MOTORCYCLE DEFECTS ON MOTORCYCLE SAFETY IN THAILAND

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ABSTRACT

This paper presents a review of past research works that examined factors affecting motorcycle safety, focusing on: human errors, infrastructure defects, vehicle defects and their interaction which contribute to motorcycle crashes, with the aim of highlighting the need for more research on the effect of motorcycle defects safety. Overview of the global motorcycle crash situation was conducted using data and various information sources. Non-English publications on motorcyclists and motorcycles were consulted. Sources of motorcycle accident information in Thailand included those of the Royal Thai Police, Department of Land Transport, and Road Accident Victims Protection. Key words used in the search included motorcycle safety, motorcycle crash/accident, motorcycle stability/balance, motorcycle defects, and motorcyclist. The results show that human errors, speeding, alcohol impairment, disregard of traffic laws, and inexperience are the most common factors involved in a motorcycle crash. Although vehicle defects such as defective components played a relatively small part of all the factors affecting motorcycle crash, but the effect was significant and increasing. One finding was clear from the review, very few research works have been done on the mechanism of motorcycle crashes due to motorcycle defects, especially those involving light weight motorcycle (101-125 cc) which is the most popular model in Thailand. Thus the study of the influence of the motorcycle and its components on a crash is needed. The outcomes of the research will help identify safer motorcycle components, including betters tire size, anti-lock braking system, crash bar, stability control system, and personal protective equipment.

Keywords: Motorcycle Crash, Motorcycle Safety, Motorcycle Defects, Motorcycle Stability, Motorcyclist

1. INTRODUCTION

Road crash data over the past 7 years show that average number of motorcycle accidents was more than personal car accidents by almost 20% (Royal Thai Police, 2013). Since motorcycle can easily become unstable, good vehicle control skills of motorcyclists are necessary. Road infrastructure elements such as road geometry, roadside installations, lighting and visibility, and pavement surface condition, if in poor conditions can increase the risk of motorcycle riding.

Although motorcycle seems to be a dangerous mode of transport, the use of motorcycle in Asian countries has been continuously increasing in popularity. The notable increase in motorcycle registrations has been reported in a number of countries in this region including Viet Nam, Malaysia, Indonesia and Thailand. The strong points of this mode of personal transport that make it more acceptable are economical vehicle, saving travel time, and ease of parking. The consequence of the popularity of this mode of transport means that road traffic accidents are increasing and currently users of motorcycles are the main fatalities globally.

In recent years, WHO announced that road traffic injuries was the eight leading causes of death and the leading cause of death in young people aged 15-29. Moreover, the statistical trend was predicted to

rise to the fifth leading cause of death in 2030 (WHO, 2013).

The implementation of road safety strategies such as strengthening institutional capacity, improving road safety network, improving vehicle safety and developing better road user behaviors were driven to reduce the road traffic accident. However, on motorcycle characteristics, including its instability, lack of protection, and multitask controlling, and warning system, there is a need to address them as they can help improve safety of motorcyclists.

This paper provides a review of comprehensive research works that addressed the issue of motorcycle safety. Both qualitative and quantitative studies were analyzed. Key elements contributing to motorcycle crashes: human errors, infrastructure defects and vehicle defects and their interaction were described in some detail.

2. MAGNITUDE OF THE PROBLEM

The most vulnerable road user group in Thailand and most Asian countries is motorcycle users. The statistics of WHO (see Figure 1) shows that four Asian countries (Vietnam, Malaysia, Indonesia, and Thailand) have more than one motorcycle for every four people. There were nearly 300,000 fatalities as a result of motorcycle crashes in 2010; seventy-eight percent of which occurred in Asian countries. Figure 2 shows that Thailand has the highest fatality rate of 28 per 100,000 populations, nearly twice that of Lao, Vietnam and Malaysia (Nguyen, 2013).

The estimated road traffic death rate in Thailand has been recently published by the University of Michigan which shows the rate at 44 per 100,000 populations, the world's second highest, using the 2008 data (Sivak and Schoettle, 2014). However, according to the 2013 WHO report, using the 2010 data, the rate for Thailand was 38.1 per 100,000 populations which ranked third in the world (WHO, 2013); there is a slight improvement, but the figure is still far too high compared to its ASEAN members. Details of ASEAN fatality rate in the WHO 2013 report are shown in Table 1; and the University of Michigan 2008 statistics are given in Table 2. The Thai fatality rate, in comparison, was more than 46 percent higher than that of Malaysia with similar income level and more than some 7 times higher than that of Singapore.

The trend of road traffic crashes in Thailand is shown in Figure 3 using the police data (Royal Thai Police, 2013). It can be seen that in the period between 2006 and 2012, a downward trend was recorded in the number of motorcycle and personal car accidents. The sharp drop started in 2009 to 2011 and then remained stable in the year after. For the past three years, 2010-2012, motorcycle crashes have fluctuated between 54-35% of the total crashes. On average there were about 85,000 road traffic accidents and motorcycle crash proportion was about 54% or 49,000 cases. Significantly, of all the road users killed or injured, about 80 percent involved motorcycle users (Rungpueng et al., 2012).

Additionally, data from the Road Accident Victims Protection (RVP, 2013) gave details of the claims involving motorcycle users from 2011 to 2013 as shown in Figure 4. There was a fluctuation in the total number of injuries consisted of slightly, moderate and serious injury, with more than 200,000 per year. The number of fatality during in 2011 to 2012 leveled off at about 8,000 cases before declining to nearly 6,000 in 2013. Fatality numbers were on average 7,400 cases per year or roughly 20 Thai motorcyclists die on the road traffic accident every day.

In spite of the high rate of motorcycle fatalities, registered numbers of Thai motorcycles have been increasing with over 1 million units sold annually; the cumulative numbers are almost 20 million vehicles in 2012. Furthermore, Department of Land Transport's statistics (see Figure 5) show the high popularity of the 125 cc model. This model has been closely associated with motorcycle fatalities and injuries in Thailand. The high rate of motorcycle fatalities and the high demand of motorcycle usage make it challenging to reduce the number of fatalities.

However, this serious situation should be looked at under the limitations of the present road safety regulations, traffic laws, medical care, road design and motorcycle design. An effective system for improving road safety should be established by integrating all angles. For example, the authorities should evaluate the failing factors. The existing related traffic rules and regulations should be analyzed and improved.

3. THE CAUSE

Road crashes are a result of at least one of the 3 elements: human errors, infrastructure defects and vehicle defects, however, these elements often form a chain of events leading to a crash. For example, the combination of a defective road surface and poor rider handling ability or unstable motorcycle can increase the potential of crashes. To effectively respond to the cause of road traffic crashes, research is needed to gain a better understanding and evaluate the effectiveness of the implementation of road safety actions. The starting step should be to study what have been done in this area. Therefore, the following sections provide a detailed literature review relating to human errors, infrastructure defects and vehicle defects.

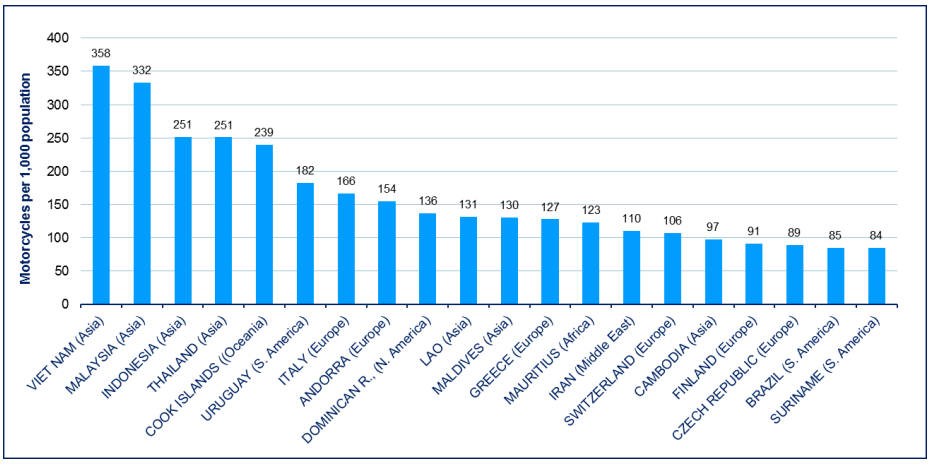

Figure 1: The leading 20 countries with high number of motorcycles per 1,000 population (Source: Nguyen, 2013, compiling from WHO 2013 data)

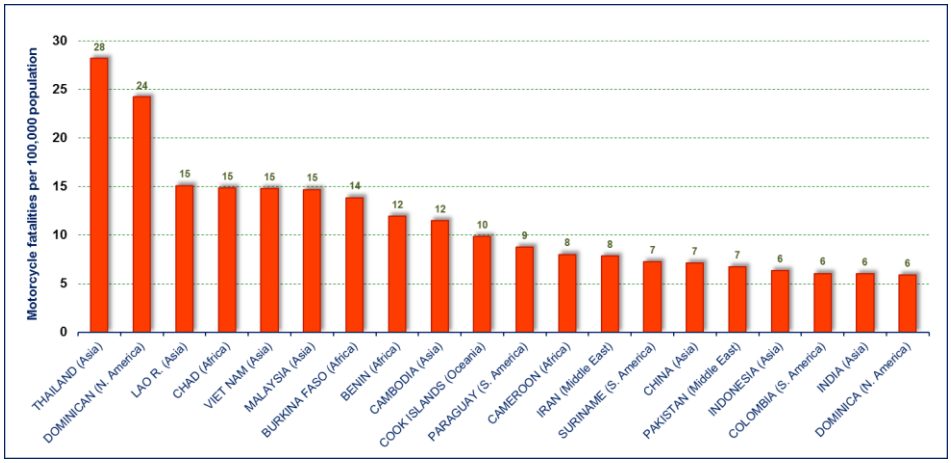

Figure 2: Twenty countries with the highest rate of motorcycle death per 100,000 population (Source: Nguyen, 2013 compiling from WHO 2013 data)

3.1 HUMAN ERRORS

Motorcycle riders are considered the most crucial component in motorcycle riding. Among three influencing factors of traffic accident; human errors, infrastructure defects and vehicle defects, Hurt who carried out an in-depth investigation into 900 motorcycle accidents and reviewed 3,600 traffic accident reports of motorcycle accidents found that the common contributing factor of all motorcycle collisions in Los Angeles during 1975-1980 was the human fault (Hurt et al., 1981). As motorcycle riders often appeared inconspicuous in traffic, and motor vehicle drivers failed to detect them, this led to many right-of-way accidents involving motor vehicles and motorcyclists. A decade later, the circumstances of US motorcycle accidents were remarkably different.

Table 1: ASEAN Road Traffic Deaths and Fatality Rate

Country	Income Level	Reported number of road traffic death	Estimated road traffic death rate per 100,000 population
Brunei Darussalam	High	46	6.8
Cambodia	Low	1,816	17.2
Indonesia	Middle	31,234	17.7
Lao People's Democratic Republic	Middle	767	20.4
Malaysia	Middle	6,872	25.0
Myanmar	Low	2,463	15.0
Philippines	Middle	6,739	9.1
Singapore	High	193	5.1
Thailand	Middle	13,365	38.1
Viet Nam	Middle	11,859	24.7

Source: Compiled from (WHO, 2013)

Table 2: Fatality Rate per 100,000 population from Road Crash (Sivak and Schoettle, 2014)

Rank	Country	Rate
1	Namibia	45
2	Thailand	44
17	Malaysia	30
	Global average	18
170	Singapore	6

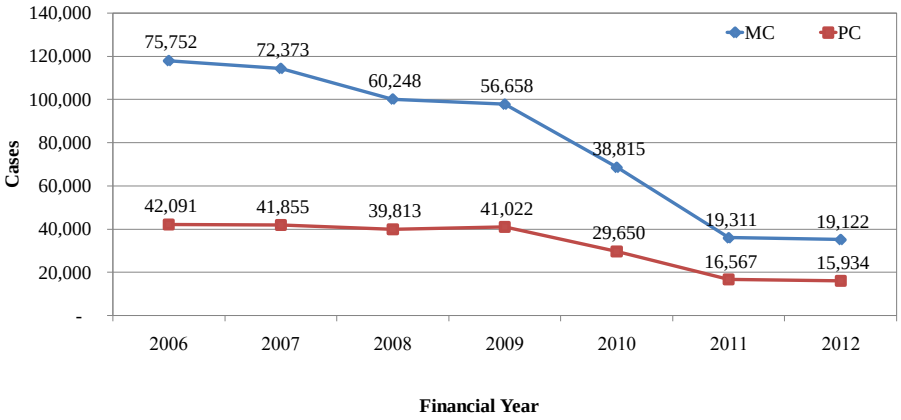

Figure 3: Road Traffic Crash Situation in Thailand (Royal Thai Police, 2013)

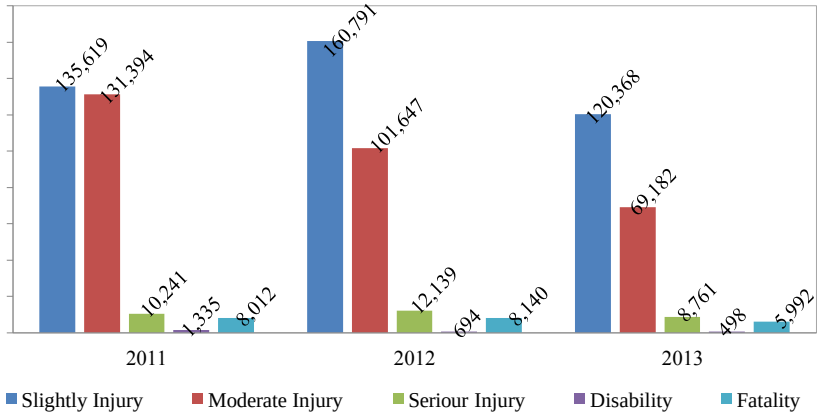

Figure 4: Claims Involving Motorcycle Users (RVP, 2013)

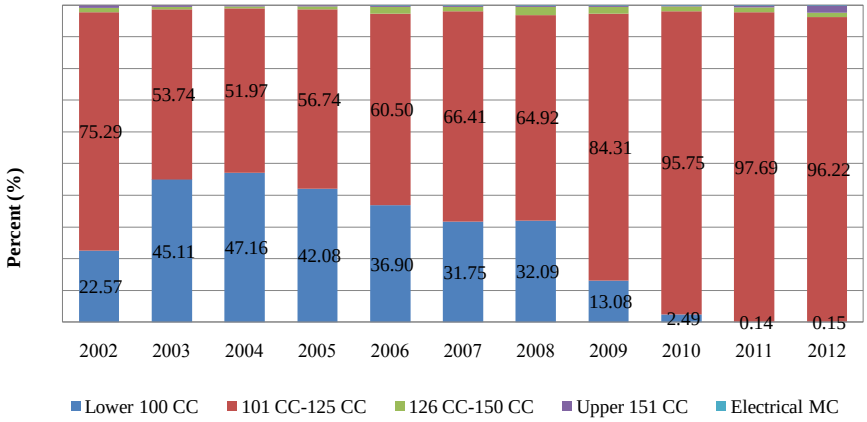

Figure 5: Percentage of Each Type of Registered Motorcycles (DLT, 2013)

A study reported that over the period of 1996-2006 the numbers of motorcycle fatality in USA had doubled and also the major contribution factors were human errors. Speeding and high alcohol level in blood hit the peak of motorcycle crash causation (Padmanaban and Eyges, 2009).

Along with human errors in motorcycle crashes in USA, the European research team, The Motorcycle Accident In-Depth Study (MAIDS) found similar contributing human failures involving powered-two wheeler (PTW) accidents in Europe. These failures were categorized as (1) perception failure, (2) comprehension failure, (3) decision failure and (4) reaction failure. Approximate 37 % of PTW collisions were caused by human errors (ACEM, 2006).

For the motorcycle accident situation in South East Asia, the trend in fatality rate in motorcycle accident in Malaysia has continued to grow since early 90's. Careless driving was the biggest proportion of driver's faults that affected fatality rate of motorcycle crashes. It was noticeable that a violation to traffic light by motorcycle riders had increased about threefolds (MIROS, 2011a and 2011b).

To increase the depth of understanding of motorcycle crash characteristics in Thailand, since the early of 2000s a number of related research works have been conducted to identifying human factors associated with motorcycle crash causation. The key finding by Rojviroon was that young motorcycle

riders had poor safe driving behavior (Rojviroon, 2006). Their habit of poor driving need to be improved. Some similar results were reported regarding poor riding. A study by Ngamsom et al. shows that the young motorcyclists in the 18-35 age group tend to violate traffic laws more than other age groups (Ngamsom et al., 2011). Moreover, it was stated that a key risk element, the inexperience of riders, would seem a primary contributing factor to motorcycle crashes (Pibool and Taneerananon, 2012).

In addition, Kasantikul found that alcohol was a major cause of motorcycle crashes (Kasantikul et al., 2005). Most of alcohol effects were evident in the "loss of control" motorcycle crashes resulting in run-off the road or single vehicle crash. Contrary to conventional findings, Saisama found that most of shuttle-motorcycle riders obeyed the traffic laws, gave responsible services to their customers and possessed acceptable behaviors regarding, emotional control, awareness of protective behaviors against accidents from motorcycle riding (Saisama, 2005).

From the literatures, it can be concluded that most young motorcycle riders in Thailand have been riding without proper concern of and awareness of road safety. It was suggested that education and the safety riding program should be used to bridge the safety gaps for motorcyclists in order to reduce the motorcycle related injuries and fatalities (Woratanarat et al., 2013). Even though there were many attempts to deal with the human factors in motorcycle crashes, however, it is still a great challenge facing the country as the registered number of motorcycles continue to increase (Figure.6). More research in this area is still needed to effectively deal with the situation for the clear purpose of saving the life of motorcycle users.

The summary of available literatures was shown in Table 3 with respect to the behavioral of young motorcyclists, senior motorcyclists, shuttle-motorcycle riders and safe riding motorcycle instructors. It is evident that the experimental research on Thai motorcyclist behaviors is an under-research issue. The larger proportion of research was conducted on the survey and correlation analysis.There were a several behaviors topic such as attitude on safe riding, receptiveness to traffic law, risk and violent patterns.

Table 3: Summary of literature on human error factor involving in a motorcycle crashes

Authors	Title	Method/ Study design	Sample Size	Main Findings
ChoonWah Yuen et al. (2013)	*Investigation on Motorcyclist Riding Behaviour at Curve Entry in Down Slope Terrain*	Measure the variables related to riding behaviour of young motorcyclist	39	▶When riding to curve, speed was reduced by applying higher brake intensity and release throttle force
Kasantikul et al., 2005	*The Role Of Alcohol in Thailand Motorcycle Crashes*	On-scene, in-depth investigation and reconstruction	1082	▶Alcohol was the most frequent cause of motorcycle crashes
Ngamsom et al., 2011	*Study of Motorcycle Driver Characteristics on Traffic Law Violation*	Interview of motorcyclists;	8285	▶Young motorcyclists (aged 15-35) were not strictly obeying traffic laws
Pibool and Taneerananon, 2012	*A Study of Crash Risk of Motorcyclists*	Analysis of collected field data and secondary data collected by police station and hospital	440	▶91 percent of motorcycle crash were consequence of human errors ▶Road defects contributed to 39 percent of motorcycle crashes ▶18 percent of motorcycle defects led to motorcycle crashes
Rojviroon, 2006	*Psychological and Safety Belief Factors Related to Safety Behavior In*	Interview young student 10th-12th grade school level	375	▶Intention, carefulness, good habit were main factors and could be

	Motorcycle Driving of The Young			described as safe driving behavior about 62.48%

Table 3: (Continued)

Authors	Title	Method/ Study design	Sample Size	Main Findings
Saisama, 2005	*Protective Behaviors Against Accident in Shuttle-Motorcycle Riding in District of Mueang Nakhon Pathom Province*	Interview of shuttle-motorcycle riders	364	▶The shuttle-motorcycle riders had an average knowledge of traffic law and high protective behaviors was high
Woratanarat et al., 2013	*Safety Riding Program and Motorcycle-Related Injuries in Thailand*	Interview of participants of safety riding program	3250	▶Motorcycle-related injury could be reduced by a safety riding program with 30% of license course and 29% of instruction course, respectively

3.2 INFRASTRUCTURE DEFECTS

Providing a safe road is a government responsibility. In terms of roadway or infrastructure safety, the impacts of roadway barrier or median on safety of motorcycle riders were higher than other automobile occupants. Even though they were designed to protect road users from road hazards, inadequate provisions of these safety devices had contributed to many roadside fatalities. In his in-depth investigations into roadside safety of highways in South Thailand, Somchainuek came to the conclusion that in thirty percent of the roadside crashes, the victims were killed by hitting roadside trees in clear zone, and motorcycle's involvement was three percent (Somchainuek et al., 2012, 2013).

Another study conducted in Australia and New Zealand show that the major causes of motorcyclist deaths involving roadside barriers were inappropriate speed and high level of alcohol or drug impairment (Jama et al., 2011). They found that single vehicle crash of a young male rider resulted in the most frequent fatality; and proposed that special consideration in the road design, especially at bends could help significantly reduce the number of motorcycle crashes on bends.

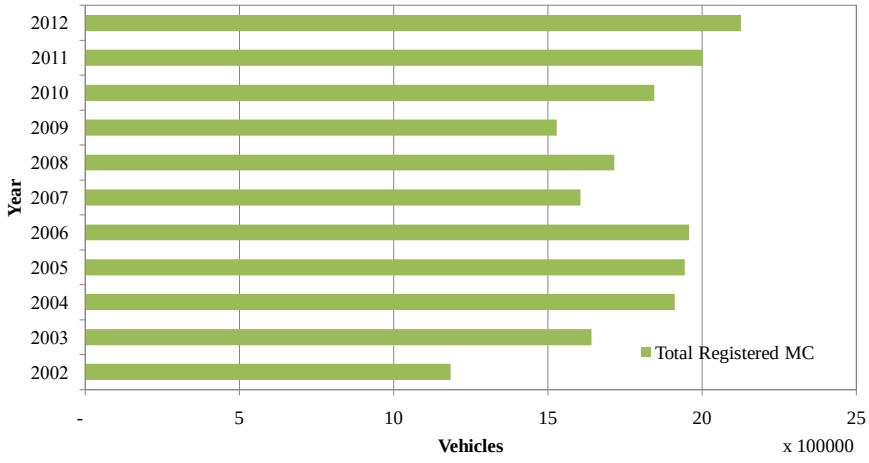

Figure 6: Registered Motorcycles (Department of Land Transport, 2013)

3.3 VEHICLE DEFECTS

Increasing vehicle safety is one of the five pillars of actions in the WHO global plan for decade of action for road safety 2011-2020. While the main thrust of vehicle safety is currently focused on the

implementation of vehicle crash avoidance technologies; very few research and development are focused on the motorcycle. This is unfortunate given the fact that the motorcycle is used extensively worldwide, and particularly in Asian region where it outnumbers cars and pick-ups by several folds.

Study by Kasantikul show that about 12.5 percent and 25 percent of motorcycle crashes in Bangkok and five upcountry provinces were single vehicle collision respectively. The highest crash types were rear-ending, falling on the roadway and running off the road, respectively (Kasantikul, 2001a, 2001b). The scooters or light weight motorcycles with engine capacity between over 50 cc to under 250 cc were the most common motorcycle involved in crashes. While a number of factors contributed to these crashes, motorcycle defects, especially stability of the motorcycle was identified as a main impact factor (ACEM, 2006). Similarly, vehicle defects influencing motorcycle crashes were found to be substantial at 18 % (Pibool and Taneerananon, 2012). It is fair to say that these small motorcycles had less stability control systems and other safety instruments than those with larger engines e.g. Heavy Scooter over 250 cc, Sports Motorcycle and Touring Motorcycle with engine around 1000 cc. or more.

The stability of a motorcycle is influenced by inertia, gyroscopic effects, and righting effect due to trail and centrifugal force. While the motorcycle mass and velocity have significant impact on inertia effect, a study has shown that the moment of inertia of the wheel, steering moment, roll moment and yaw moment were particularly crucial components of gyroscopic effects (Cocco, 2004). In order to achieve stability, a motorcycle needed to have the control of driving dynamic properties at a lateral acceleration force greater than the available friction (Seiniger et al., 2012).

To identify dynamic instability conditions of motorcycle, roll angle, yaw angle and pitch or steering angle were normally used (Nenner et al, 2008, Ghosh and Mukhopadhyay, 2009, Chelli et al., 2010, Jamieson et al., 2013). Roll angle (see Figure 7) in particularly was a vital parameter with strong influence on the motorcycle stability. The degree of the angle normally depended on lateral acceleration and gravitational force of a motorcycle. Friction forces between the tire and road surface play an important role in motorcycle lateral acceleration. A flip-over of the two wheel vehicles could easily occur whether a small perturbation of a roll momentum was generated (Seiniger et al., 2010).

All dynamical parameters such as the wobble oscillations could be characterized by steering torque, steering angles and vehicle speed. Besides, the value of frequency and damping of motorcycle could generally express its stability. These normally can be measured by using appropriate sensors (Seiniger et al., 2010). Therefore, the experimental design and methodology on riding test need to be carefully considered for getting accurate data.

Many research works on motorcycle stability were conducted on larger machines such as HONDA CBR 1100XX, high performance sports motorcycle and BMW F800S (Jamieson et al., 2013, Cheli et al., 2010, Seiniger et al., 2010). However, there are very few research works on scooters or light weight motorcycles like the popular models in Thailand. It is important to gain good understanding of the stability of light weight motorcycle as in Thailand's model; in addition, other motorcycle defects which could potentially lead to motorcycle crashes should be investigated as a means to reducing motorcycle users' fatalities. To this end, an instrumented motorcycle should be the first priority option as it can help provide a strong, precise and consistent method in collecting essential data, as suggested by Yuen (Yuen et al., 2013).

Figure 8 displays the road traffic accident statistics happened in Thailand during the period of 2006 to 2010. The data was compiled from four main causes that initiate the accidents: (1) speeding, (2) alcohol, (3) vehicle defects, and (4) improper passing. Overall, it can be seen that the speeding was the most threat, except for the years of 2011 and 2012 that the highest number of accidents were caused by the vehicle defects. When considering for the whole period, it is clearly seen that from the years 2006 to 2010 the annual accidents caused by the vehicle defects were just approximately 1,100. Then, it was dramatically increased to about 12,000 for the years 2011 and 2012. This abnormal trend led the

authors to further investigate the matter. It was found that, after discussing with the personnel responsible for compiling the data, there were some changes with respect to the definitions of vehicle defect thereby generating the very unusual data. As such, this particular cause should be further studied and clarified. Regarding the improper passing, it was observed that the annual accidents caused by this were relatively consistent. For the alcohol, however, the data shows the very scattered trend.

Table 4 summarizes studies of motorcycle stability both experimental testing and simulation modeling. The studies by Cheli and Seiniger focused on preventive systems (Advanced Driver Assistance System) and active safety system (Motorcycle Anti-Lock Brake Systems) for motorcycle. The simulation modeling focused motorcycle stability control. There are comparatively few experimental studies on small engine capacity motorcycles like the light weight motorcycle or scooter widely used in Thailand in attempts to examine the stability during all riding conditions.

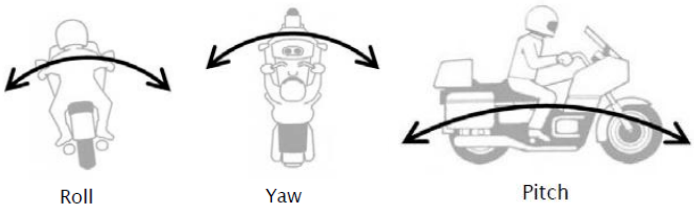

Figure 7: Roll, Yaw and Pitch (Jamieson et al., 2013)

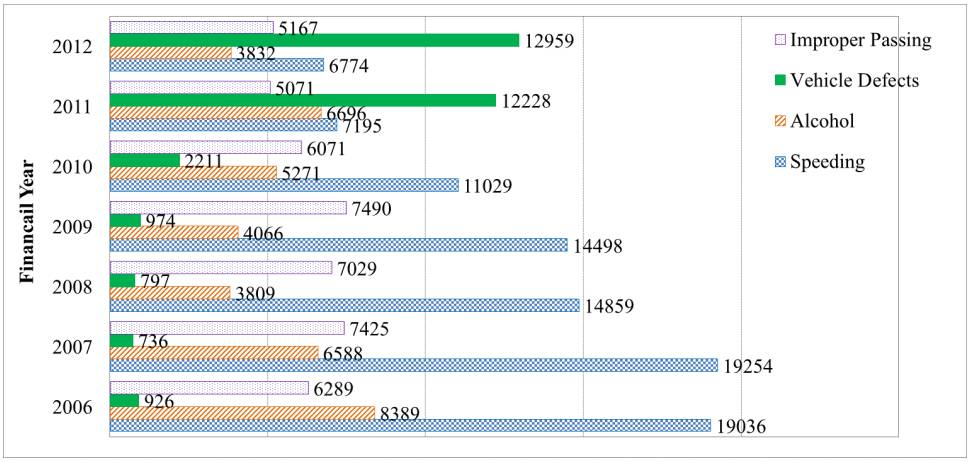

Figure 8: Four Major Causes of Thai Road Traffic Accidents (Royal Thai Police, 2013)

Table 4: Studies investigating the stability of motorcycle

Authors	Title	Method/ Experiment/ Vehicle	Performance Measure	Main Findings
Cheli et al. (2010)	*Motorcycle Dynamic Stability Monitoring During Standard Riding Conditions*	a high performance sports motorcycle	▸steering angle ▸lateral acceleration	▸Advanced Driver Assistance System (ADAS) able to identify a dynamic instability of a generic motorcycle
Ghosh and Mukhopadhyay (2009)	*Stability Analysis of a Two-wheeler during Curve Negotiation under Braking*	Study the response of roll angle by using the simulation	▸Root locus at various speeds under different braking conditions ▸roll angle	▸The roll behavior deteriorate with the applying of braking force during a turn

				▸The increased mass of motorcycle and the reducing of front wheel trail could lead to more unstable condition of motorcycle

Table 4: (Continued)

Authors	Title	Method/ Experiment/ Vehicle	Performance Measure	Main Findings
Jamieson et al. (2013)	*Stability of motorcycles on audio tactile profiled (ATP) roadmarkings*	Full-scale physical test with HONDA CBR 1100XX and simulation modeling with PC-Crash	▸vertical rear wheel load ▸vertical accelerations of the front & rear wheel ▸pitch, roll, and yaw ▸longitudinal (x-axis), lateral (y-axis), and vertical (z-axis) accelerations	▸No evidence refers that ATP roadmarkings create any instability matter for motorcycle
Nenner et al. (2008)	*Robust Stabilization of an Unmanned Motorcycle*	Develop an equation of motion for a motorcycle and design a robust cascade control using A 50 cc scooter with automatic variable transmission as the experimental system	▸throttle ▸brake force ▸roll angle ▸roll rate ▸steering angle ▸24 physical properties of motorcycle	▸ The simulation model of unmanned motorcycle using a robust cascade feedback controller could be stabilized the motorcycle for velocity ranging from 2 m/s to 6.5 m/s.
Seiniger et al., 2010	*Perspectives for motorcycle stability control systems*	Detect critical driving situation of Motorcycle Anti-Lock Brake Systems of BMW F800S	▸throttle ▸brake force ▸roll angle ▸roll rate ▸steering angle ▸24 physical properties of motorcycle	▸Motorcycle Anti-Lock Brake Systems (ABSs) have a positive effect on motorcycle and have the potential to reduce motorcycle fatalities ▸Vehicle dynamics control systems will be possible device for common motorcycle ▸ Full Electronic Stability Control for motorcycles will not be possible in the near future.
Zhang et al. (2011)	*Balance Control and Analysis of Stationary Riderless Motorcycles*	Analysis and estimated the domain of attraction (DOA) by using the Rutgers autonomous motorcycle	▸attitude rates and acceleration ▸ steering angle ▸roll and yaw angle	▸The balancing control of stationary motorcycle is quite hard due to the DOA estimate is small.

4. FUTURE WORKS

The general question considered here is: Do the Thai light weight motorcycles or scooters have different safety standards to similar models in other countries? Hence, the author's future work will involve in-depth review of related research works in order to investigate critical factors in motorcycle crash causation. Focus will be given to the vehicle factors that dominate the motorcycle stability.

Experiments will be conducted to examine the potential dynamic properties of motorcycle on its stability. These comprise two parts: the subsystem and the whole vehicle. For the first part, the effect of wheel/tyre combination on the gyroscopic moment will be investigated using the pendulum method. For the second part, riding tests will be conducted to determine the stability. The strength run test and the slalom test with instrumented motorcycles will be verified in order to measure the frequency and damping of the motorcycles. The expected outcome of this study will help create better understanding of key factors influencing motorcycle stability.

5. DISCUSSION AND CONCLUSIONS

It is obviously clear that most studies on motorcycle safety, particularly in Thailand, have focused more on motorcycle rider's behavior aspect than other elements of motorcycle crashes. These elements, road infrastructure defects and vehicle defects are significant in the chain of events leading to motorcycle crashes. They should be strongly considered and addressed in order to enable systemic elimination of all risks causing motorcycle crashes. As it has been noted, the current research works in Thailand do not touch on the stability aspect of light weight motorcycles that are widely used in Thailand and neighboring countries. Therefore it is essential to conduct more research into the stability of motorcycle and its impacts on motorcycle crashes. Physical and riding tests should be employed. The installation of motorcycle with powerful measuring devices such as sensors, accelerometers, gyroscope and also data loggers are required for measuring the dynamical parameters related to motorcycle stability. This research tool can provide the consistent and accurate data. The results that proved by riding experiment have permitted both researchers and designers to investigate, to compare, and to develop new safety devices or systems; which is not only for racing motorcycles but it is also for typical scooters and light weight motorcycles that are popular in Thailand and other Asian countries.

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