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Identification of Traffic and Roadway Variables Affecting Safe Motorcycling Along Urban Roads

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Abstract – *In Malaysia, motorcycles represented 45% of all registered vehicles. Alarmingly, motorcyclists comprise 65% of total road deaths. One major reason being that these vulnerable road users get entangled with other mixed vehicles. It is appreciated that roadway design guidelines are based on the characteristics of drivers/automobiles and not riders/motorcycles. Thus, motorcyclists are expected to occupy the dynamically changing space that is available along the roadway. An effective engineering measure to tackle motorcycle safety problems in mixed traffic conditions would be to segregate the motorcycles exclusively. However, this measure is not appropriate for urban roads. One practical approach to address motorcycling safety along urban roads is to identify the traffic and road environment variables that affects safe motorcycling. This list of variables can be used to check the safe motorcycling status along segments of urban roads. The variables relating to bicyclist's perception on the roadway segments were adopted for the variables affecting motorcycling safety along urban roads. To corroborate the adopted variables factors with the actual perception of motorcyclist, the questionnaires related to the variables affecting safe motorcycling were responded by 137 motorcyclists. The variables were identified to be pavement condition, on-street parking, traffic volume, divided/undivided roadway, left-side kerb clearance, lane width, and travelling speed. To further understand these seven variables from the aspect of motorcyclist perceptions, 14 short clips were presented to 483 motorcyclists who rated each clip based on their perception of safe motorcycling. Results found that the odds of feeling unsafe riding on bad pavement is 61.5 times greater than the odds of riding on good pavement. The odds of unsafe motorcycling along roads with on-street parking is 43.2 times higher than without on-street parking. Overall, it infers that the maintenance of road pavement conditions must be of high priority to the local authorities followed by issues of on-street parking along urban links.*

Keywords: Motorcycle accidents, urban mixed traffic, safe motorcycling, traffic and road variables, unsafe to safe motorcycling, odds ratio

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1.0 INTRODUCTION

In developing ASEAN countries, motorcycle is a popular private mode of transport because it is affordable, fuel saving, allows door-to-door travelling and ease to move around especially within the hectic urban area. In Malaysia, motorcycles represented 46% of all registered vehicles (Road Transport Department Malaysia, 2017) which made motorcycles the second highest mode of transport. The proportion of motorcycles varies from 35% to 75% depending on different states. However, motorcycle riders and pillions are the highest group of road users contributing to total road fatalities. PDRM reported that motorcycle fatal accidents reached 64.5% of all road deaths in year 1997, the highest compared to the past 9 years (Royal Malaysian Police, 2017). It is well understood that the road design guidelines are based the drivers and automobiles characteristics. In highly motorcycled countries like Malaysia, the problems arose where motorcycles need to share the road space designed for automobiles. Considering that automobiles moves in a headway pattern along the lane, while motorcyclists ride in a space pattern (Hussain et al., 2005), the potential of conflicts is prevalent. Motorcyclists are categorised as vulnerable road users such as pedestrians and bicyclists because they are not protected. Therefore, an effective engineering measure to protect the motorcyclists is by segregating them from the mixed traffic. The introduction of exclusive motorcycle lanes along the Federal Highway Route 2 in Selangor proved that it reduced motorcyclist accident by 39% and fatalities by 600% (Radin Umar et al., 1995). Non-exclusive motorcycle lanes in the form of paved hard shoulders may be implemented along trunk roads. However, the idea of segregation may not be feasible along urban roads because of the many short links, access points, and limitations in road space due to the well- built environment.

In an attempt to address the safety of motorcyclists along urban roads, this study approaches the problem from a practical aspect. Even though the rider complex problems may not be easily measured, the traffic, roads and environment exhibited to the motorcyclists does play a major role in their perception of safe motorcycling. Similarly, the traffic and roadway conditions indirectly influenced the motorcycling behaviour. The specific aim of this study is to identify and establish the risk of the traffic and road environment variables perceived to be affecting safe motorcycling along urban roads. The identified variables may serve as an auditing tool to measure the status of safe motorcycling along urban road segments. It allows the authorities to plan on the best variables to tackle within their available budget.

The road user's perception is one of the essential variables in the studies of level-of-service (LOS). In developing the bicycle LOS model for arterial roads (Petritsch et al., 2007), it measured the bicyclist's perception on the arterial roadway geometric and the expected operational characteristics. A study by Jensen (2007) attempts to quantify pedestrians' and bicyclist's satisfaction with regards to the existing traffic operations and geometric condition in the urban and rural areas. Their study found that the factors which has significant influence on the level of the satisfaction of pedestrian and bicyclist are motorized traffic volume and speed; urban land use; rural landscapes; the types and widths of pedestrian and bicycle facilities, the number and widths of drive lanes; the volume of pedestrians, bicyclist, and on-street parked cars; and the presence of median and bus stop. A study in China by Tan et al. (2007) introduced a LOS assessing standard by solely referring to traffic flow operation. It considered the perception of pedestrians (comfort and safety variables) in the LOS for sidewalk. Presently, safety is also included in many LOS studies carried out at intersections (Ha & Berg, 1995; Zhang & Prevedouros, 2003; Lu et al., 2008; Wang et al., 2009). All these studies were conducted on parts of the road segment.

2.0 MATERIALS AND METHODS

This study is divided into two phases. Initially in Phase 1, the variables pertaining to motorcycling and bicycling safety are identified from past and present studies. In order to confirm the identified variables as perceived by the motorcyclists, a structured dichotomous questionnaire is constructed. It covers the identified variables: mixed traffic volume, roadway configuration, pavement condition, posted speed limit, lane width, presence of on-street parking and paved left shoulder width. A total of 137 motorcyclists participated in the questionnaire exercise.

In Phase 2, video clips associated with the identified variables were captured at various road segments and traffic conditions within the urban area. To ensure the time taken to complete the questionnaire is not troublesome to the respondents, the range of every variable is limited to two groups only. The total of fourteen short video clips at 8 seconds each capturing two significantly different types of mixed traffic volume, posted speed limit, pavement condition, lane width, type of roadway, left-side clearance width and on-street parking conditions will be presented to respondents. Respondents will then rate five scales on their perception of safe motorcycling (very safe, safe, not so safe, dangerous, and very dangerous) in accordance to each video clip.

Before embarking on a full-scale survey, a pilot study was conducted on a sample of 30 motorcyclists to ensure that the respondents fully understood the questionnaires related to the 14 video clips. Apart from that, to determine if a particular scale is appropriate for measuring a particular variable, an inter-rater reliability test to check the degree of agreement among raters is also conducted. The test determines how much homogeneity or consensus is in the ratings given by various motorcyclists which is useful in refining the tools given to human judges. In this pilot study, the Krippendorff's Alpha test was used (Hayes & Krippendorff, 2007) to estimate the inter coder reliability. Macro is needed to run the Krippendorff's Alpha analysis because it cannot be carried out directly from the standard interface in SPSS 20 software.

Eventually, the refined questionnaires and 14 short video clips were conducted on 483 motorcyclists representing all regions in Malaysia. The Odds Ratio of Unsafe/Safe Motorcycling is calculated for each variable. Chi-square test to check the significant difference between the responses and the respective variables.

3.0 RESULTS AND DISCUSSIONS

From Phase 1, the 137 respondents are aged between 18 and 70 years old, and comprised of 20 % female and 80 % male motorcycle riders. Riding experience among respondents varies from 1 to 45 years. 66% of the respondents use motorcycle in their daily routines to work or study place and leisure purposes, whereas those rides ad-hoc basis consist of 34%. Majority of the respondents (74%) possessed other class of driving license (not solely holding motorcycle riding license). More than half of respondents (56%) had been involved in motorcycle accident before while 43% have family members involved in road accident.

Table 1 presented the perceptions of safe motorcycling by 137 motorcyclists who participated in answering the questionnaires pertaining to the seven identified variables: mixed traffic volume, roadway configuration, pavement condition, posted speed limit, lane width, presence of on-street parking and paved left shoulder width.

Table 1: Perception of safe motorcycling under 7 different traffic and roadway conditions (N=137)

Item	Statement/Variable	Yes	No	Ratio Yes/No
1	I do not feel safe when riding within the *high mixed traffic volume*	108	29	3.7
2	I do not feel safe when riding along the two-way *roadway*	101	36	2.8
3	I do not feel safe when riding on *poor pavement condition*	126	11	11.5
4	I do not feel safe when riding along *roadway posted speed limit of above 60 km/hr*	113	24	4.7
5	I do not feel safe when riding along the *roadway with the narrow lane*	90	47	1.9
6	I do not feel safe when riding along the *roadway with on-street parking*	85	52	1.6
7	I do not feel safe when riding along the *roadway with narrow paved shoulder width*	122	15	8.1

A ratio value of 1.0 means that the dichotomous question obtained equal number of responses. It implied that the statement/variable is indifferent and does not seem to affect safe motorcycling. Table 1 shows that the ratios for all the seven variables deviated from ratio value of 1.0, thus indicating that all the seven variables are relevant and affects safe motorcycling. The poor pavement condition (ratio 11.5) seems to be the main concern in safe motorcycling.

In Phase 2, a pilot study was conducted on thirty respondents to test that the questionnaires and the related 14 video clips are totally understood by the motorcyclists. All motorcyclists possessed valid motorcycle riding license. Their age ranges from 20 to 50 years old, and have riding experience between 2 to 35 years. Of the 30 respondents, 60% were male and 40% were female. The analysis output of Krippendorff's Alpha test as shown in Table 2. It was found that the inter coder reliability was relatively high ($\alpha = 0.7642$) which proved that all the 30 respondents have no difficulty to understand the 14 video clips. Table 2 also showed that there is an estimated 0.01% chance that the alpha would be below 0.70 if the whole population is tested.

Table 2: SPSS output for Krippendorff'S Alpha analysis (N=30)

Macro
Kalpha judges = R1 R2 R3 R4 R5 R6 R7 R8 R9 R10 R11 R12 R13 R14 R15 R16 R17 R18 R19 R20
R21 R22 R23 R24 R25 R26 R27 R28 R29 R30/level = 2/detail = 0/boot =10000.
Run MATRIX procedure:
Krippendorff's Alpha Reliability Estimate

	Alpha	LL95%CI	UL95%CI	Units	Observrs	Pairs
Ordinal	**.7642**	.7248	.7989	14.0000	30.0000	6090.0000

Probability (q) of failure to achieve an alpha of at least alphamin:

alphamin	q
.9000	1.0000
.8000	.9791
.7000	.0009
.6700	.0000
.6000	.0000
.5000	.0000

Number of bootstrap samples:
10000
Judges used in these computations:
Columns 1 - 14
R1 R2 R3 R4 R5 R6 R7 R8 R9 R10 R11 R12 R13 R14
Columns 15 - 28
R15 R16 R17 R18 R19 R20 R21 R22 R23 R24 R25 R26 R27 R28
Columns 29 - 30
R29 R30
Examine output for SPSS errors and do not interpret if any are found
------ END MATRIX -----

The questionnaires were improved based from the pilot study, and the responses to the finalised questionnaire and 14 video clips by 483 motorcyclists from all regions in Malaysia were analysed. Respondents are aged between 17 to 69 years old, and comprises of 68 males and 32% female. About 64% of the motorcyclists has more than 5 years' motorcycle riding experience.

The focus of the questionnaires is on how unsafe does a motorcyclist perceived when exhibited with a particular roadway or traffic conditions. The input pertaining to unsafe motorcycling conditions is useful to rank the 7 variables in accordance to their seriousness. The perceived safe motorcycling scores of each of the 14 video clips by the 483 motorcyclists is as presented in Table 3. The perceived unsafe motorcycling scores is obtained from the summation of scores from the scales: "3-not so safe", "4-dangerous" and "5-very dangerous. While the unsafe motorcycling scores is the sum from the scales: "1-very safe" and "2-safe". Hence, the odds of unsafe to safe motorcycling is computed as:

$$(f_{\text{not so safe}} + f_{\text{dangerous}} + f_{\text{very dangerous}}) \div (f_{\text{very safe}} + f_{\text{safe}}) \qquad (1)$$

Table 3: Safe Motorcycling Score and odds ratio of unsafe/safe motorcycling for different traffic and roadway conditions

Traffic Volume	Perceived Safe Motorcycling Score					Odds of Unsafe/Safe
	Safe			Unsafe		
	1-Very safe	2-Safe	3-Not so safe	4-Dangerous	5-Very dangerous	
High (>800 pcu/h)	9	38	195	204	37	9.28
Low (< 800 pcu/h)	17	273	166	20	7	0.67
(df = 1, χ2 =269.097, p<0.001) , Unsafe to Safe OR=9.28/0.67=13.8 (R-4)						

Type of Roadway	Perceived Safe Motorcycling Score					Odds of Unsafe/Safe
	Safe			Unsafe		
	1-Very safe	2-Safe	3-Not so safe	4-Dangerous	5-Very dangerous	
Undivided (2-way)	88	136	137	85	37	1.16
Divided (multilane)	153	283	33	7	7	0.11
(df = 1, χ2 =214.973, p<0.001) , Unsafe to Safe OR=1.16/0.11=10.5 (R-5)						

Street Parking Conditions	Perceived Safe Motorcycling Score					Odds of Unsafe/Safe
	Safe			Unsafe		
	1-Very safe	2-Safe	3-Not so safe	4-Dangerous	5-Very dangerous	
On-street	16	62	258	115	32	5.19
Off-street	127	303	39	7	7	0.12
(df = 1, χ2 =514.438, p<0.001) , Unsafe to Safe OR=5.19/0.12=43.2 (R-2)						

Paved Shoulder Width	Perceived Safe Motorcycling Score					Odds of Unsafe/Safe
	Safe			Unsafe		
	1-Very safe	2-Safe	3-Not so safe	4-Dangerous	5-Very dangerous	
Narrow (≤1.50m)	36	328	101	9	6	0.33
Wide (>1.50m)	270	159	39	9	6	0.13
(df = 1, χ2 =29.750, p<0.001) , Unsafe to Safe OR=0.33/0.13=2.54 (R-7)						

Pavement condition	Perceived Safe Motorcycling Score					Odds of Unsafe/Safe
	Safe			Unsafe		
	1-Very safe	2-Safe	3-Not so safe	4-Dangerous	5-Very dangerous	
Damaged	8	120	275	71	9	2.77
Good	297	165	9	5	7	0.045
(df = 1, χ2 =485.769, p<0.001) , Unsafe to Safe OR=2.77/0.045=61.5 (R-1)						

Posted Speed Limit	Perceived Safe Motorcycling Score					Odds of Unsafe/Safe
	Safe			Unsafe		
	1-Very safe	2-Safe	3-Not so safe	4-Dangerous	5-Very dangerous	
> 60 km/h	37	200	171	58	17	1.04
≤ 60 km/h	57	337	75	7	7	0.23
(df = 1, χ2 =112.642, p<0.001), Unsafe to Safe OR=1.04/0.23=4.5 (R-6)						

Lane width	Perceived Safe Motorcycling Score					Odds of Unsafe/Safe
	Safe			Unsafe		
	1-Very safe	2-Safe	3-Not so safe	4-Dangerous	5-Very dangerous	
Narrow (≤ 3.00m)	16	86	252	100	29	3.74
Wide (>3.00m)	218	181	63	16	5	0.21
(df = 1, χ2 =365.763, p<0.001), Unsafe to Safe OR=3.74/0.21=17.8 (R-3)						

Chi-square test for all odds ratios showed that responses are significantly different at alpha 0.05. As in Table 3, the bad pavement conditions are of prime concern by motorcyclist with regard to safe motorcycling. The odds of feeling unsafe riding on bad pavement is 61.5 times greater than the odds of riding on good pavement. The odds of unsafe motorcycling along roads with on-street parking is 43.2 times higher than without on-street parking roadway. Meanwhile, the odds of feeling unsafe riding within narrow lanes is 17.8 times greater than within wide lanes. The odds of feeling unsafe when riding in heavy traffic volume is 13.8 times greater than in low traffic volume roadways. The odds of safe motorcycling along undivided roadway is 10.5 times higher than along divided roadway. The odds of unsafe motorcycling within posted speed more than 60km/h is 4.5 times greater than posted speed limit 60km/h, and the odds of feeling safe riding along narrow paved shoulder is 2.5 times greater than along wider paved shoulder roadway.

4.0 CONCLUSION

The seven identified traffic and roadway variables is useful for authorities to inspect which variables are the most unsafe to motorcyclists along a segment of urban roads. It also allows authorities to plan on the feasible solutions. Among all variables, the odds of feeling unsafe riding on bad pavement is 61.5 times greater than the odds of riding on good pavement. It infers that the maintenance of road pavement conditions must be of high priority and continuous procedure to the local authorities. The odds of unsafe motorcycling along roads with on-street parking is 43.2 times higher than without on-street parking roadway highlighted the importance of traffic management policies by the authorities to address the issue of on-street parking along some links affecting safe motorcycling. The rest of the variables perceived unsafe to motorcyclists are narrow lanes, heavy traffic volume, undivided roadway, posted speed more than 60km/h, and narrow paved shoulder. Further manipulation of these odds values will enable the composite safe motorcycling index to be developed. This index will be a more detailed output indicating the range of perceived safe motorcycling with respect to the seven traffic and road environmental variables.

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