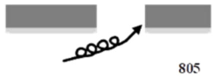
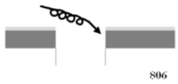
รหัสการชน	รูปแสดง	คำอธิบาย
800	OTHERS 800	อื่น ๆ ที่เกี่ยวกับนอกทางบนทางโค้ง (Other off carriageway accidents on the bend)
801		เสียหลักตกถนน ขณะวิ่งบนทางโค้งขวา (Off carriageway during on the right bend)
802		เสียหลักตกถนน ขณะวิ่งบนทางโค้งซ้าย (Off carriageway during on the left bend)
803		เสียหลักตกถนนขณะวิ่งบนทางโค้งขวา ชนเสาไฟ ต้นไม้ ฯลฯ (Off carriageway and hit the fixed object during on the right bend)
804		เสียหลักตกถนนขณะวิ่งบนทางโค้งซ้าย ชนเสาไฟ ต้นไม้ ฯลฯ (Off carriageway and hit the fixed object during on the left bend)
805		แฉลบเสียหลักตกถนนบนทางโค้งซ้าย ขณะเลี้ยวซ้ายเข้าทางเชื่อม (Off carriageway at the access on the left bend during left turn)
806		แฉลบเสียหลักตกถนนบนทางโค้งขวา ขณะเลี้ยวขวาเข้าทางเชื่อม (Off carriageway at the access on the left bend during right turn)

Figure 12. Collision diagrams for the crash off the path on the curve section

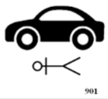
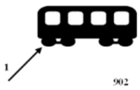
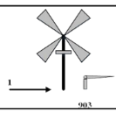
รหัสการชน	รูปแสดง	คำอธิบาย
900	OTHERS 900	อื่น ๆ ที่นอกเหนือจากข้างต้น (Other passenger and miscellaneous accidents)
901		ตกจากรถ (Fall in/from vehicle)
902		ชนรถไฟ (Hit train)
903		ชนประตูกั้นทางข้ามรถไฟ (Hit railway crossing furniture)
904	VEHICLE MOVEMENTS NOT KNOWN 904	ไม่มีรายละเอียด (Vehicle movement not known)

Figure 13. Collision diagrams for the others

3.3 Development of hazardous location ranking system

The algorithm for hazardous location ranking was developed based on the cost of crash and risk locations. In this research, the economic loss of any location can be estimated using Equation 1.

$$\textit{Economic loss} = a(\textit{Fatalities}) + b(\textit{Disabilities}) + c(\textit{Serious injuries}) + d(\textit{Slight injuries}) + e(\textit{Non-injuries}) + f(\textit{Risk locations}) \qquad \text{Equation 1}$$

where *a* is the economic loss per fatality,
b is the economic loss per disability,
c is the economic loss per serious injury,
d is the economic loss per slight injury,
e is the economic loss per non-injury,
f is the economic loss per risk location.

In Equation 1, *a*, *b*, *c,* and *d* are the unit cost per a casualty classified by the severity. *e* is the loss for each uninjured person (e.g. driver, rider, or passenger). In this study, *e* is assumed to be the time lost during a crash, which is approximately 1 hour. In addition, the minimum salary (300 baht per day) is used to estimate the value of *e*. *f* is the cost for a risk location. In this study, it is assumed that if any crash occurs at a risk location it would result in the property damage only cost.

In this research, the unit costs of each casualty and each risk location, presented in Equation 1, were estimated using the studies of DOH (2007) and Ongkittikul and Jaensirisak (2018) and can be summarized in Table 2. However, these unit costs should be revised in future research.

Table 2. The unit cost of each casualty and risk location

Severity	Unit cost in the year of					
	2017	2018	2019	2020	2021	2022
Fatality (a)	10,000,000*	10,250,000	10,506,250	10,768,906	11,038,129	11,314,082
Disability (b)	11,601,911**	11,891,959	12,189,258	12,493,990	12,806,339	13,126,498
Serious injury (c)	3,000,000*	3,075,000	3,151,875	3,230,672	3,311,439	3,394,225
Slight injury(d)	65,395**	67,030	68,705	70,423	72,184	73,988
Non-injury (e)***	-	119	122	125	128	131
Risk location (f)****	86,347	88,505	90,718	92,986	95,310	97,693

Notes: * The costs per a fatality and a serious injury were obtained from Ongkittikul and Jaensirisak (2018)
** The costs per disability and a slight injury were estimated using the costs from of Ongkittikul and Jaensirisak (2018) with the cost proportion from DOH (2007).
*** The cost per non-injury was estimated from the lost time (approximately 1 hour) and the minimum salary (300 Baht/day)
***** The cost per risk location was assumed to be the property damage only cost

From Equation 1 and Table 2, the total cost for any location is the summation of the casualty costs (i.e. fatalities, disabilities, serious injuries, slight injuries), the non-injury costs (e.g. drivers, riders, passengers) and the estimated cost of the risk at that location. The total costs of different locations in the study will be ranked. Therefore, any location with the highest total cost will be identified as the top hazardous location.

The above concept was applied to develop the hazardous location ranking system embed in the ATRANS Safety Map application. The marker clustering technique (Google Developers, 2018) was also applied to group the losses of some crash locations and risk locations in a specific area (cluster). This method uses the grid-based clustering technique that divides the map into squares of a certain size (the size changes at each zoom level), and groups the markers into each square grid. It creates a cluster at a particular marker (i.e. crash location or risk location) and adds markers that are in its bounds to the cluster. It repeats this process until all markers are allocated to the closest grid-based marker clusters based on the map's zoom level. If markers are in the bounds of more than one existing cluster, the Maps JavaScript API determines the marker's distance from each cluster and adds it to the closest cluster. As the results, the user interface of a hazardous location ranking system can be illustrated in Figure 14.

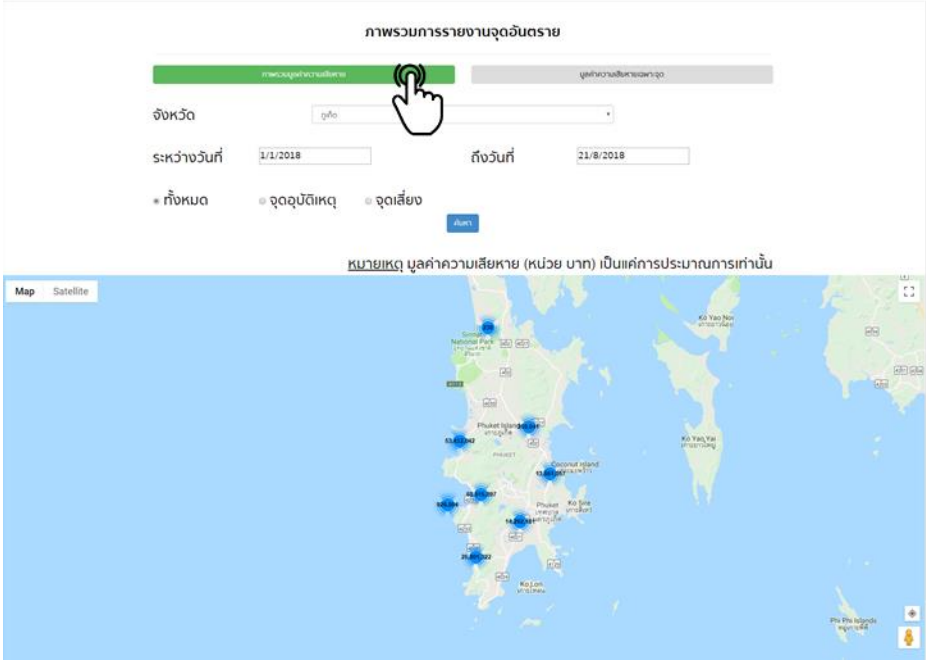


Figure 14. The user interface of hazardous location ranking system

3.4 Data collection

The data of crash and risk locations were collected, using the revised version of ATRANS Safety Map application, by users (i.e. police and rescue teams report for the crash data when communities report for the risk location data) in the study areas in the previous research project. In addition, some workshops were conducted in order to increase the number of users.

The first workshop was conducted on 8th May 2018. Over 40 road safety personals from the Department of Disaster Prevention and Mitigation (DDPM) in Songkhla, Trang and Phatthalung attended the workshop as shown in Figure 15.


Figure 15. The workshop in Songkhla province

On 11th May 2018, the second workshop was conducted in the Thaluang Cementhaianusorn Technical College, Saraburi province. More than 1,200 first-year students attended the workshop as shown in Figure 16.

Figure 16. The workshop in Saraburi province

The research team visited Ban Don Municipality, Suphanburi province and demonstrated the application to approximately 40 community representatives and government personals as shown in Figure 17.

Figure 17. Application Demonstration in Suphanburi province

Apart from the above workshops, the exhibition booth of ATRANS Safety Map was showed during the PSU Engineering open week (10-19 August 2018). Over 200 persons visited the booth and used the application. Some photos during the activity are presented in Figure 18.

On 31st July 2018, the project team visited the Phuket Provincial Police Office in order to follow up the data collection since the last research project and discussed the potential hazardous location found in the application. Approximately 50 police personals and partner road safety staffs attended the meeting as illustrated in Figure 19.

Figure 18. ATRANS Safety Map during PSU Engineering open week

Figure 19. The meeting in Phuket Provincial Police Office

3.5 Data analysis

The data obtained from the previous step have been analyzed in several aspects, which include

- characteristics of crash location and risk location,
- a relationship between the crash location and the risk location,
- contributing factors affecting the crash and severity,
- identification of hazardous locations.

a. Characteristics of crash location and risk location

The characteristics of crash location and risk location were mainly analyzed from the data collected in the application using common descriptive statistic, e.g. frequency, mean.

b. Relationship between the crash location and the risk location

Prior to investigating the relationship between the crash location and the risk location, both locations were verified whether they are the same location or in the same cluster area.

c. Contributing factors affecting crash and severity

In general results, contributing factors affecting to crash and severity of the crash and risk locations collected have been investigated using regression analysis techniques. The Haversine formula (Inman, 1835) was applied to calculate the distance between those two locations.

The Haversine formula is a very accurate way for computing the distance between two points on the surface of a sphere using the latitude and longitude of the two points. The Haversine formula is a re-formulation of the spherical law of cosines, but the formulation in terms of Haversines is more useful for small angles and distances. This technique has been widely used in the GPS application of Google Map has applied the theory to calculate the distance of the position within the map system (for the details see ESRI, 2017 and Movable Type Ltd.). The following equations were applied in this research.

$$\Delta lat = lat_2 - lat_1$$

$$\Delta long = long_2 - long_1$$

$$a = \sin^2\left(\frac{\Delta lat}{2}\right) + \cos(lat_1)\cos(lat_2)\sin^2\left(\frac{\Delta long}{2}\right)$$

$$c = 2a\tan 2\left(\sqrt{a}, \sqrt{(1-a)}\right)$$

$$d = rc$$

where

lat_1	is the latitude of location 1
lat_2	is the latitude of location 2
$long_1$	is the longitude of location 1
$long_2$	is the longitude of location 2
Δlat	is the difference of latitude
$\Delta long$	is the difference of longitude
r	is earth's radius (mean radius = 6,371km)
d	is the distance

d. Identification of hazardous locations

The hazardous location in the study areas (e.g., Phuket, Songkhla) were identified using the hazardous location ranking system developed in this research (described in Section 3.3). The top three locations were then selected to investigate the risk issues and the contributing factors leading to the crashes in each location. Potential risk treatments and safety measures were also recommended.

3.6 Countermeasure design

The hazardous locations found in the study areas have been investigated using both crash data from the developed application and at scene data collections (e.g. traffic volume, speed, and geometry data). The results from the investigation will be used to design the road safety measures for each hazardous location. Focus group meeting in the study area has been conducted to discuss in the potential countermeasures. Finally, the potential safety improvement programs (e.g. shortlist, preliminary designs) will be recommended to the concerned authorities in the study areas.

3.7 Safety improvement

For any potential area, the safety improvement programs obtained from the previous step will be implemented in the study areas.

3.8 Conclusion

Some significant findings from the study areas were concluded and highlighted. Recommendations for safety improvement and future research were also be mentioned.

CHAPTER 4 RESULTS

4.1 Results of crash and risk locations data

a. Characteristics of crash data in general

From the database, there were a total of 1,135 crashes and 2,748 road victims reported using the application between April 1, 2017, and January 31, 2019. Figure 20 shows that more than a half of the crashes (68%) were reported from Phuket, followed by Songkhla (21%), Suphanburi (5%), Bangkok (1%) and the other provinces (5%).

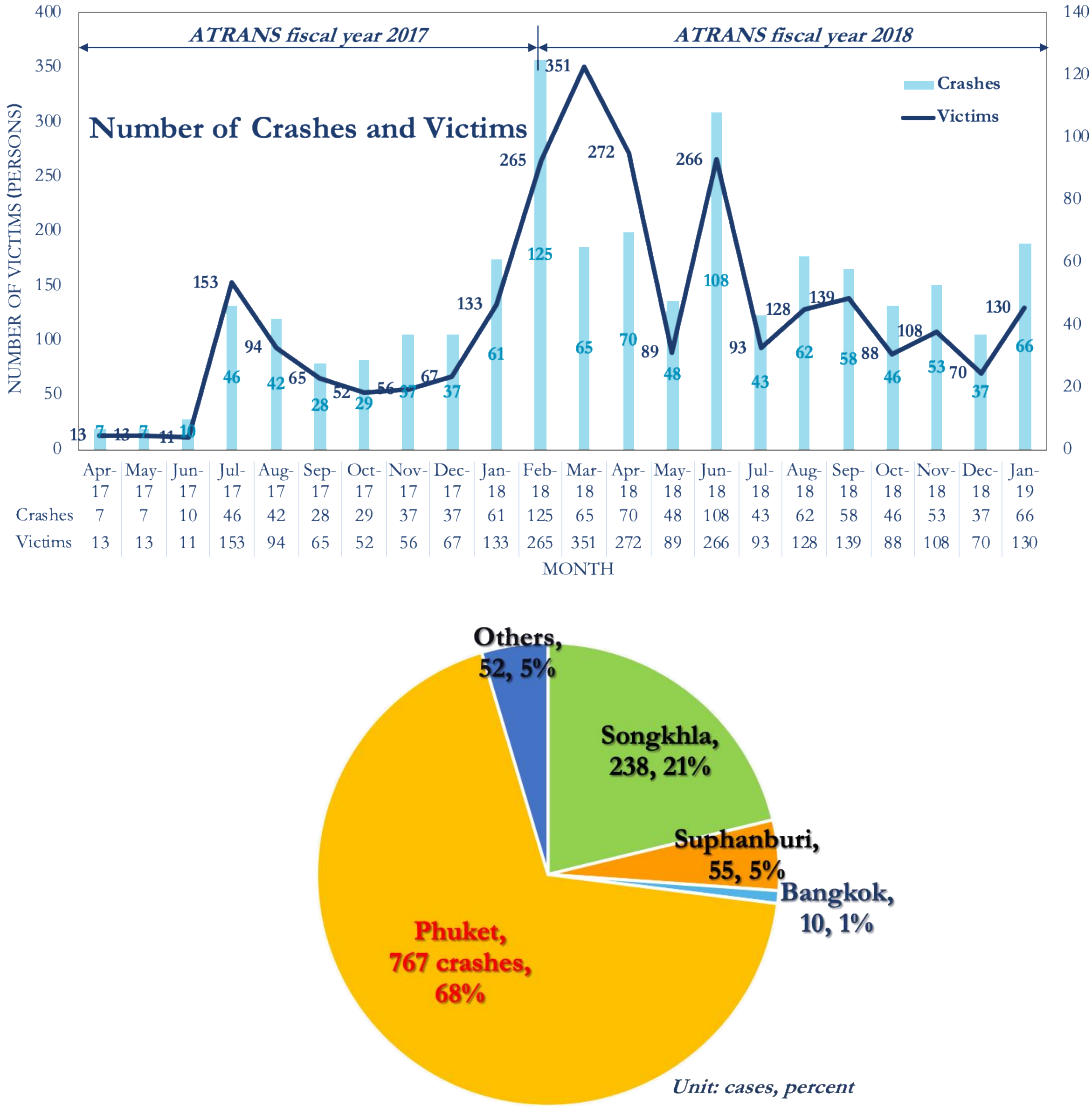


Figure 20. Number of crashes and victims reported in the database

The 1,135 crashes reported in the system resulted in a total of 2,748 road victims and 1,984 vehicles involved. Figure 21 shows that among 2,748 road victims, most of them (45%) were slightly injured, followed by no injured (29%) and seriously injured (18%) and died 8%.

Figure 22 shows that from 1,984 vehicles the top three vehicle types were a motorcycle (49.5%), passenger car (21.6%), and pickup (13.1%), respectively. From this result, it can imply that about half of the vehicles involved the crashes were related to vulnerable road users (motorcyclist).

Figure 23 shows the percentage of crashes classified by day of the week. It was found that a number of crashes occurred on each day are almost the same. However, the crashes frequently occurred on Monday and Friday (17% each). Regarding the time of the crashes occurred, Figure 24 illustrates that the crashes often occurred during 15:01-18:00 (3:01-6:00 pm).

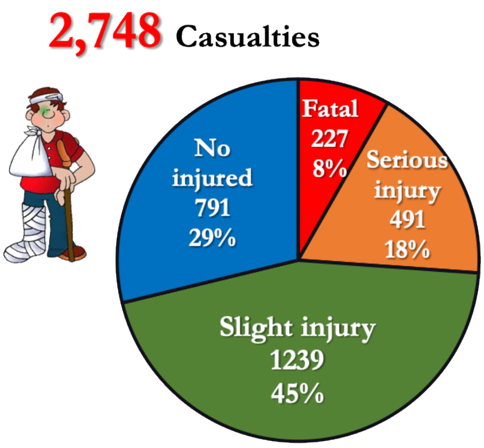


Figure 21. Percentage of road victims classified by injury type

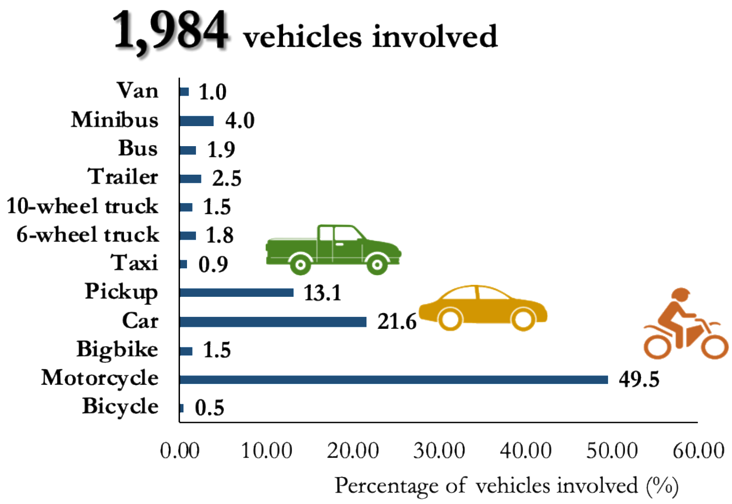


Figure 22. Percentage of vehicles classified by vehicle type

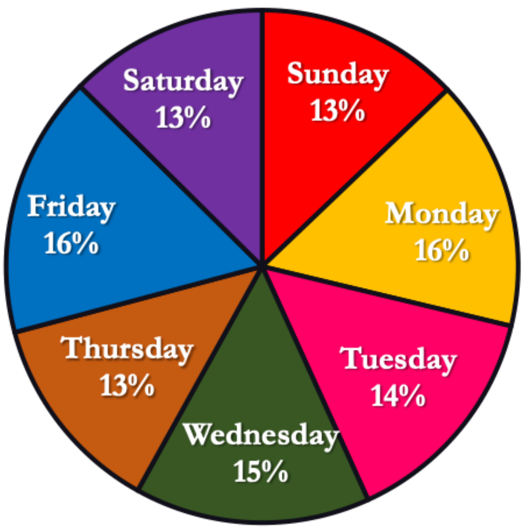


Figure 23. Percentage of crashes classified by day of the week

Figure 25 shows that approximately 56% of the crashes happened along the road sections (midblock), 40% were at the junctions, and 4% were at the U-turn. Regarding the crashes occurred along the road sections, approximately 67% were on the straight sections, 33% on the curves which include left-turning curves, right turning curves, s curves, sharp curves, and broken back curves. For the crashes occurred at the junctions, most of them were found at the T-leg intersections (approximately 48%) following by 4-leg intersections (29%), Y-leg intersections (16%), and roundabout (7%), respectively. Regarding the crashes occurred at the U-turns (4.4%), 60% of them were along the midblock sections when 40% were at the intersections.

Regards road characteristics, Figure 26 shows the details of different characteristics of road geometry related to crash locations.

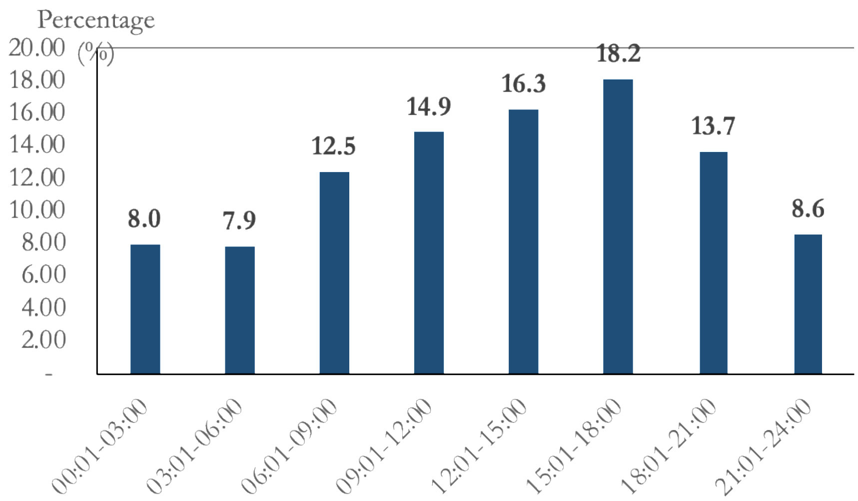


Figure 24. Percentage of crashes classified by time of day

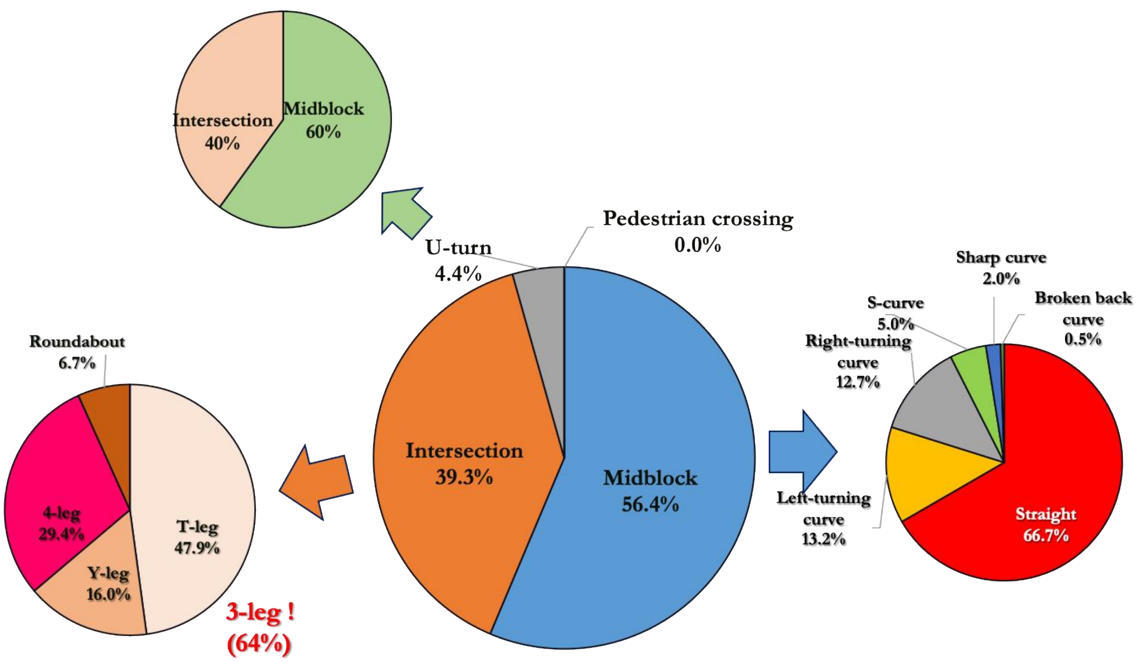


Figure 25. Crash locations classified by type of road section

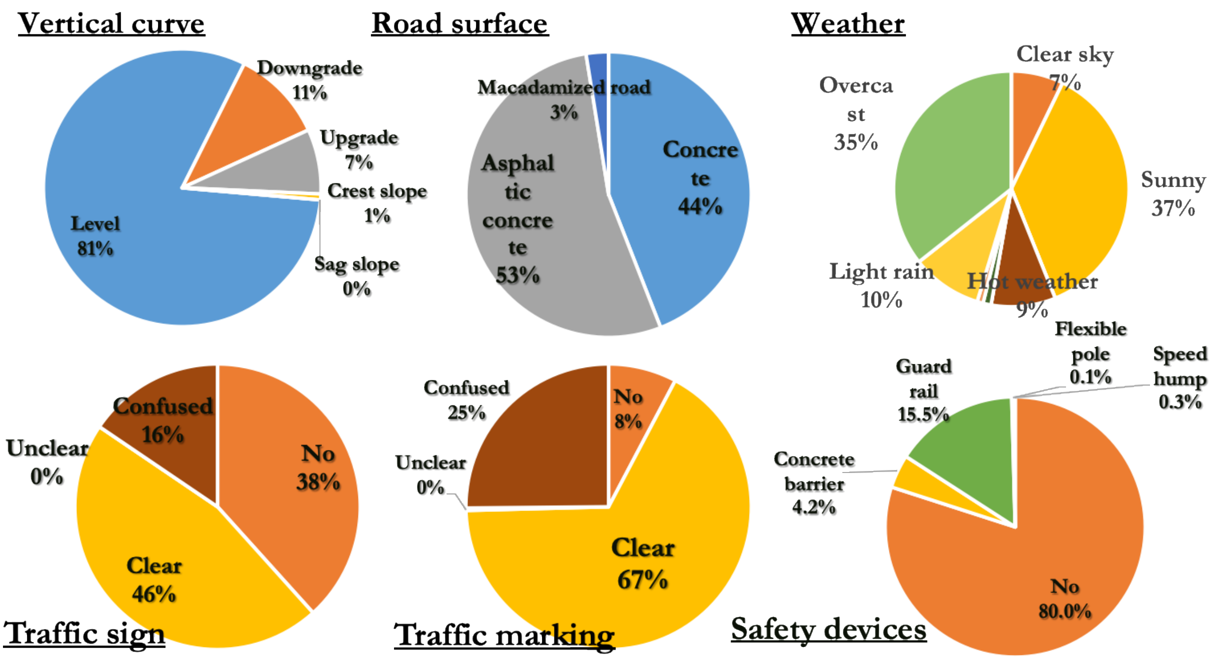


Figure 26. Crash locations classified by type of road characteristics

b. Characteristics of crash data in Phuket

Apart from the results of crash locations mentioned above, the data of crashes in Phuket were also analyzed. From the database, there were a total of 767 crashes and 1,392 road victims reported between April 1, 2017, and January 31, 2019.

Figure 27 shows that among 1,392 road victims, 724 (52%) were slightly injured, followed by no injured 498 (36%) and seriously injured 114 (8%) and died 56 (4%), respectively.

Note that the number of casualties recorded in the database has encountered with under-reporting issue. Figure 28 shows the data comparison between the ATRANS safety map and Thai RSC system (insurance database). It was found that the number of crashes, fatalities, and injuries reported in the safety map were about 5%, 36%, and 5%, respectively, of those reported in the insurance database (Thai RSC system).

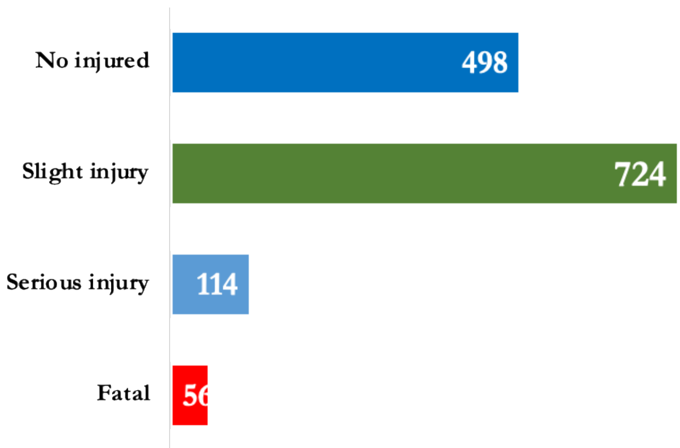
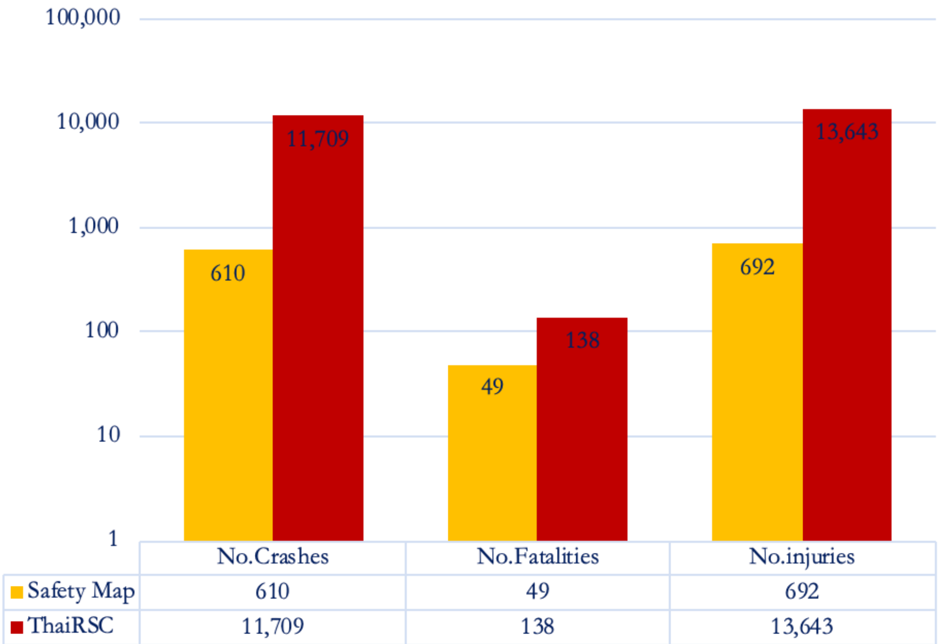


Figure 27. Percentage of road victims in Phuket classified by injury type



	No.Crashes	No.Fatalities	No.injuries
Safety Map	610	49	692
ThaiRSC	11,709	138	13,643

Note: 1) Focused on the crash data in Phuket.
2) The data obtained from ThaiRSC website (insurance) during 1 April 2017 – 31 October 2018.

Figure 28. Under-reporting issue

Figure 29 shows that from 1,041 vehicles involved the top three vehicle types were a motorcycle (57.0%), passenger car (19.9%), and pickup (8.4%), respectively. It was also noted that big bike significantly involved in the crashes (i.e. 2.2%).

Figure 30 shows the percentage of crashes classified by day of the week. It was found that a number of crashes occurred on each day are almost the same. However, the crashes frequently occurred on Friday (17%). Regarding the time of the crashes occurred, Figure 31 illustrates that the crashes often occurred during 12:01-15:00 (12:01-3:00 pm).

Regarding the road section involved, Figure 32 shows that approximately 58% of the crashes happened along the road sections (midblock), 40% were at the junctions, and 2% were at the U-turn. Regarding the crashes occurred along the midblock, 64% were on the straight sections, 36% on the curves. For the crashes occurred at the junctions, most of them were found at the T-leg intersections (54%) following by 4-leg intersections (25%), Y-leg intersections (17%), and roundabout (4%), respectively. Regarding the crashes occurred at the U-turns (4.4%), 73% of them were along the midblock sections when 27% were at the intersections.

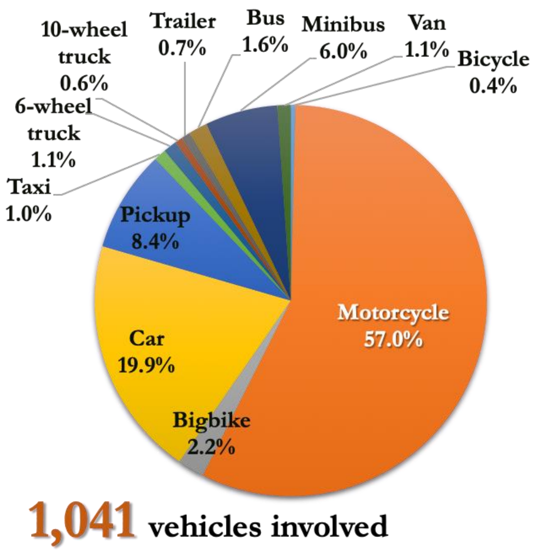


Figure 29. Percentage of vehicles involved in Phuket classified by vehicle type

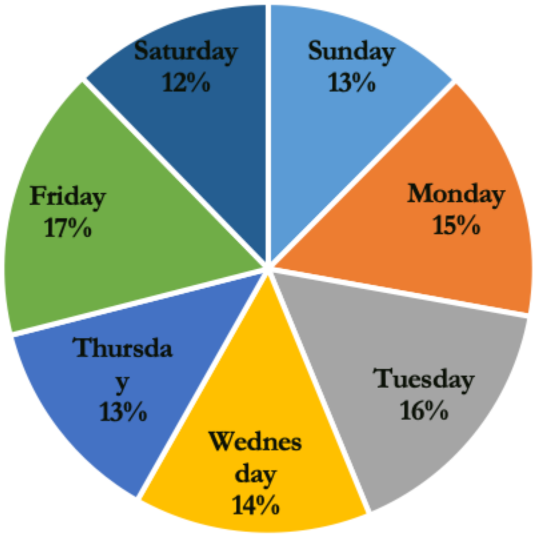


Figure 30. Percentage of crashes in Phuket classified by day of the week

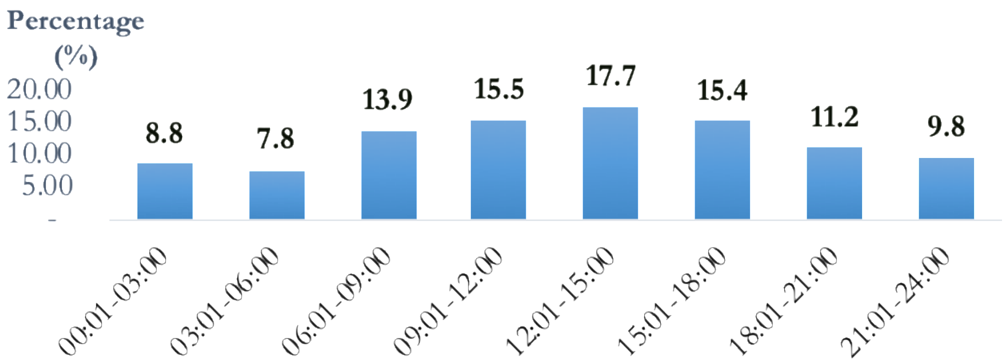


Figure 31. Percentage of crashes in Phuket classified by time of day

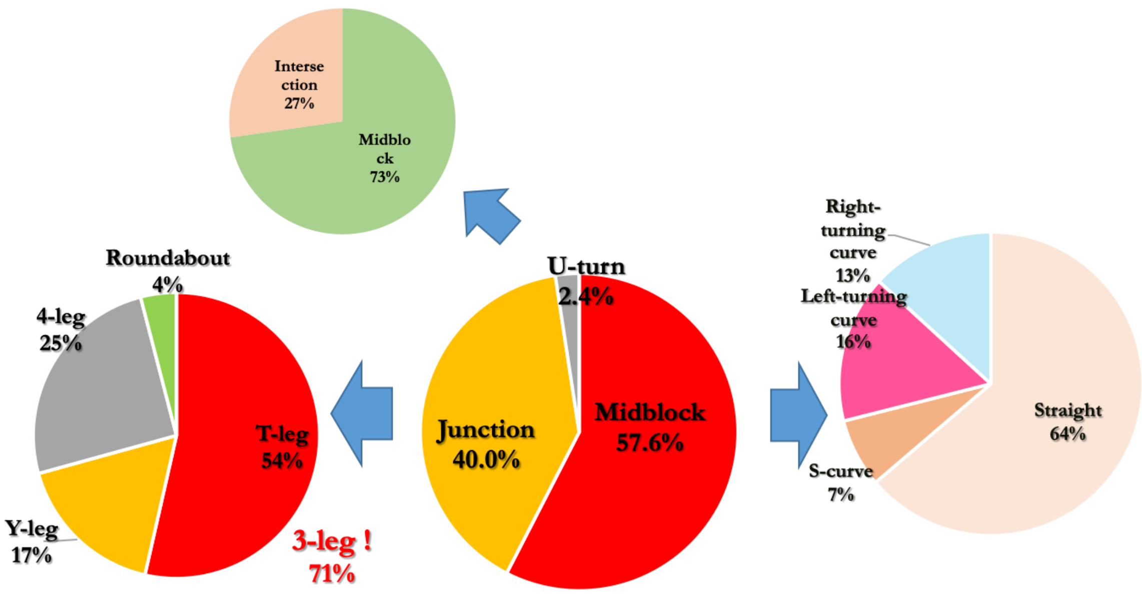


Figure 32. Crash locations classified by type of road section

Regards road characteristics, Figure 33 shows the details of different characteristics of road geometry related to crash locations.

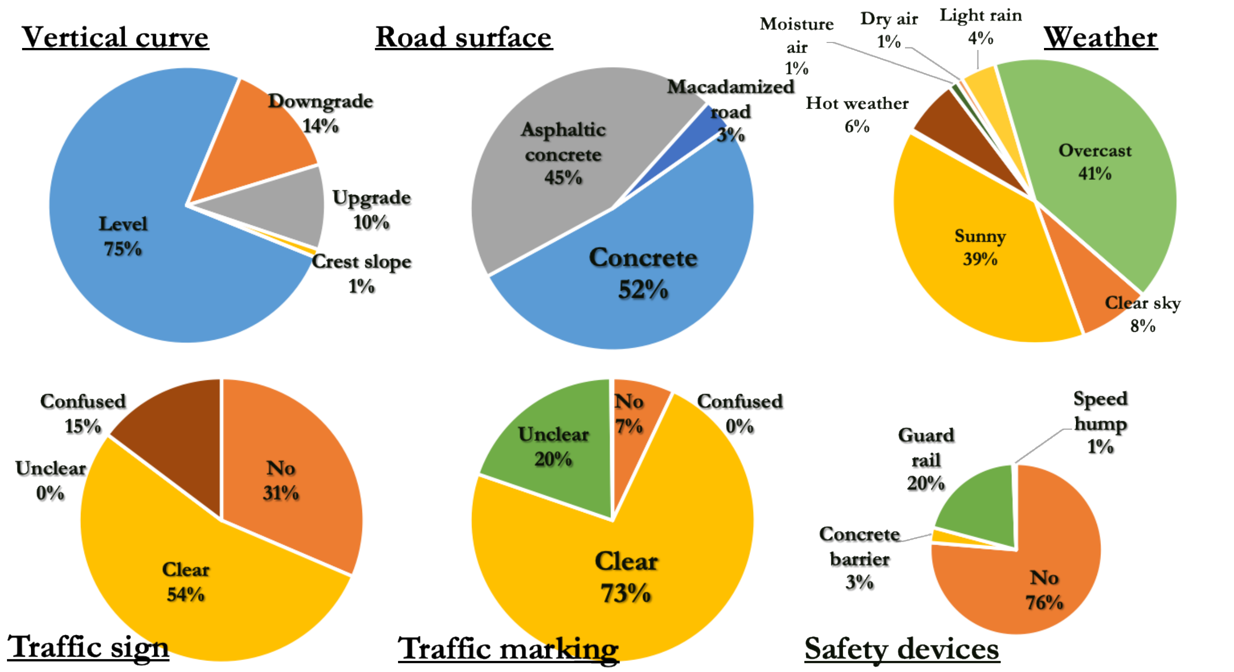


Figure 33. Crash locations in Phuket classified by road characteristics

Considering motorcycle crashes in Phuket, 628 crashes were reported. Figure 34 shows that those 628 crashes can be classified into 198 single motorcycle crashes (32%), 66 multiple motorcycles crashes (10%) and 364 motorcycle with other crashes (58%). From the figure, most crashes were a motorcycle with others, resulting in 72 riders died (10%). Similar to the single motorcycle crashes, 24 riders died (10%). However, for the multiple motorcycles crashes (10%), only 1.5% died.

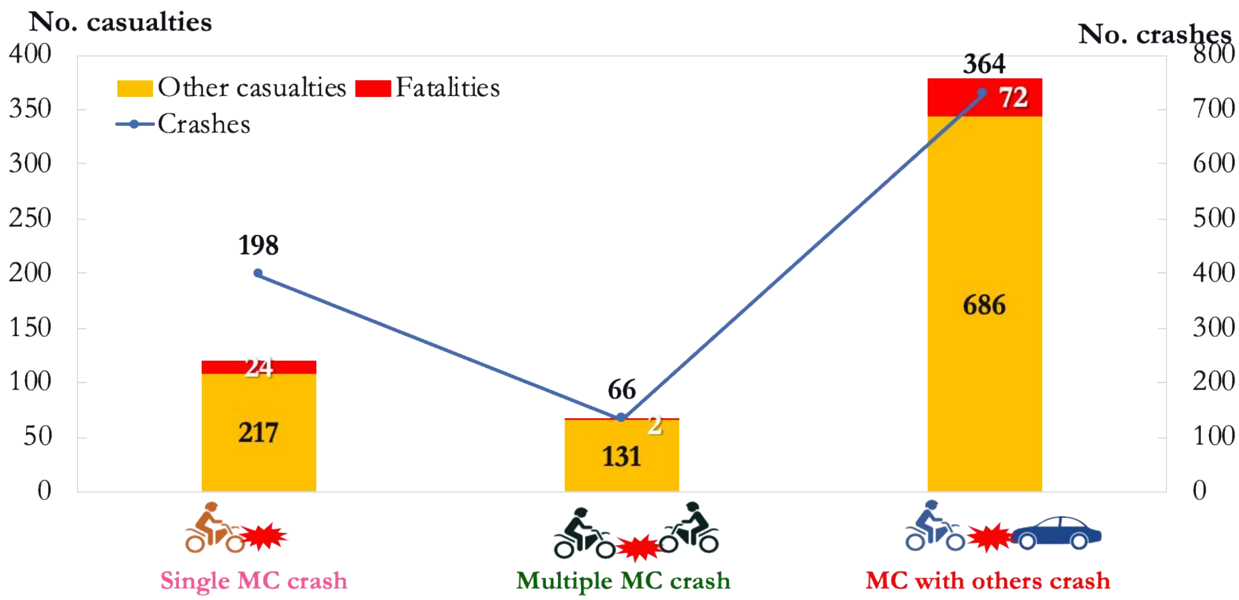


Figure 34. Motorcycle crashes in Phuket

Regarding victims from motorcycle crashes as shown in Figure 35, for the case of multiple motorcycle crashes, most victims were slightly injured (73%) and non injured (20%). Only 7% were seriously injured and 0.5% died. For the case of single motorcycle crashes and motorcycle with others crashes, the patterns are quite similar (i.e. slight injuries > no injuries > serious injuries > deaths, respectively)

For the day and time of the motorcycle crashes occurred, Figure 36 shows that the percentages of the day that crashes occurred are similar. However, for the time, they were slightly different. For the case of single motorcycle crashes, they frequently happened during 9 am – 12 pm when multiple motorcycle crashes occurred during 6 am – 9 am, and 12 pm – 15 pm for the case of motorcycle with others.

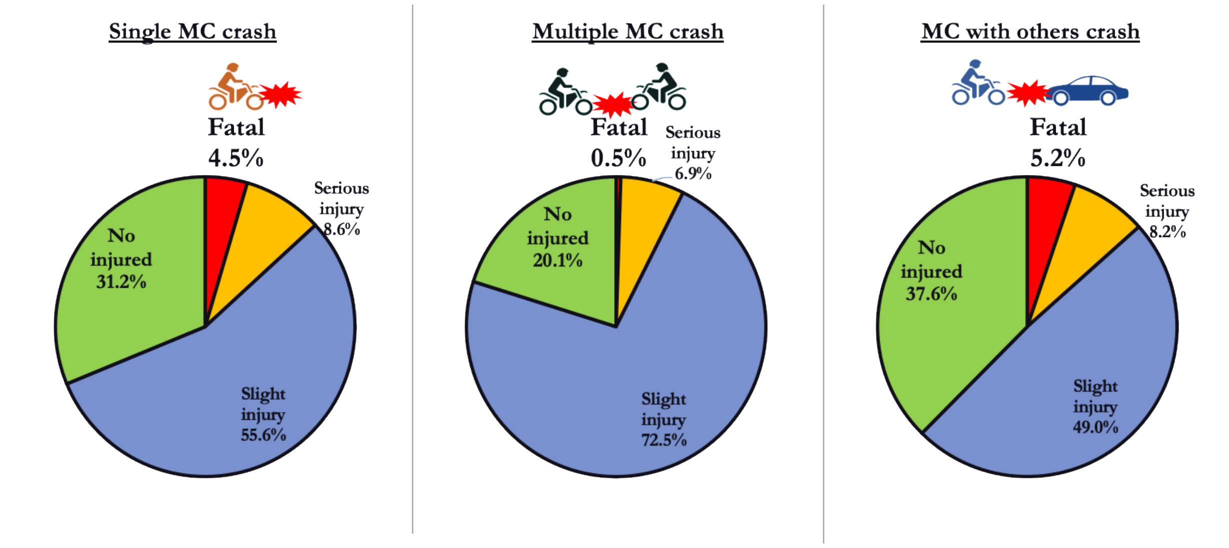


Figure 35. Victims from motorcycle crashes in Phuket

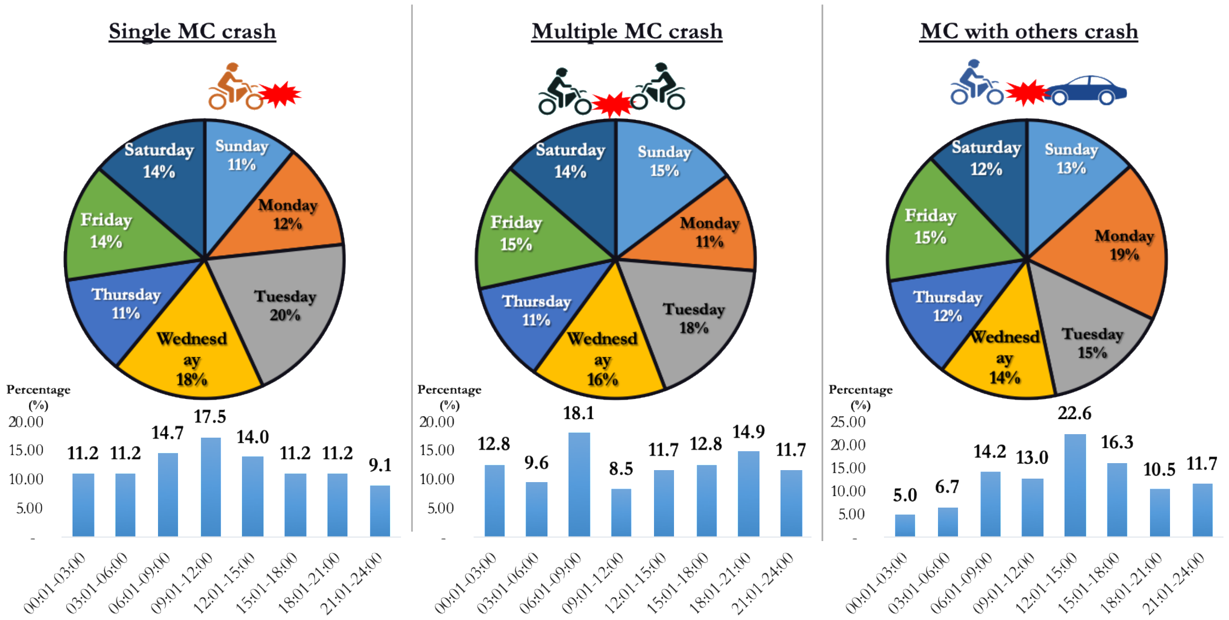


Figure 36. Day and time of motorcycle crashes occurred

Figure 37 shows the road sections involved motorcycle crashes. It was found that most of them (i.e. 75% of single motorcycle crashes and 51% of the motorcycle with other crashes) occurred along the midblock section, especially on a straight section. This may lead to speeding and consequently cause high severity for these two cases. These results conform to the details of road sections involved the motorcycle crashes as presented in Figure 38. Regarding the crashes occurred along the midblock, most crashes happened on the straight section. On the other hand, for the intersection, the portion of the locations for the case of multiple motorcycle and motorcycle with others are in a similar manner. However, there was no crash at the roundabout for a single motorcycle case.

Apart from the above results, the data collected in the safety map system can be used to investigate the road characteristics involved the motorcycle crashes (Figure 39), traffic facilities of the road involved (Figure 40), and environment of the crashes (Figure 41).

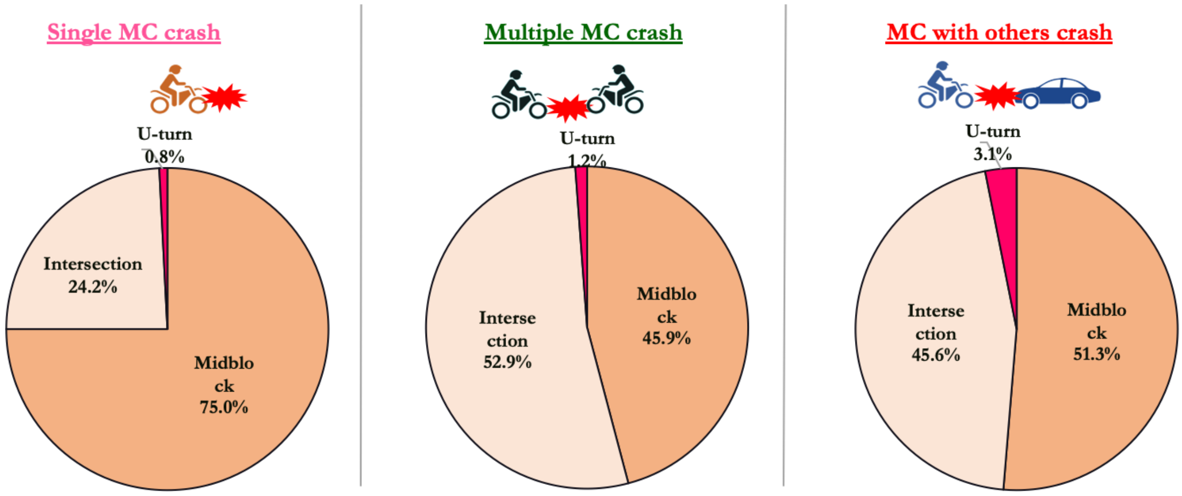


Figure 37. Road sections involved the motorcycle crashes

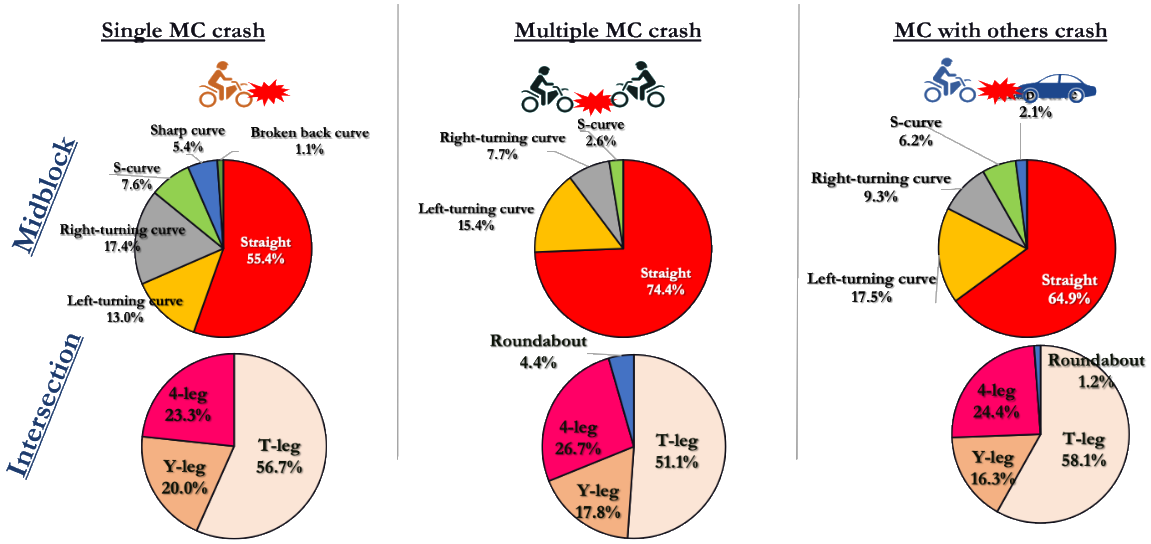


Figure 38. Details of road sections involved the motorcycle crashes

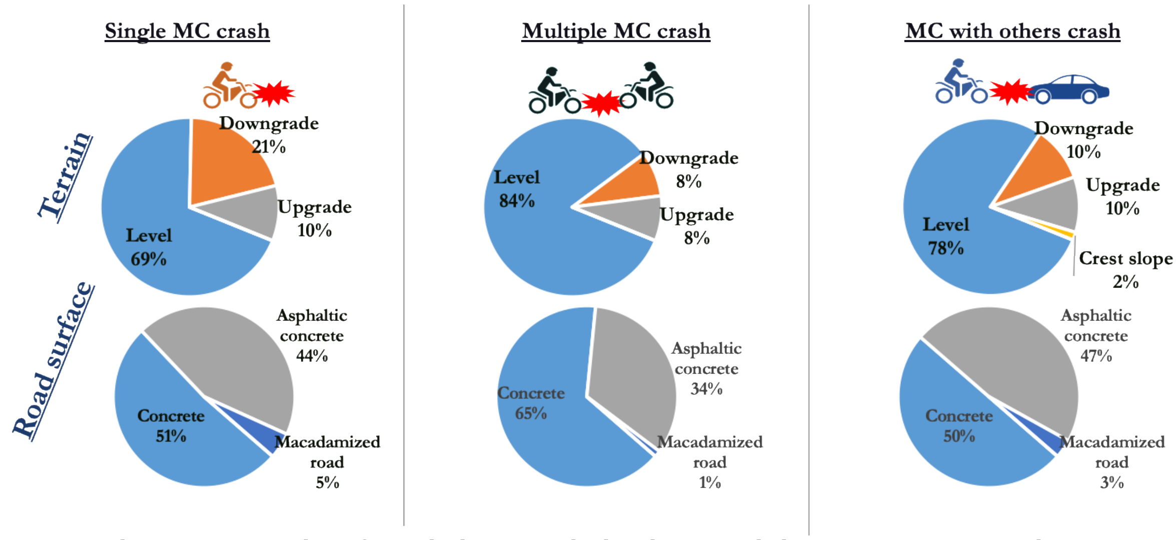


Figure 39. Details of road characteristics involved the motorcycle crashes

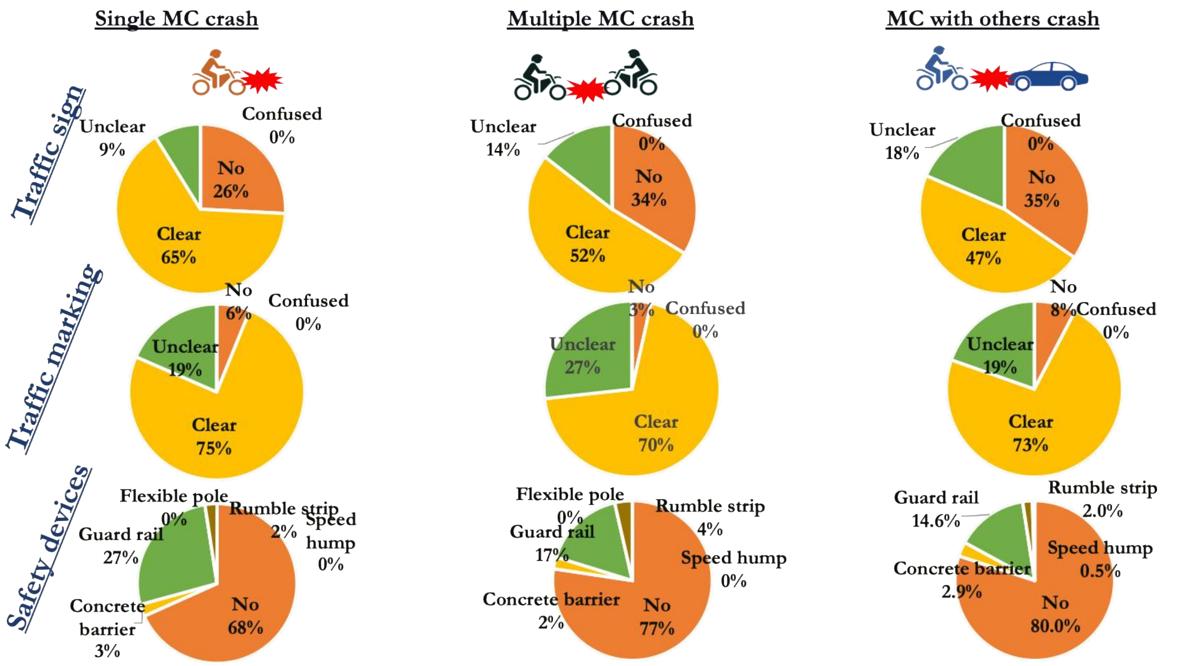


Figure 40. Traffic facilities of the road involved the motorcycle crashes

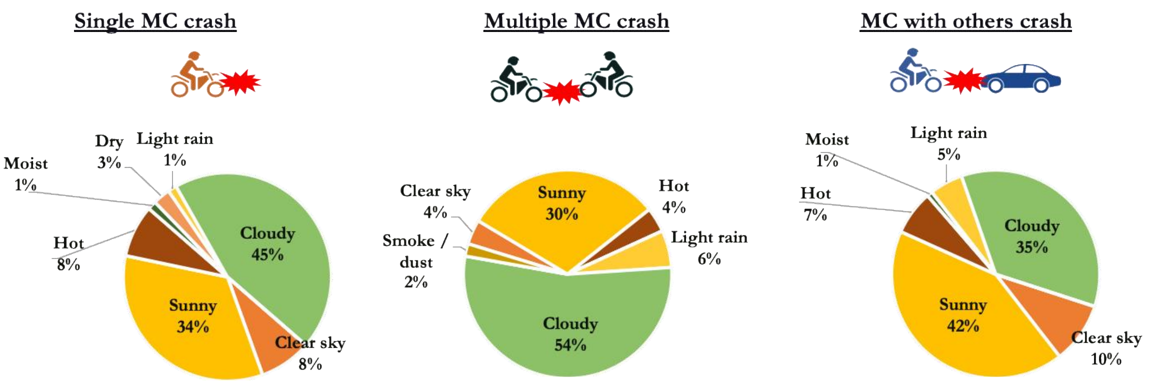
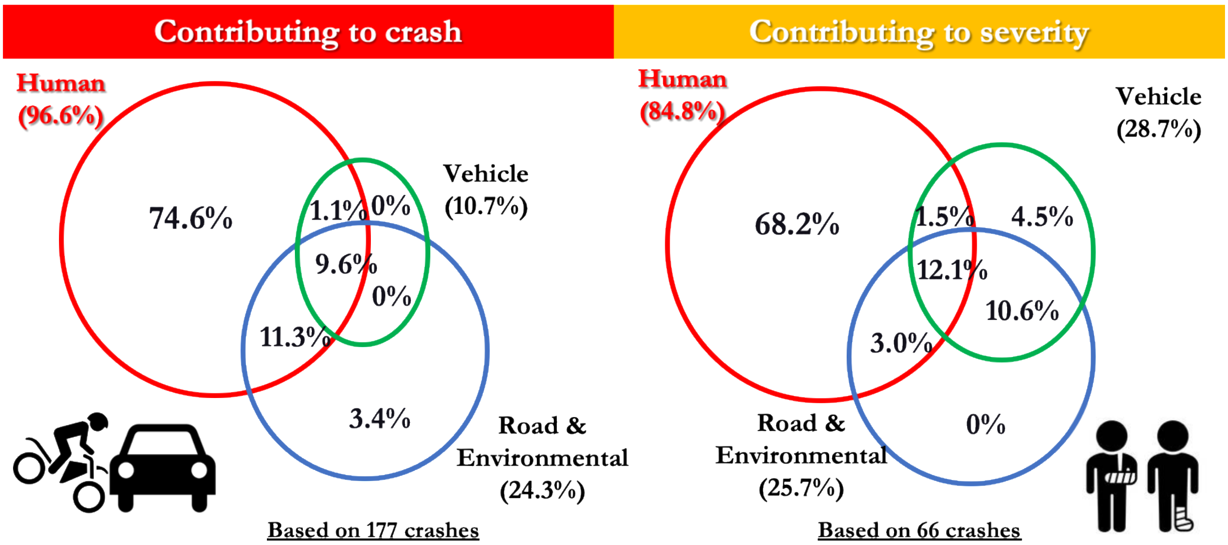


Figure 41. Environment of the motorcycle crashes

c. Factors contributing to crash and severity

From the crash data, 177 cases were employed to analyze the factors contributing to crashes and 66 cases were used to analyze the factors contributing to their severity. The results are presented in Figure 42. As expected, human-related factor is the main cause of crash and severity. Figure 43 shows that the top three human-related factors contributing to crashes are driving to close to the leading vehicle (24%), exceeding the speed limit (19%), and not giving to the right of way (14%), respectively. Considering the human-related factors contributing to the severity, the top two are improper clothing and wearing slippers (32.3% each), following by not wearing a helmet (21.9%), and not fastening seatbelt (4.2%), respectively.



*** Note**: *the analysis was based on the preliminary factors reported by police officers. For more details, in-depth crash investigation is needed.*

Figure 42. Factors contributing to crash and severity

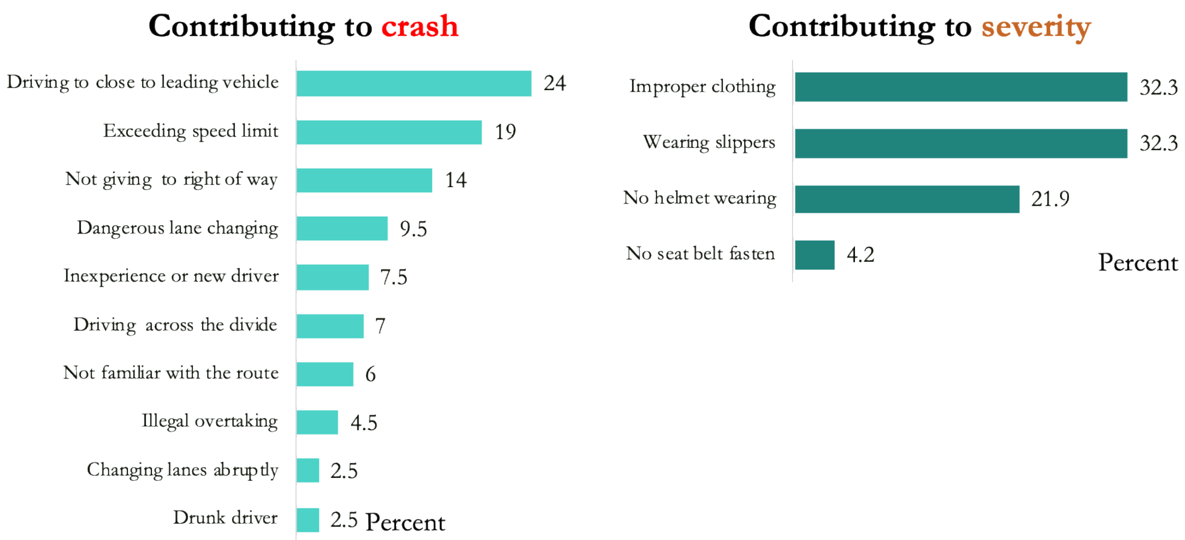


Figure 43. Human-related factors contributing to crash and severity

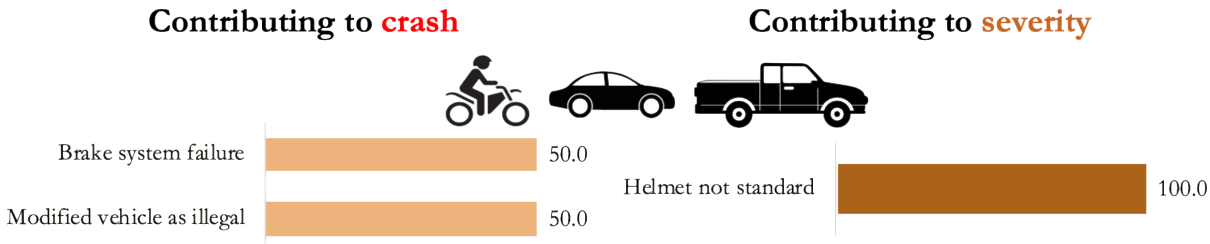


Figure 44. Vehicle-related factors contributing to crash and severity

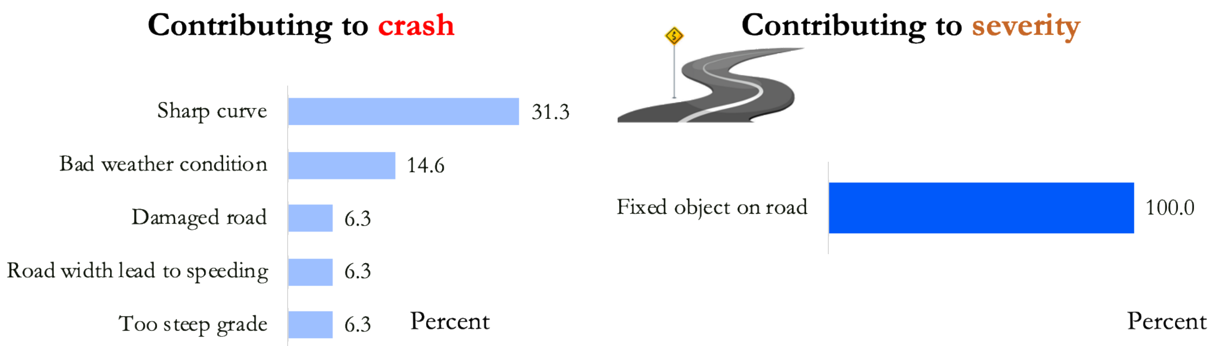


Figure 45. Road and environment-related factors contributing to crash and severity

d. Characteristics of risk locations

From the database, there are a total of 1,202 risk locations reported during April 2017 until the end of January 2019. From the risk locations reported, Figure 46 shows that more than three-quarter of road users affected by the risk locations are vulnerable road users, i.e., motorcyclist (31%), pedestrian (30%), and bicyclist (16%) when 23% are a car driver.

Figure 47 through Figure 50 present the percentage of several risk factors reported related to each type of road users.

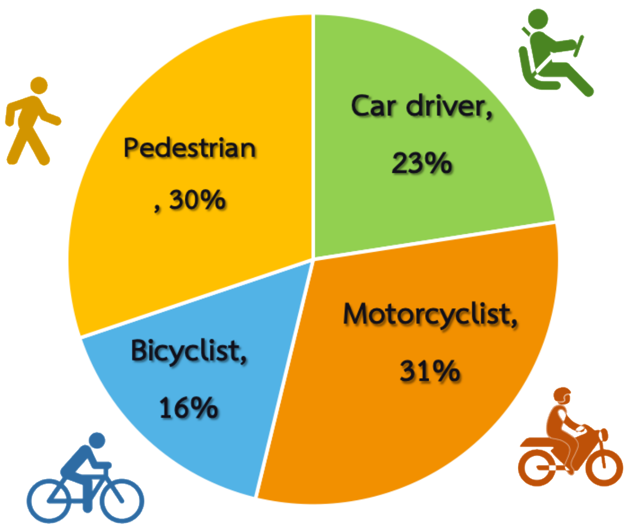


Figure 46. Percentage of road users involving in risk locations

Regarding the top five risk factors related to each road user, for the motorcyclist, Figure 47 shows that pavement surface, e.g., rough surface, broken surface, is the first risk factor (12.59%), followed by no motorcycle lane (7.3%), no and ineffective traffic marking (5.66%), driving behind too close (5.47%), and other issues related to median, e.g. unclear median, (4.6%), respectively.

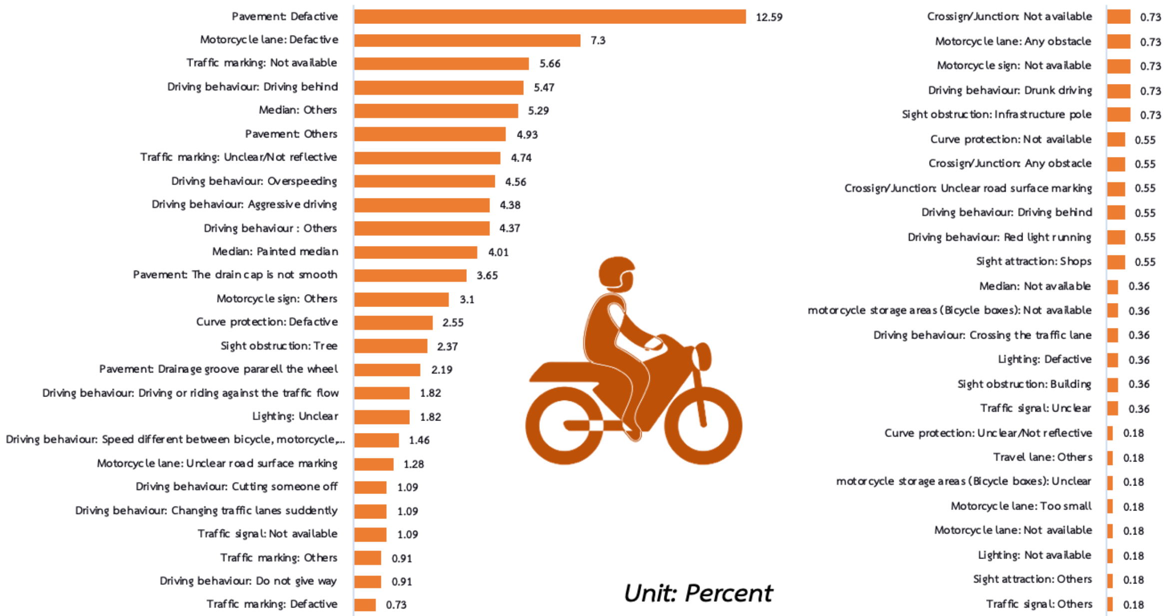


Figure 47. Risk factors related to the motorcyclist

Figure 48 shows that, for the pedestrian, vehicle not stop for a pedestrian is the most risk factor (13.92%), followed by unclear crossing (12.41%), vehicle speeding (8.35%), footpath condition is not (7.97%), and no footpath (6.46%), respectively.

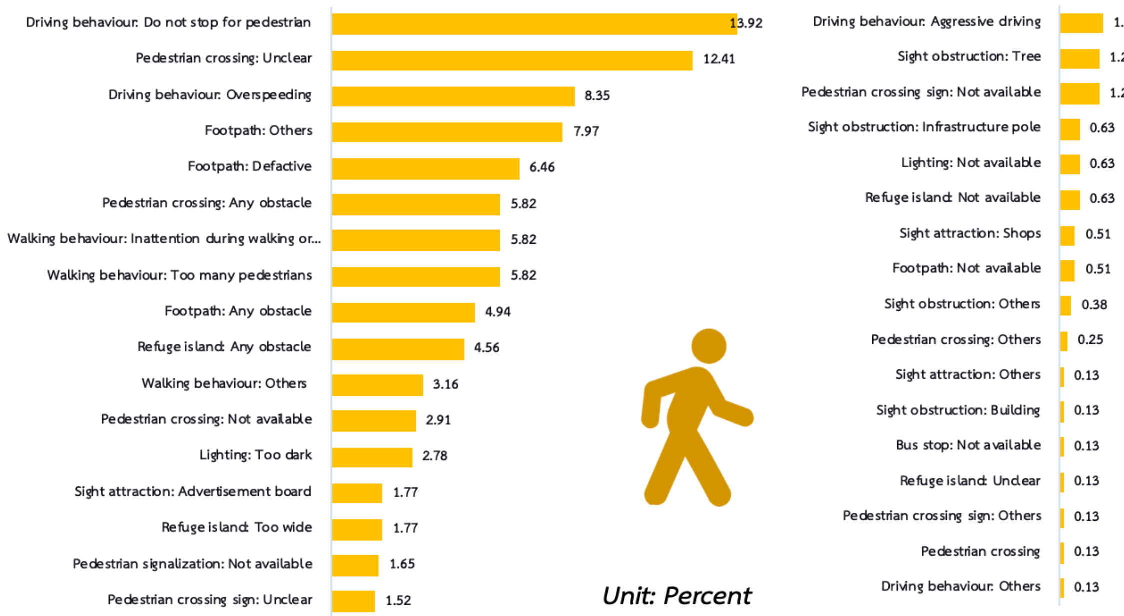


Figure 48. Risk factors related to pedestrian

For the car driver, Figure 49 shows that pavement surface, e.g., rough surface, broken surface, is the first risk factor (9.05%), followed by vehicle speeding (7.0%), ineffective traffic marking (6.79%), unclear traffic marking (6.11%), and unclear median (5.20%), respectively.

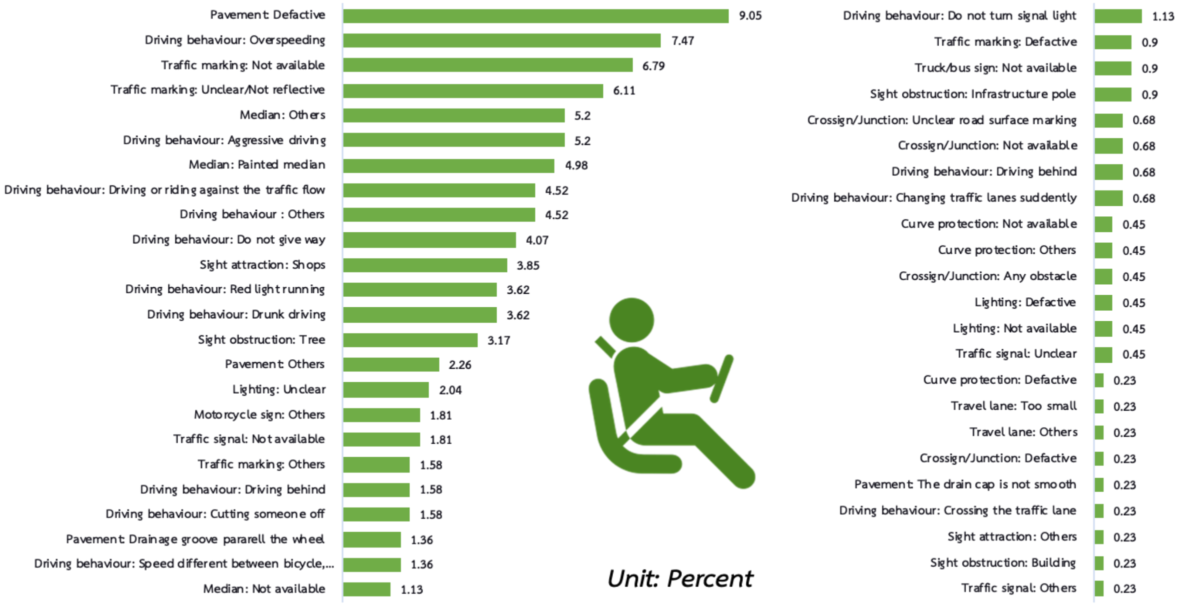


Figure 49. Risk factors related to the car driver

Finally, for the bicyclist, Figure 50 shows that pavement surface, e.g., rough surface, broken surface, is the first risk factor (17.31%), followed by cycling along no overtaking zone (7.49%), drainage groove parallel the wheels (5.43%), lighting too dark (5.43%), and unclear or nonreflective traffic marking (4.65%), respectively.

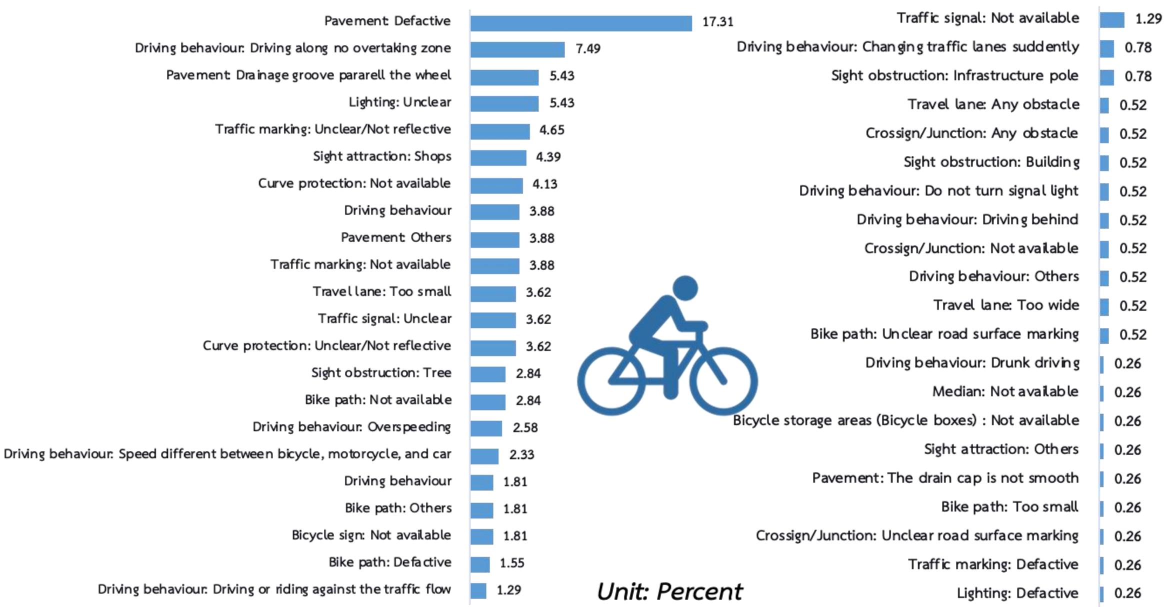
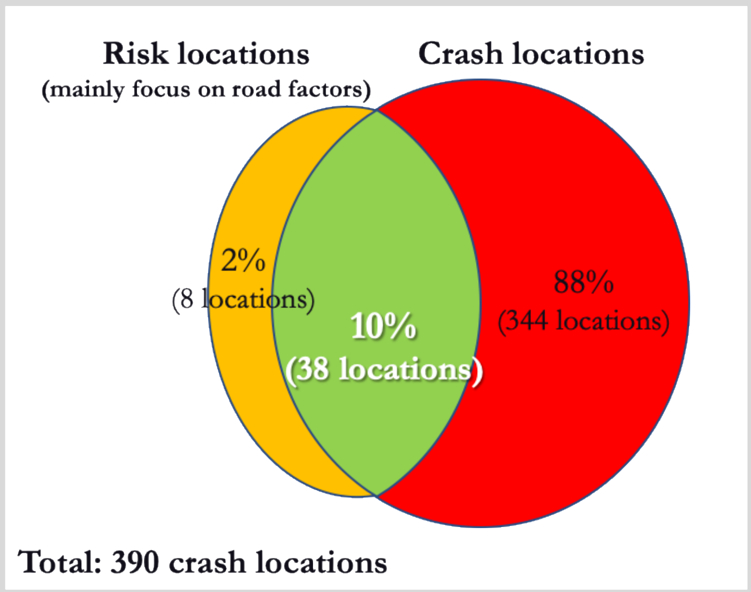


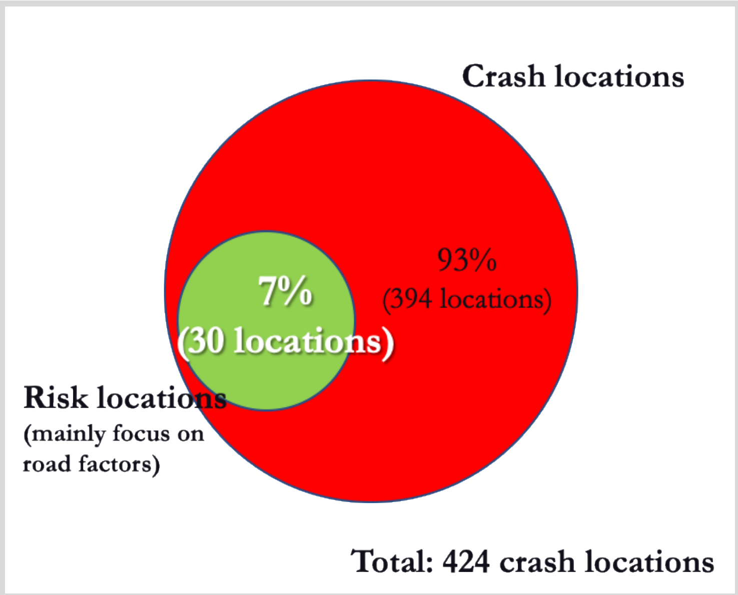
Figure 50. Risk factors related to the bicyclist

e. The relationship between crash and risk locations

The relationships between crash and risk locations were analyzed and presented in Figure 51. For the case of motorcycle-related crashes, Figure 51a) shows that only 10% of the crash locations and risk locations were directly related. Similar to the case of passenger car related crashes (Figure 51b), only 7% were directly related. This is because of a limit number of risk location data. In addition, the risk factors reported in the risk location database were mainly based on the road and infrastructure factors. In reality, several risk factors related to driving behavior may involve crashes. This issue needs further investigation.



a) Motorcycle-related crashes



b) Passenger car related crashes

Figure 51. The relationship between crash locations and risk locations

Another issue is whether the risk locations affecting to the crashes. Figure 52 and Figure 53 show the distance between the risk locations and crash locations reported in the database. On average, each crash location and risk location were approximately 24 and 38 meters for the case of motorcycle crashes and passenger car crashes, respectively. The results could verify that the risk locations affect to crashes. However, it needs further investigation on how these two locations are related (e.g. risk factors affect a crash).

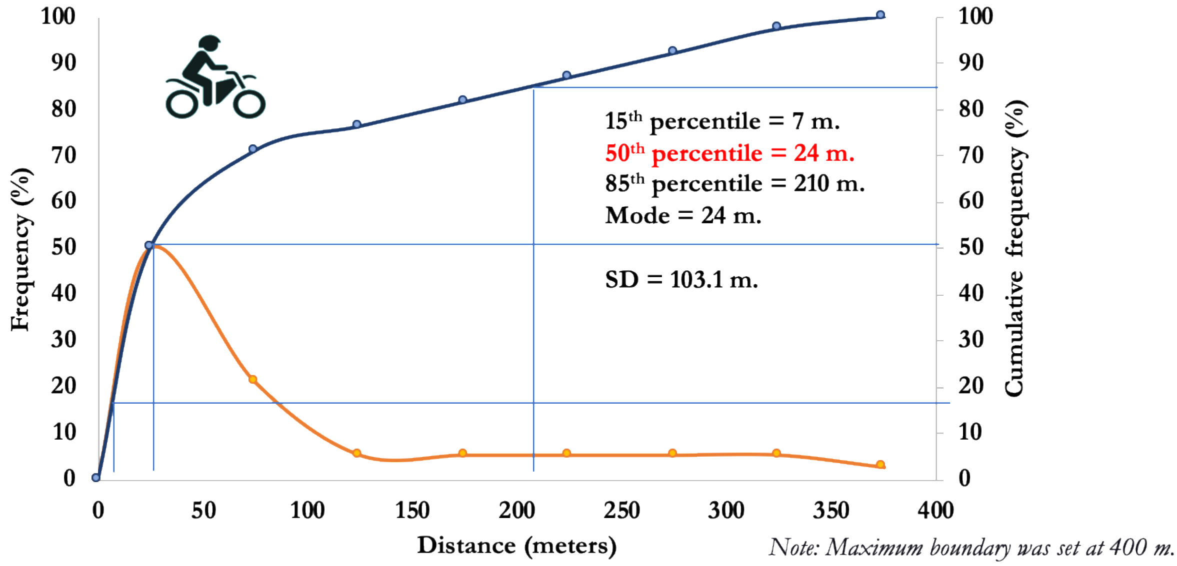


Figure 52. The distance between motorcycle-related crash locations and risk locations

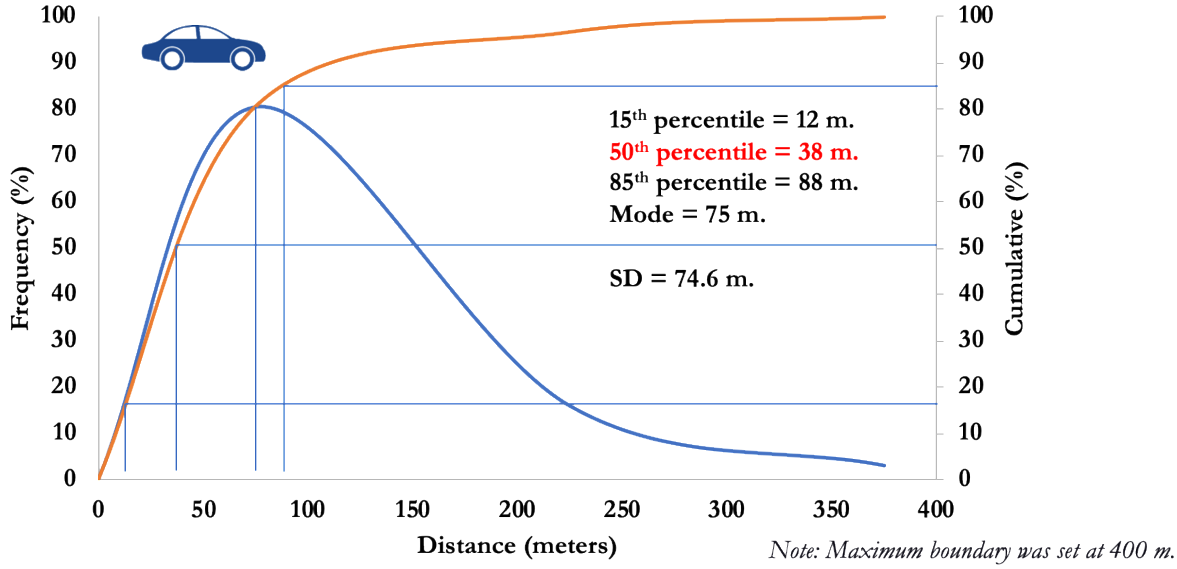


Figure 53. The distance between passenger car-related crash locations and risk locations

4.2 Results of hazardous locations identification

a. Hazardous locations in Phuket province

Top three hazardous locations with the highest costs presented in Figure 54 are Kuan Yak, Pra Phuket Kaew, and Ban Kuan Yang. The details are as follows.

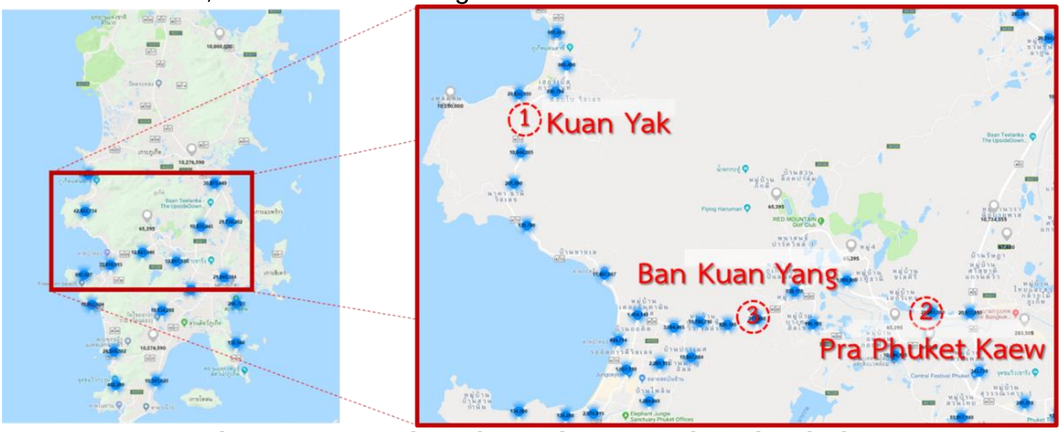
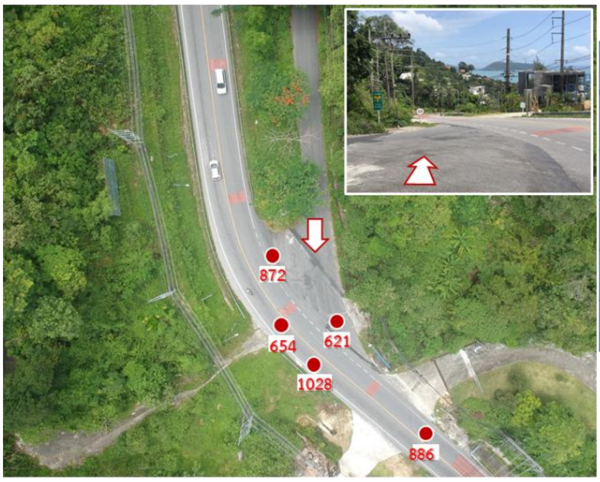


Figure 54. Top three hazardous locations in Phuket

i. Kuan Yak (Highway No. 4233)

Kuan Yak is the intersection on Highway No. 4233. The photos of the intersection are presented in Figure 55. From the database, there were five crashes in three months. Three motorcyclists died from three crashes. Traffic volume and speed data collected were summarized in Figure 56 and Figure 57, respectively.



Crash data

Case	ID	Date	Time	V1	V2	Fatalities	Injuries
1	621	6/2/18	12:23	Va n	Truck	-	1
2	654	17/2/18	04:10	PC	MC	1	-
3	872	14/4/18	18:30	MC	Van	1	
4	886	20/4/18	18:14	MC	-	-	1
5	1028	25/5/18	03:30	MC	-	1	-

Figure 55. Kuan Yak Intersection and crash data

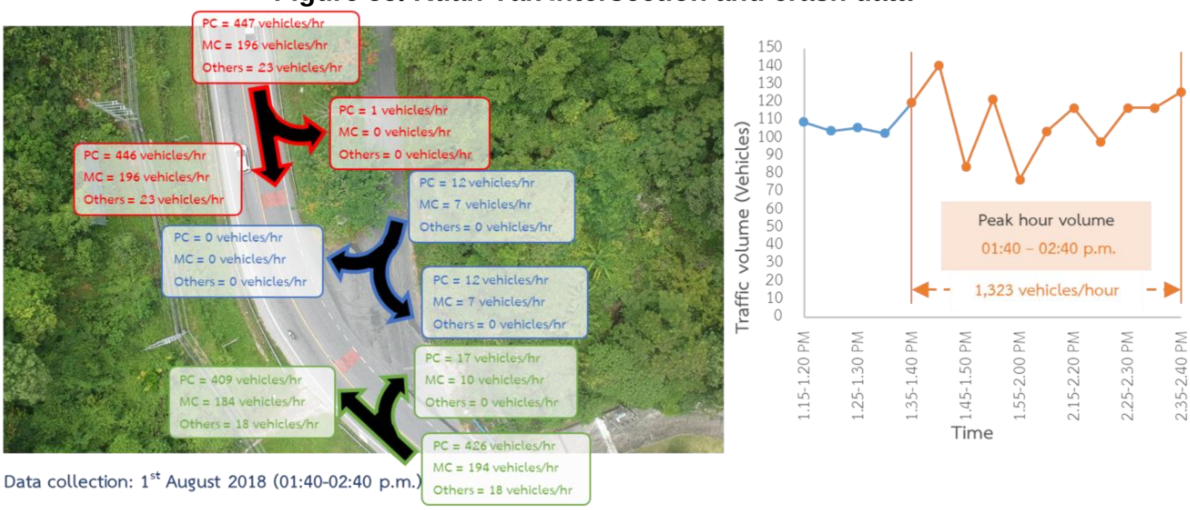
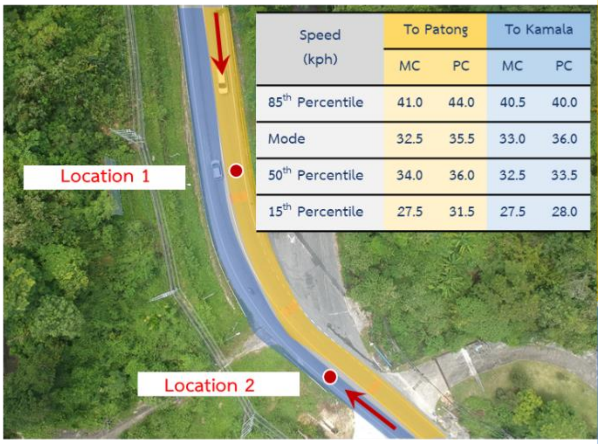


Figure 56. Traffic volume data collected at Kuan Yak Intersection



Speed (kph)	To Patong		To Kamala	
	MC	PC	MC	PC
85th Percentile	41.0	44.0	40.5	40.0
Mode	32.5	35.5	33.0	36.0
50th Percentile	34.0	36.0	32.5	33.5
15th Percentile	27.5	31.5	27.5	28.0

Data collection: 1st August 2018 (01:40-02:40 p.m.)

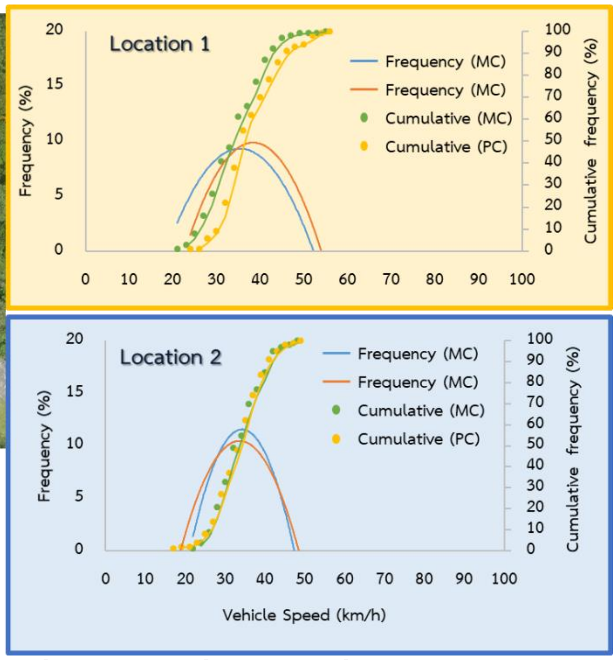
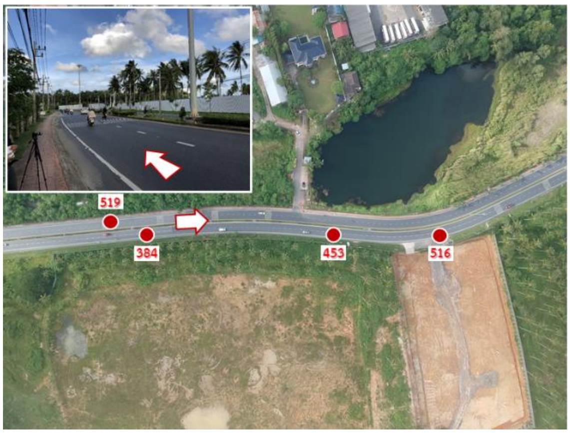


Figure 57. Speed data collected at Kuan Yak Intersection

ii. Pra Phuket Kaew (Highway No. 4020)

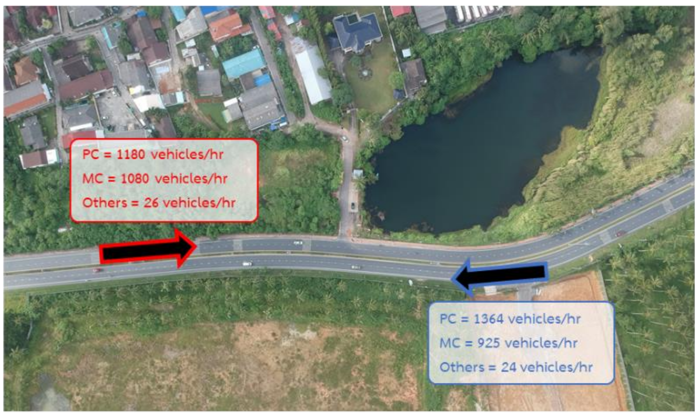
Pra Phuket Kaew is the road section on Highway No. 4020. The photos of the intersection are presented in Figure 58. From the database, there were three deaths from four crashes. Traffic volume and speed data collected were summarized in Figure 59 and Figure 60, respectively.

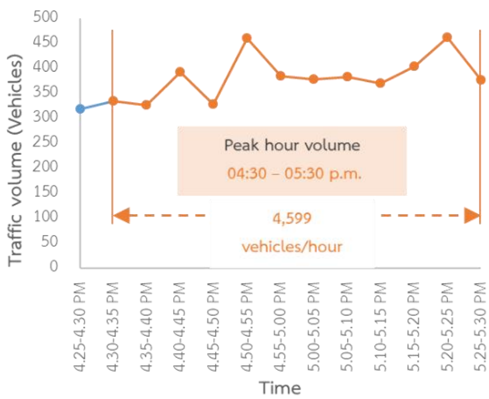


Crash data

Case	ID	Date	Time	V1	V2	V3	V4	V5	Fatal	Injury
1	385	22/10/17	22:00	MC	MC	MC	PU	PU	1	3
2	453	14/11/17	03:32	MC	-	-	-	-	-	1
3	516	20/12/17	01:30	PU	-	-	-	-	1	-
4	519	29/12/17	16:45	MC	-	-	-	-	1	-

Figure 58. Pra Phuket Kaew and crash data





Data collection: 31st July 2018 (04:25-05:30 p.m.)

Figure 59. Traffic volume data collected at Pra Phuket Kaew

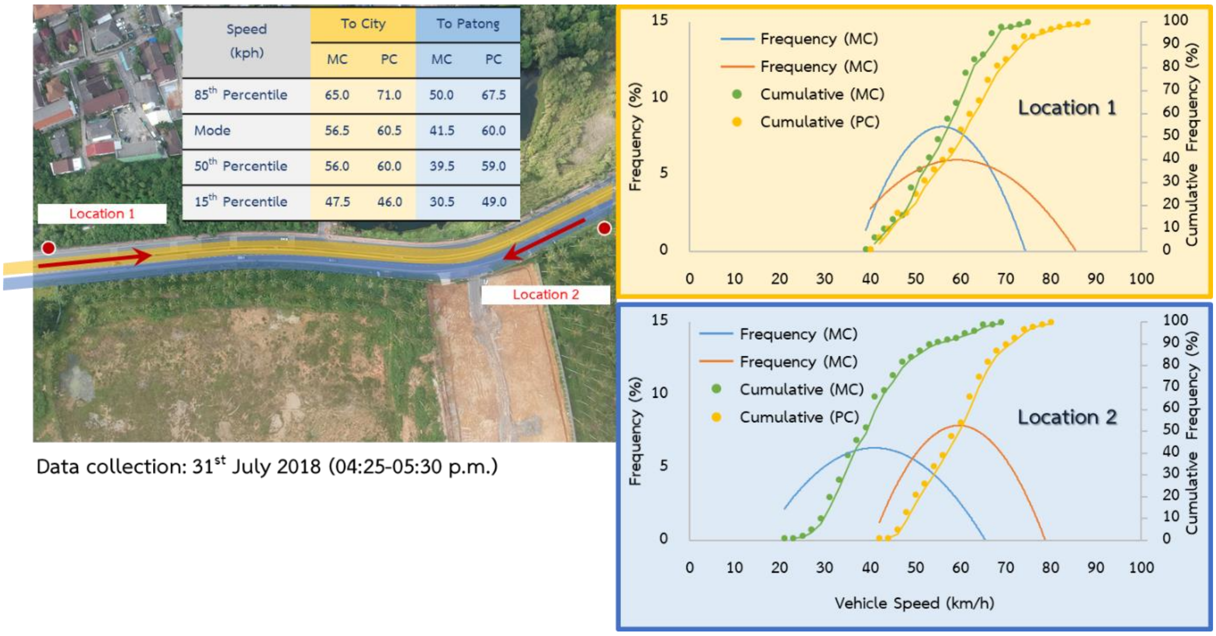
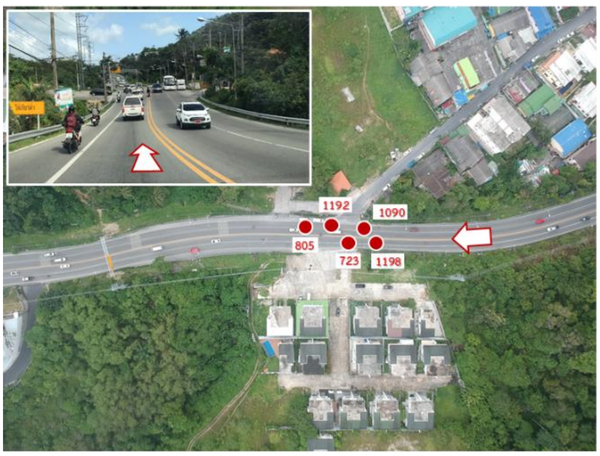


Figure 60. Speed data collected at Pra Phuket Kaew

iii. Ban Kuan Yang (Highway No. 4029)

Ban Kuan Yang is the intersection on Highway No. 4029. The photos of the intersection are presented in Figure 61. From the database, there were five crashes in five months. Although the only motorcyclist died, this location is risky due to high traffic volume, especially during morning and evening peaks. Traffic volume and speed data collected were summarized in Figure 62 and Figure 63, respectively.



Crash data

Case	ID	Date	Time	V1	V2	V3	Fatal	Injured
1	723	22/02/18	22:50	MC	Car	-	-	1
2	805	01/04/18	15:50	MC	MC	-	-	2
3	1090	12/06/18	17:56	Car	Car	MC	1	2
4	1192	01/07/18	18:08	MC	Van	-	-	1
5	1198	05/07/18	08:45	Car	MC	-	-	1

Findings:
- Y junction
- Sag vertical curve

Figure 61. Ban Kuan Yang and crash data

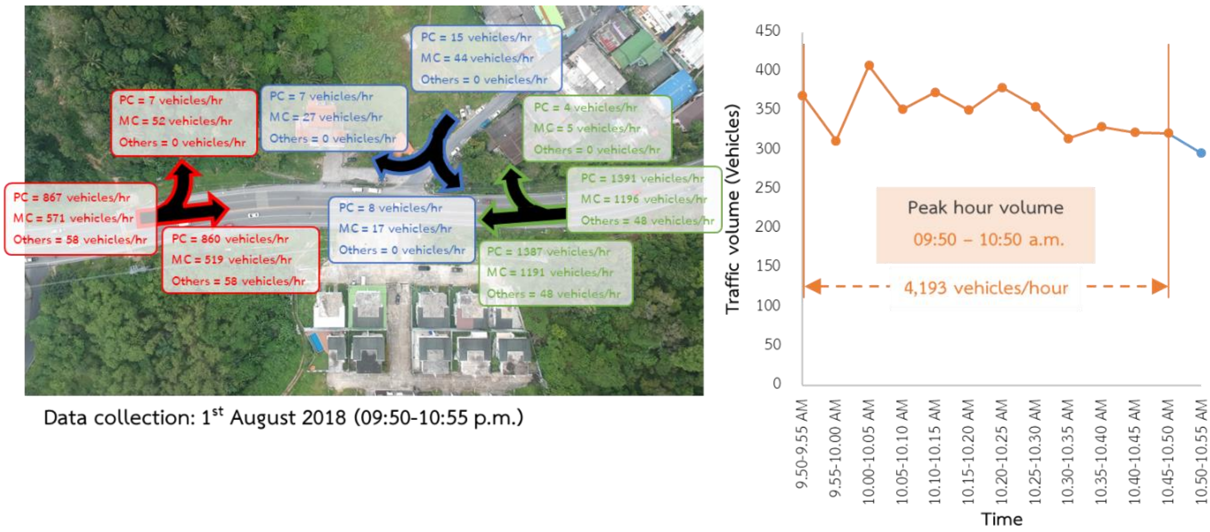


Figure 62. Traffic volume data collected at Ban Kuan Yang

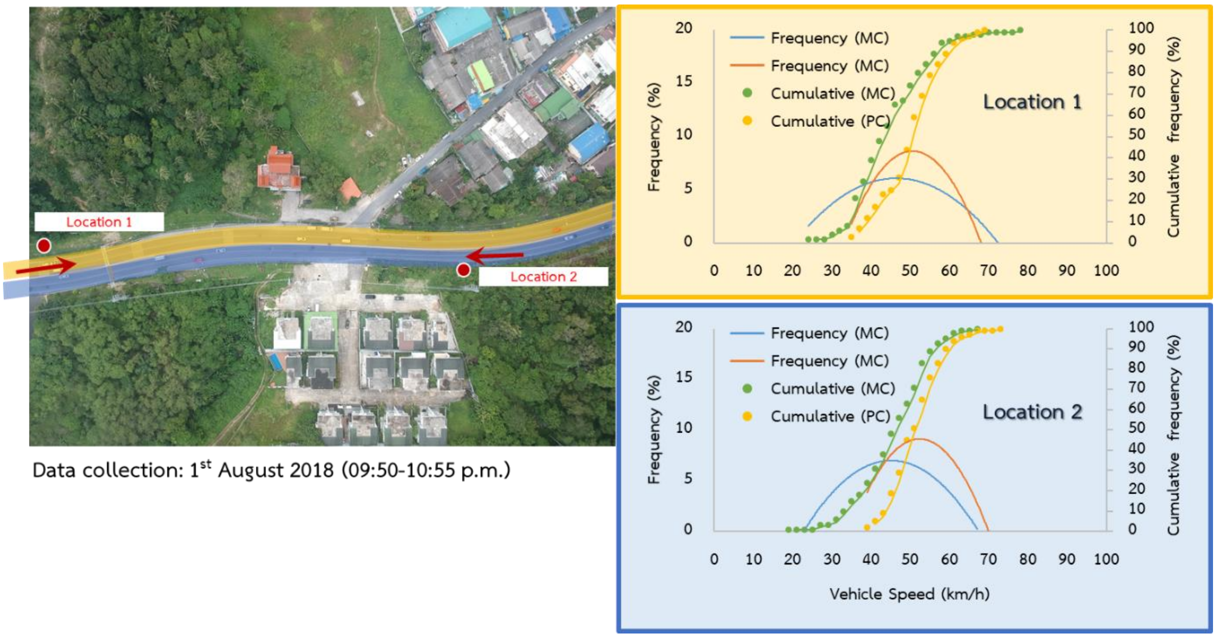


Figure 63. Speed data collected at Ban Kuan Yang

b. Countermeasures to improve road safety

The countermeasures for road safety improvement of the three hazardous locations in Phuket have been studied and designed. The preliminary measures for the three locations can be illustrated from Figure 64 to Figure 66, respectively.

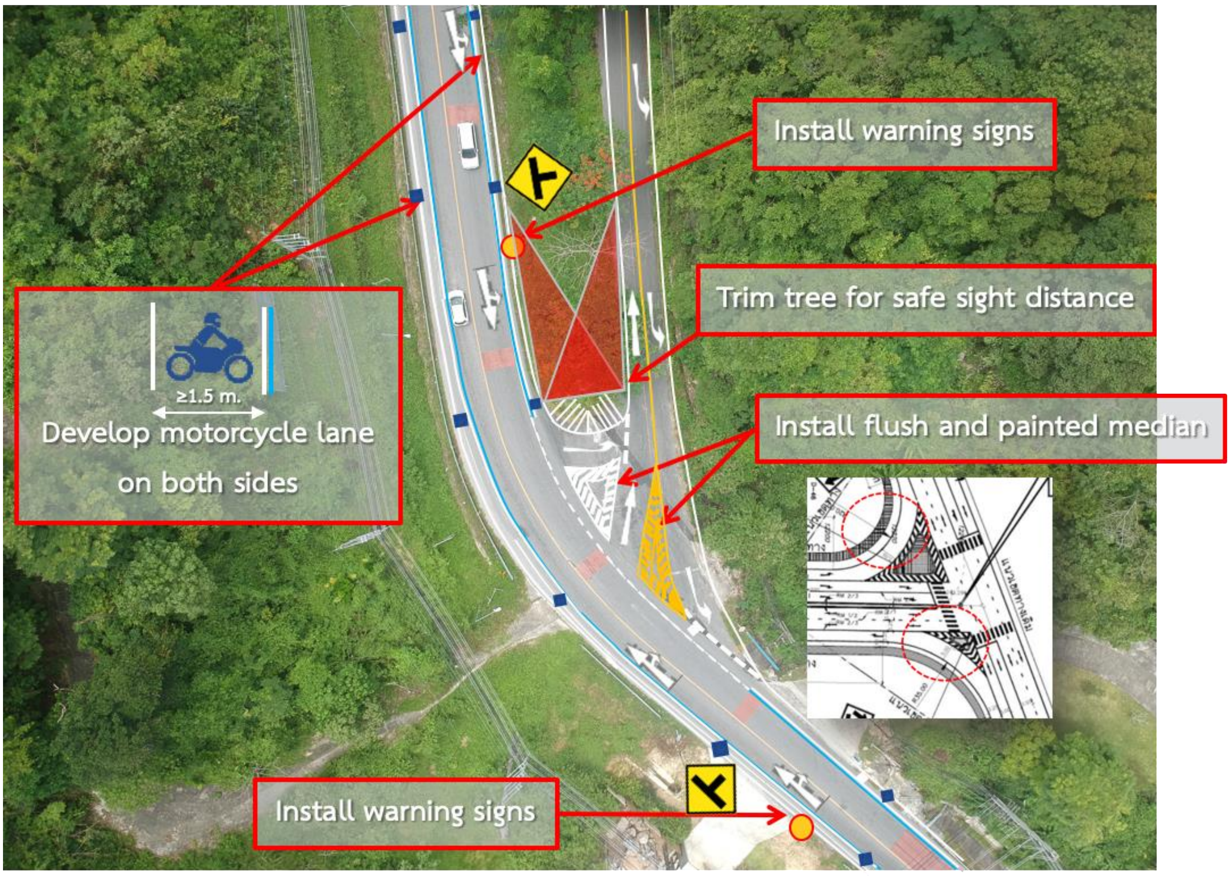


Figure 64. Potential measures for the case of Kuan Yak

Figure 65. Potential measures for the case of Pra Phuket Kaew

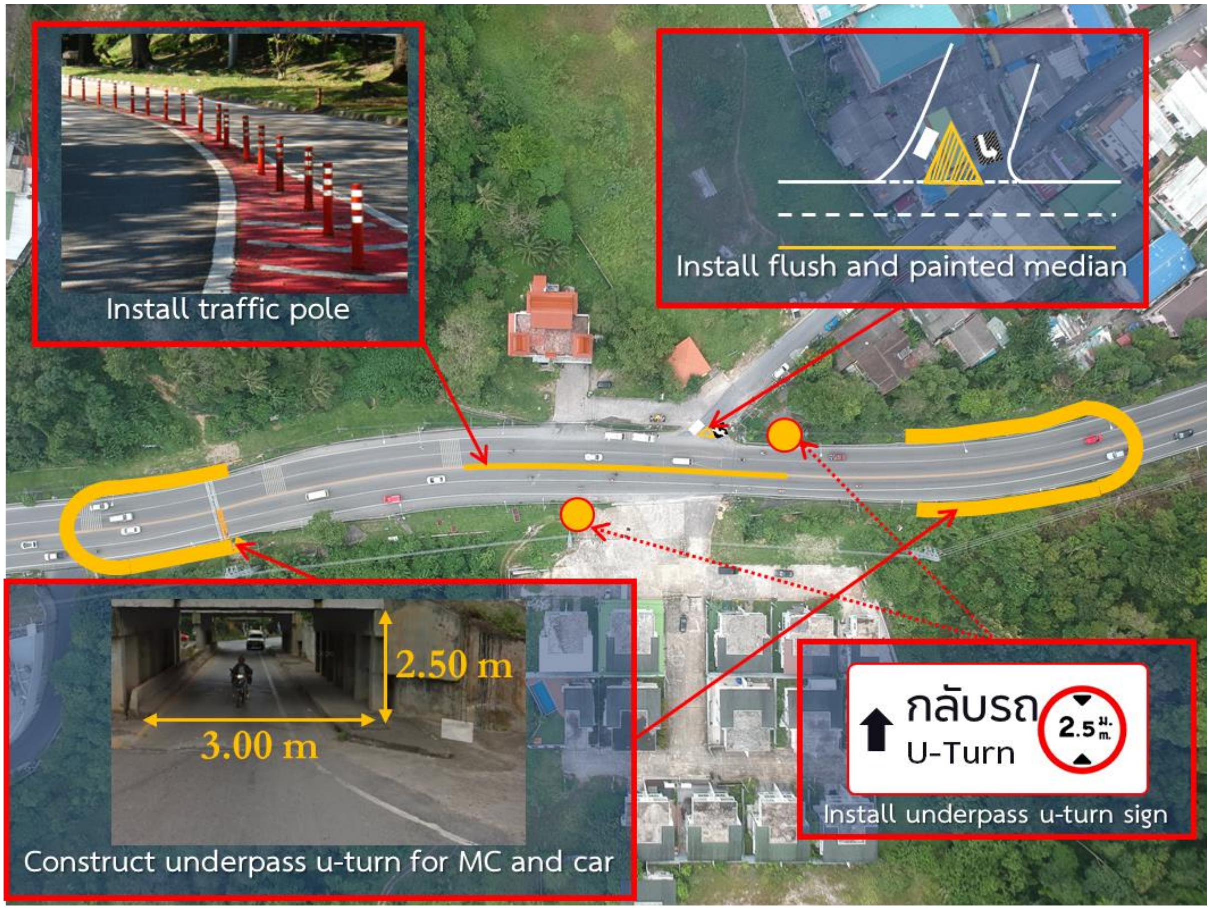


Figure 66. Potential measures for the case of Ban Kuan Yang

CHAPTER 5 CONCLUSIONS

5.1 Conclusions

In this research, a couple major features of ATRANS Safety Map application were improved order to allow the users to input the collision diagram and preliminary contributing factors of a crash. In addition, hazardous location ranking system was developed based on the accident costing technique. The later function allows local staff to easily identify the hazardous locations in their response area.

Crash data and risk location data of several areas in Thailand were collected. The data were then analyzed in order to investigate the characteristics of crashes in general, e.g., number of crashes, victims, vehicles involved, day and time of the crashes, crash locations and road characteristics. In addition, the crash data collected in Phuket province were investigated more in details. It was significantly found that more than half of vehicles involved (57%) were the motorcycle. Approximately 10% of the riders died in the crashes with other vehicles. This portion is similar to the single motorcycle crash. As expected,

Considering the preliminary factors contributing to a crash and severity, as expected, the major factors were related to human behaviors (i.e., 97% and 85%, respectively). However, road geometry factors also contribute to crashes and severity significantly (i.e., 24% and 25%, respectively).

Regarding the risk locations, this research also showed the risk factors related to various road users including the motorcyclist, pedestrian, car driver, and bicyclist.

Finally, the top three hazardous locations in Phuket province were identified and investigated. Potential countermeasures based on road safety engineering approach were designed and proposed to local authorities for their safety improvement program.

5.2 Recommendations

Preliminary contributing factors showed in this research should further investigated by other road safety experts (e.g., doctor, engineer). In-depth-crash investigation is a another approach in order to study the details of the contributing factors, e.g. is there any the road factor (wide travel lane) leading the driver to be more aggressive (speeding).

Decision support system for safety improvement program can be further studied.

References

ATRANS. (2018). *Development of Compiled Road Safety Data And Analysis for Safety Research: Phase 4.* Final Report.

Austroads. (2004). *Guide to Traffic Engineering Practice Series: Part 4 Treatment of Crash Locations.* Canberra.

Austroads. (2006). *Guide to Road Safety Part 7: Road Network Crash Risk Assessment and Management.* Sydney.

DOH. (2007). *The Study of Economic Losses due to Raod Crashes.* Department of Highways (DOH).

ESRI. (2017, October 5). *Distance on a sphere: The Haversine Formula*. Retrieved from The ESRI Community: https://community.esri.com/groups/coordinate-reference-systems/blog/2017/10/05/haversine-formula

Google Developers. (2018). *Marker Clustering*. Retrieved from Google Maps Platform: https://developers.google.com/maps/documentation/javascript/marker-clustering

Haight, F. (1994). Problems in Estimating Comparative Costs of Safety and Mobility. *Journal of Transport Economics and Policy, 28*(1), 7-30.

Inman, J. W. (1835). *Navigation and Nautical Astronomy: For the Use of British Seamen.* London, UK.

Jaensirisak, S. (2018). *Valuation of Injuries and Deaths due to Road Crashes.* Siam Cement Group.

Movable Type Ltd. (n.d.). *Calculate distance, bearing and more between Latitude/Longitude points*. Retrieved from https://www.movable-type.co.uk/scripts/latlong.html

Ogden, K. W. (1996). *Safer Roads: A Guide to Road Safety Engineering.* Aldershot, Hants, England; Brookfield, Vt.: Avebury Technical.

OTP. (2018). *Action Plan Study for Road Accident Reduction: The Manual of Accident Data and In-depth Accident Data Management.*

WHO. (2015). *Global Status Report on Road Safety 2015: Supporting a Decade of Action.* World Health Organization (WHO).

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