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Development of Composite Motorcycling Safety Index along Urban Roads in Malaysia

A. P. Tan[*1], H. Hamid[1], T. H. Law[1], F. M. Jakarni[1] and S. V. Wong[2]

[1]Department of Civil Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[2]Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

[*]*Corresponding author: aiping153@gmail.com*

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Abstract – *Motorcycle is a preferred private transportation mode (45%) among Malaysian due to its affordability and eases to move around especially in the hectic urban areas. These vulnerable road users are exposed to greater risk in road collisions due to sharing the roadway with other motor vehicles and unprotected. Worse still, the road was designed without concern for the motorcycle's characteristics. No doubt, segregating motorcycles exclusively from the roadway is an effective engineering measure to address motorcycle safety. But it may not be feasible to introduce in the well-built urban areas. Identification of the road and traffic variables that affecting safe motorcycling in the urban roadway is an initiative to create a safer riding environment. The initial study was carried out to identified traffic and roadway variables that affecting safe motorcycling. The seven pre-determined variables that were found to significantly influencing Malaysian motorcycle riders' safety perception are: pavement condition, paved shoulder width, posted speed limit, mixed traffic volume, type of roadway, lane width, and parking condition. These pre-determined variables were further investigated in the subsequent study, questionnaire with fourteen short video clips representing different traffic and roadway conditions was aired to 483 respondents to rate the motorcycling safety score (MSS) based on their safe riding perception. The response on MSS was further developed into Motorcycling Safety Index (MSI). Lastly, 114 combinations of different traffic and roadway conditions for seven pre-determined variables were formed to establish the Composite MSI boundary. The development of Composite MSI is to enable the road authorities and agencies and/or practitioners to assess the problematic road segments that required immediate remedial actions.*

Keywords: Urban road, mixed traffic, safe motorcycling, traffic and roadway variables, Composite Motorcycling Safety Index (Composite MSI)

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1.0 INTRODUCTION

The rising number of injury and death which related to road traffic accident has alarmed the transportation research all around the world to focus on the global crisis of road safety issues. According to the road safety assessment carried out by the World Health Organization (WHO, 2004), over 178 countries have found that road collision fatalities are predicted to increase to 2.4 million by the year 2030. Over 90% of the world's road fatalities occur in low-income and middle-income countries if no new intervention is taken to resolve this public health epidemic, particularly in Asia (WHO, 2009). It is expected that half of those killed has come from vulnerable road users which include motorcyclists, bicyclists, and pedestrians. Traffic accidents are projected to increase rapidly in years to come in the developing countries and this outbreak may worsen those developing countries with promptly increasing in the number of vehicles. Various studies have been carried out in developing countries (Hubbard et al., 2007; Oluwadiya et al., 2009; Solagberu et al., 2006), all provide insight to tackle this epidemic from severely spreading around.

Malaysia has been undergoing rapid growth in population, industrialization, and motorization. Based on the population estimation by the Department of Statistics Malaysia, the population in Malaysia will reach 32,049,700 inhabitants in 2017. The increase of approximately 2.5% of the population per annum over the years has indirectly led to the increase of registered vehicles in Malaysia. Comparably to other Asia countries, many Malaysian opts for the motorcycle as their preferred personal transport as it is least pricy to own one, fuel-saving, and easy to move around especially in the hectic urban area. Yet, the statistic revealed the uppermost road fatalities involved motorcycle riders and the rate was ascending over the years. An alarming remark was recorded in the year 2017, where the motorcycle-related fatalities rate had reached 64.5% (PDRM, 2018). Previously, motorcycle-related accident fatalities rates were between 59.7% to 62.7% (2008 to 2016) (JKJR, 2018). When life is valued at 1.3 million Ringgit on fatalities, the outcome has been staggering lost as high as RM 9.3 billion in the year 2016 alone to the road crashes involved purely on fatalities (MIROS, 2017). Those lives squandered in road crashes are intolerable and mitigation actions should be taken to reduce the number of road fatalities. Thus, motorcycle users are the key group to be targeted to reduce the national fatality number.

The current roadway design guidelines used in Malaysia were mainly based on the drivers' and automobiles' characteristics, thus it may not be ideal for the road segments that have a significant presence of motorcycles. The problem arose in highly motorcycled countries where motorcycles need to share road space with other motor vehicles. The potential of conflicts is prevalent when motorcycle riders ride in a spacious manner rather than moves in a headway manner (Hussain et al., 2005).

Motorcycle riders were classified as vulnerable road users such as pedestrians and bicyclists due to lack of a protective layer between motorcycle riders and other vehicles and/or the road itself that susceptible to severe injuries. Therefore, an effective engineering measure to protect the motorcycle is by segregating them from the mixed traffic. The introduction of exclusive motorcycle lanes along the Federal Highway Route 2 in Selangor proved the reduction of a motorcycle accidents by 39% and fatalities by 600% (Radin et al., 1995). However, when dealing with urban major trunks and arterial roads with many access points, short link, intersections, and limitations in road space, the idea of segregation may be impractical. The municipal roads had contributed an average of 19.5% of the total road

accidents fatalities between the year 2000-2011 (Darma et al., 2017). Conjure up with life valued RM1.3 Million per fatality, the life cost loss due to fatalities accidents in municipal urban roads is reaching RM1.8 Billion, which significantly added great loss to the country. PDRM reported that the highest number of accident frequencies occurred within municipal roads (PDRM, 2009). Yet, little attention was given to motorcycle studies within urban municipal roads in Malaysia compared to other developing countries likes Puerto Rico, Taiwan, Thailand, or Vietnam (Alberto et al., 2008; Chu et al., 2005a, Chu et al., 2005b; Liu et al., 2008; Nguyen et al., 2007; Terdsak & Charong, 2005).

Since the '90s, various proactive actions were taken by the government to create better road safety conditions and results in Malaysia (Eusofe & Evdorides, 2017). For instance, a road safety audit has been implemented in Malaysia in 1997 with the aim to impart the road safety aspects into road design, detecting deficiencies in road safety measures, and auditing the road condition (Karim et al., 2003). This proactive low-cost measure was originally developed and introduced in the United Kingdom in 1989. The benefit of the road safety audit method was soon recognized by many other professionals around the world.

In general, the roads in Malaysia are classified into two main categories, i.e. Federal and State roads. All roads declared under the Federal Roads Ordinance (1959) and the major interurban roads linking the state capitals and roads joining to points of entry to and exit from the country shall be categorized under Federal Roads. Public Work Department (PWD) and Malaysia Highway Authority (MHA) are the key administrative agencies for the planning, design, construction, maintenance, and upgrading works of Federal Roads. State Roads consist of the primary roads providing intra-state travel between the district administrative centers, rural inhabited areas, and the urban municipalities. Road networks in Malaysia are interconnected between expressway, highway, arterial, collector, and local roads. Unfortunately, each of the road category may be under different administrative agencies. The road design used in Malaysia is standardized across the nation but not on the road safety requirements. It is still non-compulsory to perform road safety audits on the arterial, collector and local roads, which is under the responsibility of local authorities. The effectiveness of this method over the existing road sections heavily burdened by accidents issues is relatively low (Karim et al., 2003; Pietrantionio & Bornszein, 2010). Road sections were chosen or prioritization of the project to be audited is relying greatly on the crash data, where the crash data takes sometimes to be published by the relevant government agencies. With the constraint to obtain the instant crash data, it may prolong the identification of the problematic road sections and the safety level improvement on the exiting road sections is unable to be accomplished instantaneously. The crash data is normally being used to interpret the value of life wasted in road accidents and countries' safety status (Melhuish, 2003; WHO, 2013). However, the quality of crash data is highly essential, especially when relates to the evaluation of road safety status. Mindful, crash data normally is relating to the under-reporting issues as well especially when an accident involves vehicle damages without any injuries is often under-reported. This may lead to misleading during prioritization of identification of actual locations that need immediate road safety improvements works.

As per aforementioned, presently road design standards and guidelines mainly used in Malaysia that known as *Arahan Teknik Jalan* (ATJ) and Malaysian Highway Authority (MHA/LLM) Design Guidelines derived from guidelines named "A Policy on the Geometric Design of Highways and Streets", which is better known as "Green Book" and published by the American Association of State Highway Transportation Officials (AASHTO). Despite the

good establishment of this guideline, it was developed based on the automobile characteristics in the United States of America. Different traffic composition was observed between Malaysia and the U.S., where motorcycle falls under the local composition, while the proportion of motorcycle is insignificant in the U.S. Besides, Malaysian riders, who majorly use smaller motorcycles of 110 cc engine size, do not have a preference for high-powered motorcycles. Accordingly, road design standards and guidelines used in Malaysia, which mainly refer to automobile characteristics, may not be suitable with motorcycles especially on the roadway with substantial motorcycle volume.

The guidelines (JKR, 2015a; JKR, 2018) are the key references made available for designing motorcycle facilities in Malaysia. However, these guidelines mainly covered exclusive and non-exclusive motorcycle lanes with separators and designated pavement marking to define the motorcycle lane facilities. The non-exclusive motorcycle lane involved verge, marginal strip, and paved shoulder are not accentuated. Currently, the available guidelines are emphasized on the segregation of motorcycle paths from mixed traffic and were not being fully synchronized with the other existing guidelines on the mainstream geometric design and configuration. For instance, in the latest edition of geometric design of road guidelines (JKR, 2015b), was not reviewed on the paved shoulder width in the mainstream road design that ideal to be utilized by motorcycles. The previous study on the motorcycle riders' behavior towards usage of motorcycle facilities corroborated that paved shoulder was one of three common types of motorcycle lanes in Malaysia and its usage is made mandatory by law and other motorists are prohibited from the paved shoulder unless in the emergency condition (Abdul Sukor & Satoshi, 2011). Under road geometric design guidelines (JKR, 2015b), the width of the paved shoulder is varying from 1.5 to 3.0 meters and it is depending on the standards of the attached roads. Adverse effects to motorcycle riders may take place if the overlay wide paved shoulder is provided. From the above-mentioned, it can be concluded that current road design guidelines, which also use as a basis in road safety audit in Malaysia still has gaps to fill in respect of motorcycle safety concern, especially on the mixed traffic road environment.

The roadway environment influences road crashes as it determines the road user's perception of the environment and provided information to the road users on the necessary actions for them. Poor road design, which includes the negative road engineering elements and road defects, may result in a collision. Furthermore, misleading road environment elements would also mislead the road user and create potential human errors. In the '70s, Dr. William Haddon Jr. (1972) developed a matrix representing the series of events in a road crash, where human, vehicles, and roadway environment factors were found to contribute to road crashes. According to Highway Safety Manual (HSM) published by AASHTO (2010), road environment factors led to 3% of road crashes, while 34% of road crashes were caused by a combination of the road environment and other factors. A study by Rudin-brown et al. (2014) found that the contribution of road environment factors towards road crash occurrences was accepted by scholars based on the evidence that road environment complexity was highly correlated to the high risk to drivers. Although the road environment factor was not the main factor leading to road crashes, it was easier to be controlled and predicted through investigation compared to the human factor.

Understanding motorcycle riders' safety perception is essential to ensure practical engineering approaches are implemented along the road sections with high motorcycle volume. Though the rider complex problems may not be easily measured, the roadway environment and

traffic do play a major role in their perception of safe motorcycling. Likewise, motorcycling behavior may influence by traffic and roadways conditions. In consideration of the limited study on motorcycling in the mixed traffic, cross-references on passenger cars and other vulnerable road users on the road safety and comfortability perception were signified in determining the attributes to be included in this study.

Many previous studies recorded the interrelation between traffic and roadway attributes. To illustrate, Allen et al.'s (2017) investigation on the contributing factor of motorcycle injury crashes in Austria reported that apart from the human errors, the traffic and road environment factors, including traffic density and speed, were found to be significantly associated with the multivehicle crashes between the powered two-wheelers vehicle and other road users. A total of 235 riders with previous experience in road crash injuries were recruited into a questionnaire-based interview. In Milling et al.'s (2016) study to explore the improvement of road infrastructure to reduce motorcycle casualties, it was found that lane width, shoulder width, and condition of road surface were parts of the identified road environment factors influencing the likelihood of motorcycle crash in Australia.

Motorcycle has smaller size and eases motorcyclist to maneuver around particularly in heavy traffic in urban networks. Most people are considered motorcycles as their preferred mode of transport as it can be a ride along with other vehicles and not subjected to the lane-based progression, which enables them to travel faster compared to other modes of transport. Research in New Zealand discovered that the possibility for motorcycle and scooter riders to exceed the speed limit was approximately 3.4 times higher compared to other road users (Walton & Buchanan, 2012). It was also found that the mean motorcycle speed was independent of lane positioning. A similar finding was also observed in a study related to motorcycle speed in Malaysia (Abdul Manan et al., 2017). The researchers found that the motorcyclists were shown with a propensity in exceeding the speed limit (42.2%) and 28.6% of the motorcyclists traveled beyond the 85th percentile of the traveling speed of other road users. This study also found that the tendency of the motorcyclists, which exceeded the 85th percentile speed of other road users, was lower when they traveled on the paved shoulder or road with the shoulder at the dual and single carriageway. Although the speed limit served as a guide for the road users to travel safely in an average condition, many of the road users exceeded the speed limit. This finding was in line with the finding made by Kanellaidis et al. (2000), where drivers often overlooked the posted speed limit, which led to speeding violations. Another speed-related study (Goldenbeld & Van Schagen, 2007) revealed that road and roadside features affect the credibility of speed limits. The driving speed was often 10% faster compared to the speed on the road with 80 km/h posted speed limits. Although most of the speed-related studies were related to the car driver, a close correlation with the safety of motorcycle riders was present particularly when they traveled on mixed traffic roadways.

The case study on motorcycle crashes in Colombia found that wider urban road was another recurrent contributory factor, besides motorcycle group accidents, inexperienced motorcyclists, and infrequent infrastructure maintenance factors (Jimenez et al., 2015). Wider urban roads were believed to lead to speeding and risky overtaking maneuvers in high traffic flow rates. The influence of the lane width has a strong correlation with the driving speed. It was found that the driving speeds could be reduced on the road lane with 2.5 m width. However, a minor difference was present between the driving speed on the lane width of 3.0 m and 3.6 m (Godley et al., 2004). The study by Abdul Manan et al. (2017) also revealed that the

percentage of the motorcyclist exceeding 85th percentile speed of other road users positively increased with the increase in the road width.

Another study on the design factor effects on speed found that lane width strongly impacted the straight roads in suburban, indicating that higher speeds were expected on larger lane width (Fitzpatrick et al., 2000). It was also found that the presence of the median with roadside development influenced the speed choice on the curve road sections. Besides, the type of road was also found to influence road user safety. The experiment performed by Filders et al. (1987) recorded that the type of road led to a significant impact on the mean speed in an urban area. The free speed measured varied posted speed limit based on the road type. Narrow-divided roads resulted in a reduction in speed, which was associated with an increase of perceived safety comparing to the wide-divided road.

Based on the study by Damant-Sirois and El-Genedy (2015) in a bicyclist study done in Canada, the perception of safety was found to be the key influential factor of the frequency of cycling. Therefore, understanding the factors influencing cyclists' perception is essential to create a safe ambiance for riding. The level of bicycling could be increased by improving the perceived safety of bicycling infrastructure. Some similarities in the traffic and road environmental factors were found to affect the safety perception of cyclists and motorcyclists. For instance, Highway Capacity Manual (2010) took traffic and road environments factors into accounts, such as pavement condition, parking, lane width, number of through lanes, speed, traffic volume, and percentage of the heavy vehicle when evaluating the bicycle Level-of-Service (LOS) for the urban street.

In another bicyclist-related study (Sener et al., 2009) found that the bicyclists, in general, preferred to ride on the routes with lower traffic volume and speed limits and often avoided high-speed limit roadways due to increased safety hazards. Alongside traffic volume and speed limit attributes, this comprehensive study also considered other attributes, such as parking, bicycle lane, and paved shoulder lane width. It was also found that bicyclists preferred to ride on the routes with continuous bicycle facilities and no parking. Comparatively, the study performed by Li et al. (2012) in Nanjing, China on the physical environments influencing the bicyclists' perception of comfort recorded that the cyclists' comfort for on-street bicycle facilities was reduced when faced with heavy motor vehicle volumes. The negative impact was possibly due to exposure to a higher risk of potential collision when sharing space with other road users. Other variables, including lane width and parking, were parts of the variables recorded to positively increase the cycling comfort.

A study performed in Ottawa, Canada on six mixed traffic sites discovered that speed, lane width, traffic volume, presence of parking, and the number of lanes were significant in the bicycle comfort perception (Apasnore et al., 2017). Other findings were recorded that lanes wider than 4.5 m allowed other motor vehicles to increase speed beyond the permitted speed limit, leading to a negative impact on bicycling comfort, which was found comparable to the previous motorcycles studies (Abdul Manan et al., 2017; Jimenez et al., 2015). However, the researchers did not suggest the provision of on-street parking on the roadway with a width lesser than 3.6 m. The previous study (Schramm & Rakotonirainy, 2009) that investigated the impact of lane width on cyclist safety in an urban, also suggested that the reduction of the lane width of fewer than 3.5 m might create a safer road environment. Whereas Kimer and Penha (2011) affirmed that two major factors promoting bicycling were lane width and motor vehicle

speed, which originated from 14 attributes describing the quality of road environments in Brazilian Cities.

Notably finding were developed by Klop & Khattak (1999), where the interaction between the speed limit and shoulder-width variables significantly impacted the bicyclist injury severity. On top of that, a negative trend was observed between the average annual daily traffic and injury severity due to a crash, while lower average annual daily traffic was found to be highly associated with increased injury severity. Another study performed on urban bicycle route safety also found that the direction of traffic volume was counterintuitive due to operating speed. As the traffic volume reached its capacity, the operating speed might decrease, with a likelihood of reducing the injury severity during a crash (Allen-Munley et al., 2004).

Pavement condition is an imperative factor to be deliberated as it impacts the quality of bicycling. Besides speed and curb lane width factors, other environmental factors, including surface quality and traffic volume, were found to be the important factors considered during the selection of cycling routes based on a survey conducted on 552 cyclists in Michigan (Antonakos, 1994). Meanwhile, Winters et al. (2011) recorded that uneven road surface and/or damaged road surface (potholes) was a part of the road environment factors, which were the deterrents to cycling.

Parking was another significant factor in the cyclists' comfort perception (Li et al., 2012). Bicyclists would commonly opt for a route alternative, which had no on-street parking next to bicycle lanes (Sanders, 2013). The presence of parking could risk the cyclists' safety due to the likelihood of the door opening and vehicle pulling out from the parking. A similar result was obtained by Tesche et al. (2012), who indicated that the major street with no car parking was safer compared to the car parking roadway in their bicyclists' route preference survey in Metro Vancouver. It was also found that most cyclists preferred to ride on facilities with low traffic compared to the dense roadway, which was associated with a higher risk of crashes.

Based on afore cross-references, the traffic and road environment characteristics that have a likely impact on motorcycling safety is designed to unravel several inquiries. In an attempt to validate that the identified variables as perceived by Malaysian motorcycle riders, a structured dichotomous questionnaire that embraced paved shoulder width, parking condition, lane width, mixed traffic volume, posted speed limit, pavement condition, and roadway configuration was assembled. Motorcycle riders were randomly selected, and 137 questionnaires were distributed around Klang Valley in the initial stage before this study. The pre-determined variables that significantly influence safe motorcycling are identified and ranked in descending order of pavement condition, paved shoulder width, posted speed limit, mixed traffic volume, the configuration of roadways, lane width, and parking condition (Hamid et al., 2019).

The main objective of this study is to determine the Motorcycling Safety Index (MSI) for the different conditions of pre-determined variables that affecting the motorcycle riders' safety perception. Secondly, the study is aimed to establish the Composite Motorcycling Safety Index (Composite MSI) boundary that can be used by the transportation and highway engineering fraternity to measure the safe motorcycling level of a specific road segment without relying on the crash data and professional judgment.

2.0 MATERIALS AND METHODS

The variables that influencing motorcycle riders' safety perception were pre-determined prior to embarking on this study. In this study, a questionnaire with the aid of short video clips associated with the pre-determined variables was adopted. Various on-the-ride video slots were captured at the different road segments and traffic conditions within the urban area. Concerning the response timeframe to complete the questionnaire not encumbrance to the respondent, the range of each identified variable is limited to two scenarios. Every short video clip was control at eight seconds capturing two different types of paved shoulder width, parking condition, lane width, mixed traffic volume, posted speed limit, pavement condition, and roadway configuration. A total of fourteen short video clips were aired to respondents together with a set of questionnaires form. A pilot study among 30 respondents was conducted before embarking on actual data collection. In order to ensure the short video clips are feasible, Krippendorff's Alpha analysis was performed. A positive result with relatively high intercoder reliability ($\alpha = 0.7642$) obtained infers respondent has no difficulty to figure out the video slots captured and able to answer questionnaire proficiently. The actual time is taken to answer the questionnaire also was recorded to obtain a brief idea of fair time allocation for each interviewee in the actual data collection stage. This information is essential since this study was involved a great number of interviewees and the assistance of enumerators due to the wide coverage of study areas. Eventually, face to face questionnaire survey with the aid of short video clips was conducted on 526 motorcyclists representing all regions in Malaysia. However, after excluding missing data, only 483 complete sets of questionnaires were considered in this study. The coverage of study areas is tabulated in Table 1.

Table 1: The coverage of study area

No.	Region	Coverage Area
1	*Northern	Kedah, Pulau Pinang, Perak, and Perlis
2	*Centre	Kuala Lumpur, Selangor and Negeri Sembilan
3	*Southern	Melaka and Johor
4	*East Cost	Kelantan, Terengganu and Pahang
5	East Malaysia	Sabah and Sarawak

Denote: '' – West Malaysia*

The Motorcycling Safety Index (MSI) for each variable under different conditions was developed based on the motorcycling safety score (MSS) rated by the respondent. The response to the questions was answered using a five scale of motorcycle safety score level of "very safe", "safe", "not so safe", "dangerous", and "very dangerous" in accordance with each video clip on their safe motorcycling perception. Then, the odds ratio of safe motorcycling under different conditions is computed to understand the motorcycle riders' perceptions towards safe riding on seven pre-determined variables. At the same time, a Chi-square test is performed to check the significant difference between the responses and the respective variables. At the final stage, the total of 114 combinations of the Composite Motorcycling Safety Index based on the summation of MSI of seven variables under different conditions is corroborated. The minimum and maximum range of the Composite Motorcycling Safety Index is determined.

3.0 RESULTS

This study involved a total of 483 responses from all regions in Malaysia, where the data was collected and analyzed from West Malaysia of Northern (26.9%), Central (33.5%), Southern (10.6%), East Coast (12.6%), and East Malaysia (16.4%) regions. According to Transport Statistic Malaysia, the total number of accidents involved central and northern regions constitutes approximately 67.4% in 2017 (JPJ, 2018). Hence, these two regions were prioritized with approximately 60% of the survey was gathered from these areas. The respondents are comprised of 68% male and 32% female motorcycle riders aged between 17 and 69 years old. 77% of the respondents use the motorcycle in their daily routines to the educational institution or workplace and/or leisure purposes, whereas 23% ride an ad-hoc basis. Riding experience among respondents varies from 1 to 47 years with 64% of motorcycle riders has more than five years of the motorcycling experience. The majority of the respondents (79%) not solely holding motorcycle riding licenses, they possessed other classes of driving license as well. 80% of the respondents are riding the motorcycle with engine capacity size of not more than 125cc. More than half of respondents (57%) had been involved in motorcycle accidents before while 52% have family members involved in a road accident.

The questionnaire was designed and emphasized how safe a motorcycle rider perceives when revealed with a specific roadway or traffic conditions. The seven pre-determined variables are to be ranked following their importance based on the motorcycling safety score (MSS) input by respondents. The perceived MSS of each of the 14 short video clips by the 483 motorcycle riders is as presented in Table 2. The perceived MSS of "SAFE" is obtained from the summation of: "1-very safe" and "2-safe". While the perceived MSS of "UNSAFE" is the totting up from the scales: "3-not so safe", "4-dangerous" and "5-very dangerous". Subsequently, the Motorcycling Safety Index (MSI) computed is computed as:

$$MSI = (MSS_{very\ safe} + MSS_{safe}) \div (MSS_{not\ so\ safe} + MSS_{dangerous} + MSS_{very\ dangerous}) \quad (1)$$

Table 2: Motorcycling Safety Score (MSS) and Motorcycling Safety Index (MSI) under different traffic and roadway conditions

		Perceived Motorcycling Safety Score (MSS)					Motorcycling Safety Index (MSI)
		SAFE		UNSAFE			
		1	2	3	4	5	
Paved shoulder width	Wide (> 1.50m)	270	159	39	9	6	7.94
	Narrow (≤ 1.50m)	36	328	101	9	6	3.06
Posted speed limit	≤ 60 km/h	57	337	75	7	7	4.43
	> 60 km/h	37	200	171	58	17	0.96
Type of roadway	Divided (multilane)	153	283	33	7	7	9.28
	Undivided (2-way)	88	136	137	85	37	0.86
Mixed traffic volume	Low (< 800 pcu/h)	17	273	166	20	7	1.50
	High (> 800 pcu/h)	9	38	195	204	37	0.11
Lane width	Wide (> 3.00m)	218	181	63	16	5	4.75
	Narrow (≤ 3.00m)	16	86	252	100	29	0.27
Parking condition	Off-street	127	303	39	7	7	8.11
	On-street	16	62	258	115	32	0.19
Pavement condition	Good	297	165	9	5	7	22.00
	Damaged	8	120	275	71	9	0.36

As in Table 3, the majority of the respondents agreed that riding on the paved shoulder is safe. Only 11.2% and 24.6% of the respondents felt that it is unsafe to ride on the wide and narrow paved shoulder path, respectively. Most of the respondents felt it is safer to ride on the wider compared to narrower paved shoulders as it provides them a more lateral clear zone from interacting with other vehicles. The odds for perceived safe to ride on a wide paved shoulder is 2.597 times greater than riding on the narrow-paved shoulder path. The result also revealed that Malaysian motorcycle riders feel unsafe when traveling on the higher posted speed limit roadway (above 60 km/h). They perceived safer motorcycling on the lower posted speed limit roadway (60km/h and below) at the rate of 4.595 times higher than riding along the roadway with a higher posted limit (more than 60 km/h). Almost all (90.3%) of respondents agreed that traveling on the divided roadway is safe to compare to the undivided roadway. The odds of feeling safe motorcycling on the divided roadway is 10.726 times greater than riding on the undivided roadway. It is unavoidable that the motorcycle must share space with another motorist in mixed traffic conditions. Hence, the lane width is an important variable that determines the safe motorcycling level. The findings exhibit that motorcycle riders felt safer riding on wide lane width (82.6%) while 78.9% agreed that it was not safe to ride on narrow roadways. The odds of perceived safe motorcycling on the wide lanes is 17.743 times higher than narrow lanes.

Meanwhile, off-street parking seems to have relatively higher perceived MSS comparing to on-street parking, which implies the motorcycle riders feel safer when riding on the roadway without the presence of parking. Proneness involves in collision with parked vehicles is higher when motorcycle riders traveling along the roads with on-street parking facilities. The result revealed that the motorcycle riders perceived motorcycling on the off-street parking roadway as safer at the rate of 42.126 times greater than on-street parking roadway. The findings discovered that the prime concern to Malaysian motorcycle riders is pavement condition where 95.7% of the respondents feel safer dealing with the roadway with good pavement condition. The odds of safe motorcycling on the good pavement is 61.016 higher than traveling on the damaged pavement condition. Pavement conditions may not be the greatest concern to other motorists, but it gives a critical impact to motorcycle riders as the motorcycle is deferring from the other vehicles where only two wheels are intact with the pavement surface. A slight defect on the pavement surface may result in a mishap to the motorcycle. Hence, pavement quality should not be compromised as degradation of the pavement condition may increase the difficulty to handle and stabilize the motorcycle.

Subsequently, the Composite Motorcycling Safety Index (MSI) was computed by summation of Motorcycling Safety Index for seven variables under different conditions. A total of 114 different configurations collaborated with the Composite MSI ranging from 5.81 to 58.01. The lowest value of 5.81 indicates motorcycling safety is under unsafe or dangerous conditions. While the Composite MSI value of 58.01 represents the safest roadway condition. The Composite MSI boundary was established based on the combinations of different conditions and illustrated in Figure 1. The computation of the Composite MSI is as described below:

$$Composite\ MSI = MSI_{tf} + MSI_{v} + MSI_{pc} + MSI_{lw} + MSI_{r} + MSI_{ps} + MSI_{pc} \quad (2)$$

Where,

	Conditions	MSI Value
MSI_{tf}	Low traffic condition <= 800 pcu/h	1.50
	High traffic condition > 800 pcu/h	0.11
MSI_{v}	Posted speed limit <= 60 km/h	4.43
	Posted speed limit > 60km/h	0.96
MSI_{pc}	Good Pavement Condition	22.00
	Poor Pavement Condition	0.36
MSI_{lw}	Wide lane width > 3.00 m	4.75
	Narrow lane width >= 3.0 0m	0.27
MSI_{r}	Divided roadway	9.28
	Undivided roadway	0.86
MSI_{ps}	Wide paved shoulder width > 1.50m	7.94
	Narrow paved shoulder width <= 1.50m	3.06
MSI_{pc}	Off-street parking	8.11
	On-street parking	0.19

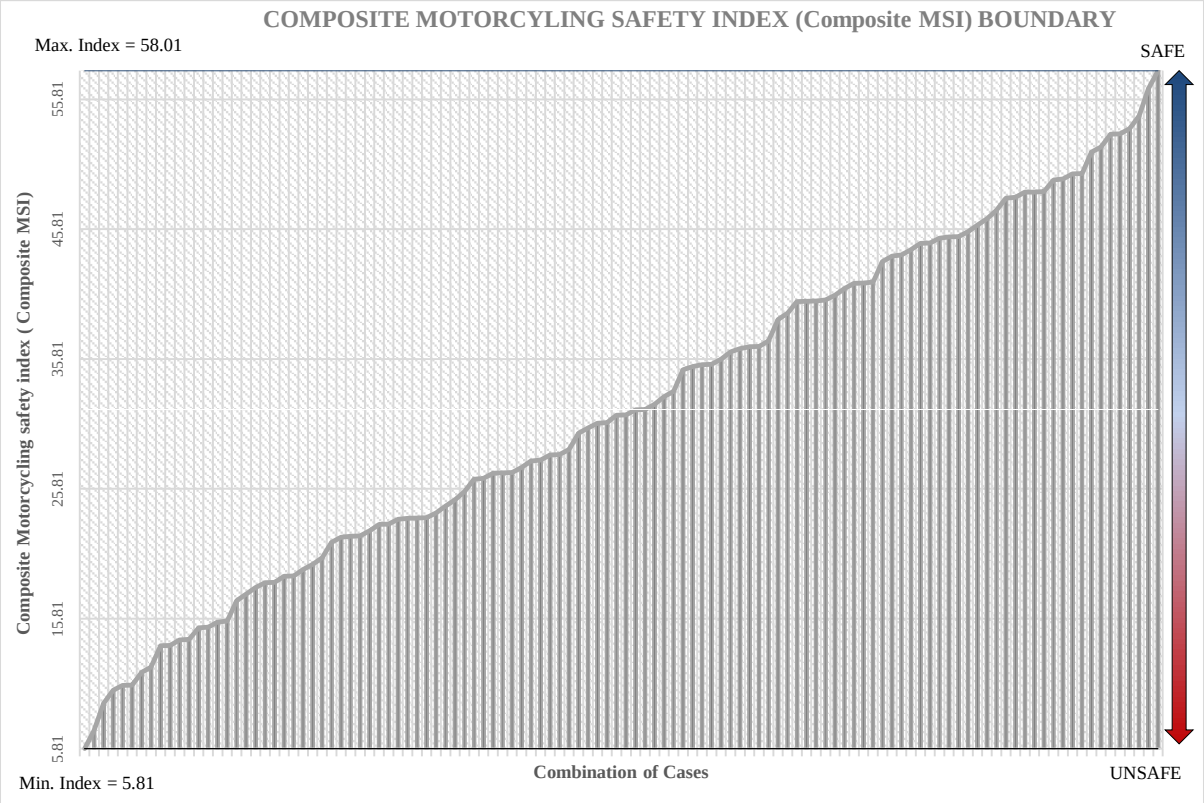

Figure 1: Composite Motorcycling Safety Index (Composite MSI) boundary

Table 3: Odd ratios for seven pre-determined variables under different traffic and roadway conditions (N = 483)

		Perceived MSS		Odd Ratio	95% Confidence Interval	
		SAFE	NOT SAFE		Lower	Upper
Paved shoulder width	Wide (> 1.50m)	429 (88.8%)	54 (11.2%)	2.597	1.829	3.688
	Narrow (≤ 1.50m)	364 (75.4%)	119 (24.6%)			
(χ2 =29.750, p<0.001)						
Posted speed limit	Low (≤ 60 km/h)	394 (81.6%)	89 (18.4%)	4.595	3.435	6.145
	High (> 60 km/h)	237 (49.1%)	246 (50.9%)			
(χ2 =112.642, p<0.001)						
Type of roadway	Divided (multilane)	436 (90.3%)	47 (9.7%)	10.726	7.558	15.222
	Undivided (2-way)	224 (46.4%)	259 (53.6%)			
(χ2 =214.973, p<0.001)						
Mixed traffic volume	Low (< 800 pcu/h)	290 (60.0%)	193 (40.0%)	13.939	9.806	19.814
	High (> 800 pcu/h)	47 (9.7%)	436 (90.3%)			
(χ2 =269.097, p<0.001)						
Lane width	Wide Lane Width (> 3.00 m)	399 (82.6%)	84 (17.4%)	17.743	12.870	24.461
	Narrow Lane Width (≤ 3.00m)	102 (21.1%)	381 (78.9%)			
(χ2 =365.763, p<0.001)						
Parking condition	Off-street	430 (89.0%)	53 (11.0%)	42.126	28.971	61.254
	On-street	78 (16.1%)	405 (83.9%)			
(χ2 =514.438, p<0.001)						
Pavement condition	Good	462 (95.7%)	21 (4.3%)	61.016	37.690	98.778
	Damaged	128 (26.5%)	355 (73.5%)			
(χ2 =485.769, p<0.001)						

4.0 DISCUSSION AND CONCLUSION

The seven pre-identified variables namely pavement condition, paved shoulder width, posted speed limit, mixed traffic volume, type of roadway, lane width, and parking condition, which were identified from the previous bicycle-related studies were found significant and resemblance the attributes that affecting the safe motorcycling were further investigate in this study (Apasnore et al., 2017; Li et al., 2012; Sanders, 2013; Sener et al., 2009; Tesche et al., 2012). One major reason being that is both motorcycles and bicycles are vulnerable road users that get entangled with other mixed vehicles when they are not segregated exclusively along roadways. Alike bicycles, the motorcycle is also an unprotected two-wheeler vehicle and needs momentum to stay balanced although it is motor-powered. It might have a difference in acceleration speed but the fundamental of handling and cornering movement will be quite

similar. In principle, the variables that affecting both vehicles are similar, but the extend that influencing safe riding might differ between motorcycle and bicycle.

The findings revealed that pavement condition is the variable that triggered motorcycle safety the most compared to other identified traffic and road environment variables. Malaysian motorcycle riders seem to feel safer when motorcycling on the good pavement comparing bad pavement conditions (OR = 61.016; 95% CI = 37.690, 98.778). Pavement condition is the most important variable to consider on safe riding for two-wheelers vehicles as they are unstable compare to other four-wheelers motor vehicles. Slight deviation on the pavement surface may give a great negative impact on motorcycle riders. The road surface with repaired patches, slippery surfaces, unevenness, longitudinal parallel grooves, road markings, drain covers, and gratings are may endanger motorcycle riders (Elliott et al., 2003). Worst still when motorcycling on the roadways with severe damages such as rutting, potholes, and/or on the bumpy roadways that facing ground settlement. This may be a challenging task for motorcycle riders in handling their motorcycle, especially for those who are new to motorcycling. Pavement condition is inevitably affecting the motorcycling safety and the likelihood of causing higher injury-severity level in multi-vehicle crashes are greater under poor pavement conditions (Lee et al., 2015). It is also created higher severity on high-speed roads when comes to single vehicles crashes. Pavement quality should not be compromised, and the maintenance of road pavement conditions must be put on high priority and continuous inspections on the existing road by the authorities are needed. Any potholes or pavement surface defects should be immediately rectified as they may expose motorcycle riders to single and/or multi-vehicle road crashes when riding across it. Attention also should give to the method on repaved works. The authorities should adopt milling of the existing pavement layer instead of opts for a simple way by overlying the new layer over the existing pavement during road resurfacing works. Improper road resurfacing methods may lead to various negative impacts on vulnerable road users. For instance, the topping up of the new pavement layer may cover the curb opening that obstructing smooth surface run-off and localized water ponding or flash flood may occur when there is a heavy downpour. Besides, without milling of the existing pavement layer during resurfacing works also may create inconsistent levels between underground utility manholes and road levels. Lower manholes level may endanger motorcycle riders and exposed them to the likelihood of road crashes involvement. For those roadways that are anticipated to have high motorcycle volumes, proper ground treatment should be considered during the construction stage, especially on the roadways that going to be built on the poor and/or soft ground conditions. This is to ensure the subgrade layer is properly treated and experienced minimal secondary settlement after construction. Stringent requirements on the allowable settlement after the construction period should be adopted on the roadways with significant motorcycle volume. Bumpy roadways are acceptable to other road users, but it gives a gravely negative impact on the motorcycle. As such, it is vital to conduct regular monitoring and well-maintained pavement. Apart from that, adopting good practices on road construction and pavement resurfacing works is essential to contribute and improve motorcycle safety.

In addition, the outcome of the study showed that motorcycle riders are feeling safer when riding on the roadway with off-street parking than on-street parking (OR = 42.126; 95% CI = 28.971, 61.252), which is alike with the findings in previous studies on bicyclist safety (Sanders, 2013; Sener et al., 2009; Tesche et al., 2012). The presence of on-street parking can create dangerous conditions for motorcycling when parking turnover can be a hazard when vehicles pulling into or out from parking lots without being aware of the presence of motorcycles. It may turn worst when the motorist is practicing front-in diagonal parking, which

creates poor visibility to other road users when the driver is backing out from the parking bay. Likewise, the motorcycle riders also were put in peril of dooring accidents when motorcycling on the roadway with parallel parking. Though it is the motorists' responsibility to check on the oncoming traffic before opening the door, an oversight or misjudgment on the oncoming motorcycles may occur. Unlike a bicycle, a motorcycle does not have the flexibility to change its preferred route and/or ride on the verge as it must follow the designated roadways and sharing the space with other vehicles.

Lane width and speed are always closely associated with one another. Wider lanes although offer greater space sharing with other vehicles and comfort riding to motorcycle riders on the other hand it may encouraging the road users to operate at higher speed, which may increase the risk of crash occurrence and severity of the injury. Lane width is identified as the key attribute to a bicyclist when evaluating the quality of bicycles in shared-use roadways (Providelo & Sanches, 2011). They are willing to ride on wider lane width provided other motorists are traveling at lower speeds. Although similar finding discovered in this study, where Malaysian motorcycle riders also perceived safer to ride on the roadway with wider lane width comparing to narrow road. Traveling speed is not a great matter to motorcycle riders in Malaysia as they are managed to ride uniformly with other motor vehicles and some even ride beyond the traveling speed of other motor vehicles (Abdul Manan et al., 2017). Lane width variable was found to be top three most influencing factors on motorcycling safety with the odds ratio (17.743) that they felt safer to ride on the roadway with wider comparing to narrow lane width. A previous study revealed that the ideal motorcycle operating width is 1.30m long and the motorcycle will apply the headway concept when traveling along a 1.70m motorcycle path (Hussain et al., 2005). With the average width of the passenger car 2.00m and other bigger size heavy vehicles, it is more challenging for a motorcyclist to deal in a shared road path. They shall only apply the headway concept on the narrow-shared road path and be subjected to accidents as the motorcycle may be blocked by larger vehicles and obstruct from another motorist's view. Respect from other vehicles is particularly important by allowing the motorcycle to ride on full lane width in the narrow-shared lane, which enabling motorcyclists to have enough room to maneuver safely.

This study discovered that the motorcycle riders in Malaysia were perceived they are 13.939 times safer to ride on the lower traffic volume comparing to higher traffic volume conditions. The result obtained seems to meet the initial prediction where we expected the motorcyclist to feel safer when riding on the free flow or low traffic volume condition compare to heavy traffic roadway. It is rather a challenging task when the motorcyclist must be sharing their riding path with other bigger size vehicles. When comes to heavier traffic condition, there will be lesser following distance, which allows the motorcyclist to ride on the safe path. It is recommended that the gap between other vehicles and motorcyclists have a safe traveling gap of at least three or four seconds (Pennsylvania Driver's Manual, 2019). This ideal condition is unachievable when the traffic volume is building up and occupied the space. The scenario may turn worst when the other vehicles are unaware of the motorcycles and tend to change lanes, especially during rush hours. A roadway with low traffic volume allows ample room for motorcycle riders to make a safe maneuver.

Normally, the median will be introduced at the higher hierarchy roadways, which come with a wider lane width and higher speed limit. Overtaking on the undivided road is challenging to motorcycle riders as slight misjudge on the overtaking gap may end up colliding with opposite oncoming vehicles or sideswipe with vehicles that he or she overtakes. The

findings from this study are concurred that type of roadway variable is significantly affecting safe motorcycling. The motorcycle riders feel safer when motorcycling along the divided road than along undivided roadway (OR = 10.726; 95% CI = 7.558, 15.222). Doubtless, lesser attention is needed when riding along the divided road as the divided roadway has lesser access points and can sway away from a head-on collision. Although divided roadway permits the motorcycle riders to ride in lesser hassle on the other hand it allows them to ride at higher speed, which may increase the crash severity. Narrow-divided roads were perceived safer than wide divided roads (Abdul Manan et al., 2017). Although a divided roadway is safer for motorcycling, understanding the impact of lane width at the roadway with the presence of roadway also is relatively important and shall be further explored in future research.

Malaysian motorcycle riders appeared to feel safer riding on the roadways with a posted speed limit that 60km/h and below compared to the posted speed limit of more than 60km/h. The odds of motorcycle riders feeling safer to ride on the roadways with lower speed limits (60km/h and below) is 4.959 times greater than riding on the higher speed limit (above 60km/h) roadways. Seems, Malaysian riders are comfortable with the urban roadway that exhibit narrower roadways with typical standard posted speed limit of below 60km/h compared to those free flow section with a posted limit higher than 60km/h. Probably, motorcycling speed can pull alongside other motor vehicle traveling speed when comes to 60km/h and below posted speed limit roadways. But motorcycle riders are facing hurdles to ride at the same speed as other motor vehicles at the higher posted speed roadway because of limited engine capacity. This imitated the findings discovered in a study in Texas (Sener et al., 2009), where the researchers encountered the roadways with lower speed limits is preferred by the bicyclist.

The paved shoulder which serves as a path for motorcycling besides emergency used deemed equally important variables in determining safe motorcycling. Motorcycle riders normally using the paved shoulder as motorcycling path particularly during the peak hour when the traffic volume is picking up. In a normal hour, the motorcycle riders are preferred to sharing paths and meandering between the other vehicles. Malaysian riders do not feel safe when riding on the 1.5m and below paved shoulder path width. The odds of feeling safe when motorcycling along a wider paved shoulder is 2.597 times greater than a narrower paved shoulder. Perhaps narrower width restrains them to ride parallel or overtake other motorcycles freely. The ideal width of 1.70m and above is required for two motorcycles riding parallel or passing each other (Hussain et al., 2005). Therefore, if to encourage motorcycle riders to use the paved shoulder as motorcycling path, the current guidelines used in Malaysia need to be reviewed. Ideal paved shoulder width should be adopted at the roadway with high motorcycle volume. This may encourage motorcycling on the paved shoulder at a non-peak hour as well. Though, strict enforcement is required to ensure other motorists not violated the regulation from using paved shoulder facilities unless on emergency or vehicle breakdown circumstances only. Implementation of the paved shoulder as motorcycling path may reduce severity and collision between a motorcycle and other motor vehicles as they need not increase speed and competing with other motor vehicles.

Development of Composite MSI is an initiative to formulate boundary evaluating the safe motorcycling level along the specific roadway segment based on the seven pre-determined traffic and roadway variables that affecting motorcycle riders in Malaysia. It will serve as a simple practical tool for an evaluator to gauge the road segments and plan on feasible solutions to improve motorcycling safety. For instance, when a road segment is experiencing an increase in motorcycle volume; site evaluation on existing motorcycling safety level can be easily

assessed, an improvement on the entire or part of unsafe conditions of seven pre-determined variables can be opted based on targeted safe motorcycling level and available budget. Similarly goes to the new proposed road, the targeted Composite MSI can be established, and the seven identified variables can be used as part of design consideration, especially dealing with the roads that are forecast to have high motorcycle volume. The current road design guidelines that regulating the design process, which purely depending on the automobile's characteristics may not be ideal for the road segments that have a significant presence of motorcycles in traffic flow. Therefore, a prediction on how the road segments performed by estimating the perceived motorcycling safety is vital to ensure it is well-functioned and safe for motorcycle riders. Bear in mind, besides the professional judgment on motorcycle safety, it is equally essential to consider motorcycle riders' views on safe motorcycling conditions when designing the road geometric. The usage of a motorcycle will keep on the increase with the recent fluctuation of fuel prices and sprouting of living costs. Overall, it is still an affordable mode of transport especially for those who are staying in the urban area and would like to opt for cheaper mobility and efficient fuel consumption vehicle to travel around. Segregation of the motorcycles from mixed traffic is undoubted an efficient measure to enhance motorcyclist's safety. But it needs funding to implement. Because of the majority road urban area is without exclusive motorcycle lanes, this study may become a major contribution in transportation engineering fields in Malaysia, as it may significantly improve the level of motorcycling safety, which is anticipated by motorcycle riders.

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