EFFECT OF HATCHED MARKING LENGTH ON ENTERING POSITION AMONG MOTORCYCLISTS DURING MERGING IN EXPRESSWAY

Adnan A.[1,*], Hanafi H.[1], Radin Umar R. Z.[2], Samuel S.[3], Shaffiar, N.M.[1], Ani M.H.[1], Hamid M.[1,]**

[1]*Department of Manufacturing and Materials Engineering, International Islamic University Malaysia, 50728, Kuala Lumpur, Malaysia*

[2]*Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, 76100, Melaka, Malaysia*

[3]*Department of System Design Engineering, University of Waterloo, Ontario, N2L 3G1, Canada*

[*]For correspondence; Tel. + (60) 189794123, E-mail:ammarcloud@gmail.com

[**]For correspondence; Tel. + (60) 132665576, E-mail: abdmalek@iium.edu.my

ABSTRACT: *Despite the risky behavior among motorcyclists, merging road design is known to have influence on how motorcyclists behave during merging in traffic. Merge into the expressway through the merging lane – safe entering position – is crucial in order to minimize the risk for road crashes. The objective of this study is to evaluate the effect of hatched marking length on entering position among motorcyclists during merging in expressway. Field observation study was conducted at sixteen scenario locations with different length of the hatched marking (13 - 127 meters). In total, 3200 motorcyclists were observed (200 motorcyclists at each scenario location). Each scenario location was observed from Monday to Thursday in two observation sessions (morning session during 9:00 AM – 12:00 PM, and evening session during 2:00 PM – 5:00 PM), during a good weather and normal traffic congestion. The dependent variable is the percentage of the safe entering. If a motorcyclist merge into expressway through the merging lane, he or she was scored 1, else he or she was scored 0 (merge through the hatched marking area). Result obtained shows that: (i)* almost 100% *of motorcyclists merged into the expressway through the safe entering position for all scenarios with the length of hatched marking below 63 meters; and (ii) a decreasing pattern of the percentage of safe entering position was observed for the scenarios with the length of hatched marking above 63 meters. Further analysis shows that there is a strong negative correlation between the percentage of the safe entering position with the length of the hatched marking with the coefficient of determination (R2) of 0.9114. Moreover, a significant regression equation was found (F (1,2) = 20.5651, p <0.0453) with the linear regression line, y = -0.7443x + 143.81, meaning that the percentage of the safe entering is decreased by 0.7443 for each meter increment of hatched marking length. The findings recommended the hatched marking design improvement for road safety. In addition, it may contribute to improving the riding education program in general, specifically, on how to merge safely during merging in traffic.*

Keywords: Road Safety, Motorcyclists Behavior, Merging Lane, Hatched Marking Length, Entering Position

1. INTRODUCTION

Around the globe, over 1.25 million of road death occurred yearly due to road crashes, and approximately, half of it involved motorcyclist, cyclist, and pedestrian [1-2]. Among the countries with the risky road, Malaysia is ranked third below Thailand and South Africa. Out of 27 million registered vehicles in Malaysia, nearly half a million involved in road crashes. In 2016, the number of road death in Malaysia has increased by 6% compared to the previous year, with the majority of the deaths toll involved motorcyclists. Moreover, the fatality rate of the motorcyclist in Malaysia is among the highest in the world [3-6].

Risky behavior among motorcyclists is known to be one of the contributing factors to those road crashes. Among the risky behavior, improper merging is one of the causes that lead to road crashes [6]. When two separate traffics stream combine into a single stream it is termed as merging. The rules during merging are to give way to oncoming vehicles that pass through the lane to be merged before complete the action [7-9]. In highway environment, Zabidi et al. [10] have shown that about 70% of motorcyclists do not perform head check during merging into an expressway. Their finding later supported by Abu Hassan et al. [11] and Adnan et al. [12] which showed that the length of the merging lane may influence the motorcyclists' behavior in performing the head check. This shows that, merging road design do play a role that affecting motorcyclists' behavior during merging into the expressway.

There are many effects of the merging road design attributes that have not been explored, and generally, this study is intended to explore the effect of the hatched marking design on motorcyclists' behavior during merging into the expressway. Hatched marking is used to separate traffic lane or protect traffic from a stationary feature. Types of hatched marking are white chevron marking and diagonally hatched marking [13-14]. Shorter hatched length may cause traffic bottleneck at the merging area, as the road user would not have an ample time to adjust their vehicle speed and manoeuvre safely in traffic [15]. Thus, hatched marking area is preferred to be long enough so that road users can manoeuvre and merge safely in traffic without causing the traffic bottleneck. However, longer hatched marking area may promote the unsafe entering position behavior among the road users especially motorcyclists.

Generally, a safe road user would merge into the expressway through the merging lane – the white dotted line that separates the merging road and the expressway. In this study, this act is named as 'safe entering position'. Unfortunately, in some situations, road user may use hatched marking area to merge directly into the traffic. This behavior is considered dangerous and may cause road crashes (e.g. colliding with the road user on the expressway), and in this study, this act is named as 'unsafe entering position'. Thus, in general, this study investigates how the hatched marking design may affect motorcyclists' behavior during merging in the expressway. Specifically, the objective of this study is to investigate the effect of hatched marking length on entering

position among motorcyclists during merging in the expressway.

2. METHODOLOGY

The study was done at the Middle Ring Road Expressway that located in Kuala Lumpur, Malaysia. Hatched marking length of forty-eight merging areas were measured (i.e. from point A to point B in figure (1)) for sampling purposes using a telescopic handle measuring wheel. Out of the forty-eight samples, sixteen scenarios were chosen based on the equal percentile rank of their hatched marking length (which is of every 6.67^{th} percentile) so that they represent ranges of length. Table 1 lists the details of each scenario: (i) the target percentile; (ii) the target length of the scenario that based on the percentile rank (in meters); and (iii) the actual length of the scenario that was selected from the forty-eight samples (in meters) that matching or close to the target length (in meters).

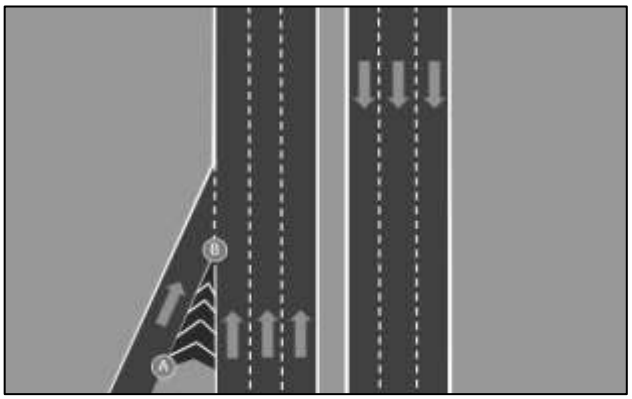

Figure (1) Hatched marking length (from point A to B)

Table (1) Sample of the scenario

Scenario No.	Target Percentile (%)	Target Length (meters)	Chosen Scenario Length (meters)
1	0.00	13	13 (min)
2	06.67	15	15
3	13.33	18	19
4	20.00	20	20
5	26.67	22	22
6	33.33	26	27
7	40.00	28	28
8	46.67	29	29
9	53.33	33	33
10	60.00	40	44
11	66.67	53	50
12	73.33	60	60
13	80.00	65	63
14	86.67	71	73
15	93.33	87	88
16	100.00	127	127 (max)

Figure (2) illustrates the motorcyclists' view, and Figure (3) illustrates the top view of a sample scenario. In general, each scenario consists of either single or two lanes merging lane with 50 km/h speed limit that merge onto a three lanes expressway with 90 km/h speed limit. Surrounding areas includes trees, residential buildings, restaurants, shops, school, gas station, and advertisement board. Note that Malaysia is left-hand side traffic.

Figure (2) Motorcyclists' view of a sample scenario

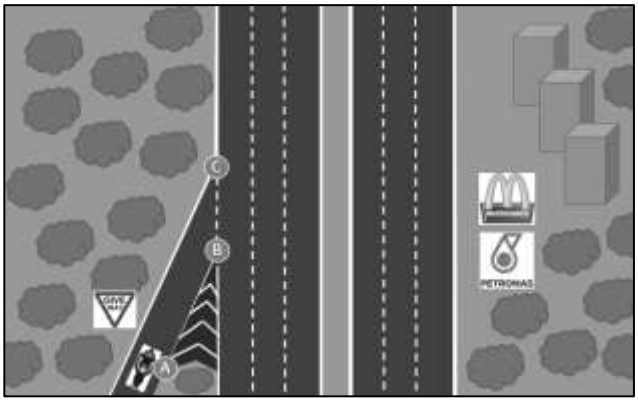

Figure (3) Plan view of a sample scenario

Panasonic HC-V210 video recording device (with 10 mega pixels' resolution and 72X zoom) was used to record the scenario locations in observing motorcyclists entering position behavior. The observation was done on Mondays to Thursdays only. Fridays, weekends, and holidays were excluded to avoid any potential effect of traffic congestion differences. Note that the lunch hour on Friday in Malaysia is longer than usual due to the Friday prayer, thus, Friday was also excluded. The observation periods were divided into morning session (9:00 AM to 12:00 PM), and evening session (2:00 PM to 5:00 PM) which excluded the rush hours (before 9:00 AM – commuting period to work, between 12:00 PM to 2:00 PM – lunch hours period, and after 5:00 PM – commuting period from work), and night hours (7:00 PM to 7:00 AM). Moreover, the observation was only run during a good weather condition (e.g. no rain), and during a normal traffic congestion condition (e.g. no road crashes in the surrounding area).

In total 3200 motorcyclists were observed throughout the study (i.e. 200 motorcyclists at each scenario location). At each scenario location, four observations were done where 50 motorcyclists were observed for each observation (i.e. equal

distribution in obtaining the total of 200 motorcyclists for each scenario location). The day and the observation period were counterbalanced so that each scenario was observed during a different day and observation period. For instance, in a particular scenario, motorcyclists were observed on each Monday, Tuesday, Wednesday, and Thursday. Two of the observations were done during the morning session, and the other two were done during the evening session.

Independent variable is the length of the hatched marking, and the dependent variable is the percentage of the safe entering position. If a motorcyclist merge into the expressway through the safe region (on merging lane, from point B to C in figure (3)), he or she was scored 1, else he or she was scored 0 (merge on hatched marking area, from point A to B in figure (3)).

3. RESULTS

Figure (4) illustrates the percentage of the safe entering for a different length of hatched marking area. As can be seen in figure (4), almost 100% of motorcyclists merged into the expressway through the safe entering position for all scenarios with the length of hatched marking below 63 meters. A decreasing pattern of the percentage of safe entering position was observed for the scenarios with the length of hatched marking above 63 meters.

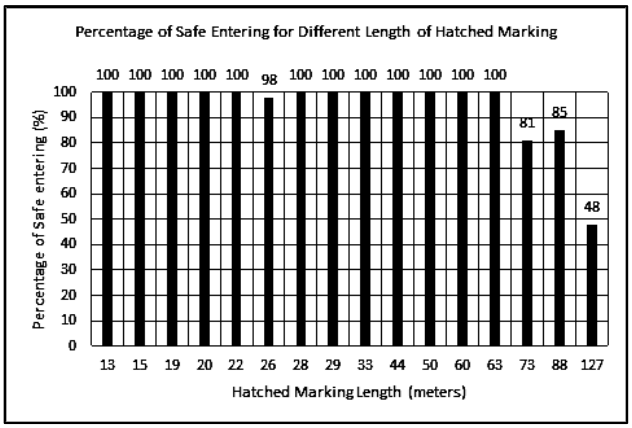

Figure (4) Percentage of safe entering for a different length of hatched marking

Because the motorcyclists have shown a nearly 100% safe entering behavior at the scenarios with the hatched marking length below 63 meters, it is safe to assume that motorcyclists tend to merge into the expressway through the safe region if the hatched marking length is less than 63 meters. Thus, only scenarios with the hatched marking length above 63 meters were analyzed further.

Figure (5) illustrates the scattered diagram of the percentage of safe entering for scenarios with hatched marking length of equal or longer than 63 meters. As can be seen in figure (5), the scattered diagram shows that there is a negative correlation between the percentage of the safe entering position with the length of the hatched marking. The coefficient of determination (R^2) obtained is 0.9114. Thus, the correlation coefficient (R) is equal to 0.9547, meaning that these two variables – the percentage of the safe entering and the length of the hatched marking – have a high negative correlation. Moreover, the linear regression line obtained is y = -0.7443x + 143.81.

A simple linear regression model (SPSS, version 23) was utilized to predict the percentage of the safe entering based on the length of the hatched marking. A significant regression equation was found ($F(1,2) = 20.5651$, $p < 0.0453$) with an R^2 of 0.9114. Thus, motorcyclists' predicted percentage of safe entering is equal to 143.81 – 0.7443 * length of hatched marking when the length of hatched marking is measured in meters. The percentage of the safe entering is decreased by 0.7443 for each meter increment of hatched marking length.

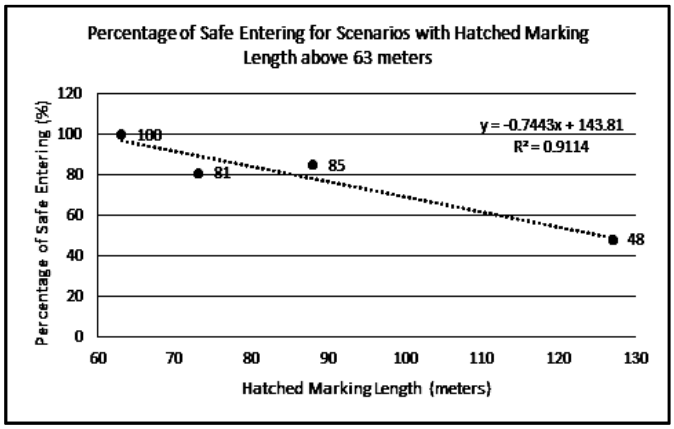

Figure (5) Scattered diagram of the percentage of safe entering behavior for scenarios with hatched marking length above 63 meters

4. DISCUSSION

The findings show that the length of the hatched marking that longer than 63 meters do affect motorcyclists' entering position behavior during merging into an expressway, in which the longer the length the less percentage of the safe entering position would be. This finding gives an insight into the hatched marking area design in which it should be less than 63 meters. However, a shorter merging area is known to cause a traffic bottleneck at the merging area [15]. Moreover, a shorter merging area also may cause the road users to not having an ample time to adjust their vehicle speed in order to match the vehicles on the expressway and manoeuvre the vehicle for a safe merging [7]. Thus, even though the finding of this study recommends that the length of the hatched marking should be less than 63 meters, it should not too short that could compromise the ability of the road users to safely enter the expressway. A future study is recommended to investigate what is the minimum length of the hatched marking should be. The finding of the future research may be beneficial in recommending the optimal range for the hatched marking length design in order to ensure a safe merging behavior among the road users in general, more specifically, among the motorcyclists.

The massive research and media statements have mentioned and blamed motorcyclists solely when it comes to road crashes because of their risk seeker behavior. For instance, finding by Zabidi et al. [10] shows that most motorcyclists are risk seeker when it comes to their head check behavior during merging into the expressway.

However, the finding in this study gives an insight that, despite the motorcyclists' risky behavior, somehow, there are many other factors involved when a road crash happen. As found in this study, road design does play a role for road safety in general, more particularly, the effect of the length of hatched marking on the percentage of safe entering position during merging in the expressway. This finding is supported by Abu Hassan et al. [11] and Adnan et al. [12] in which they found that the design on the merging area itself does have an effect on motorcyclists' head check behavior during merging into an expressway. Thus, it should be bear in mind that, when road crashes happen, the blame should not be solely be addressed to the road users. Other factors such as the road design, riding/driving education curriculum, and the environmental factors should be looked at as well.

Furthermore, in this study, it was found that for the hatched marking area with the length more than 63 meters, the percentage of the safe entering behavior among the motorcyclists were compromised, in which, the percentage of the safe entering behavior is decreased by 0.7443% for each meter increment of the hatched marking length. However, it should be noted that, in this study, because lack of knowledge of what the optimal length of the hatched marking area should be, forty-eight merging areas were sampling in order to choose the scenario locations. Thus, with the new knowledge gain from this study, it is recommended that future study should be conducted by focusing on more samples that have a hatched marking length more than 63 meters – to study on scenarios that have hatched marking length more than 63 meters only. By doing this, the more concrete correlation and regression line could be obtained.

Lastly, this study was observed during the weekdays, non-rush hours' period, daytime, good weather condition, and normal traffic congestion at the expressway road environment. Thus, how would the hatched marking length would affect motorcyclists' behavior during merging in traffic during the weekend, rush hours' period, night time, bad weather condition, and abnormal traffic congestion as well as at the different type of road environments such as town, residential, and rural area are unknown and only future research could answer.

5. CONCLUSIONS

In general, the length of the hatched marking does not affect motorcyclists entering position behavior during merging into expressway if the length is less than 63 meters. From 63 meters onward, a decreasing pattern in the percentage of safe entering was observed. It is shown that for hatched marking length more than 63 meters, there is a strong negative correlation between the length of the hatched marking and the percentage of safe entering among the motorcyclists during merging into an expressway. Finding from this study recommend that the length of the hatched marking should be less than 63 meters in order to promote a safe merging behavior among the motorcyclists, however, it should be long enough so that road users would have an ample time to manoeuvre and merge safely into the expressway. Moreover, this study also gives insight on the needed improvement of the riding education curriculum which is to promote awareness among the motorcyclists on how to merge safely in traffic in general, more particularly, into the expressway.

6. ACKNOWLEDGEMENT

The research was supported by the Malaysian Ministry of Higher Education through the RAGS15-066-0129 grant to International Islamic University Malaysia (Malek Hamid, PI), and the FRGS17-035-0601 grant to International Islamic University (Mohd Hanafi Ani, PI). This study was also supported by the Department of Manufacturing and Materials Engineering, International Islamic University Malaysia, Malaysia.

7. REFERENCES

[1] Association for Safety International Road Travel. Annual Global Road Crash Statistics. http://asirt.org/Initiatives/Informing-Road-Users/Road-Safety-Facts. Accessed on April 3, 2017.

[2] World Health Organization. Global Status Report on Road Safety 2015. www.who.int/violence_injury_prevention/road_safety_status/2015/GSRRS2015_Summary_EN_final2.pdf?ua=1. Accessed April. 3, 2017.

[3] Ministry of Transport Malaysia. Transport Statistics Malaysia 2013. Ministry of Transport, Putrajaya. www.mot.gov.my/en/lands/road-transport/miros. Accessed April. 7, 2017.

[4] Malaysian Institute of Road Safety Research. Road Fact. General Road Accident Data in Malaysia (1997-2016). www.miros.gov.my/1/page.php?id=17. Accessed April. 15, 2017.

[5] Nunn, S. (2011) Death by Motorcycle: Background, Behavioral, and Situational Correlates of Fatal Motorcycle Collisions. *Journal of Forensic Sciences*, Vol. 56, No. 2, pp. 429–437.

[6] Manan, M., and Várhelyi, A. (2012). Motorcycle Fatalities in Malaysia. *IATSS Research*, Vol. 36, No. 1, pp. 30–39.

[7] Riener, A., Kashif, Z., Alois, F., Beltran, C. R., and Rubio, J. J. (2013). Traffic Flow Harmonization in Expressway Merging. *Personal and Ubiquitous Computing*, Vol. 17, No. 3, pp. 519–532.

[8] Adnan, M. A., Ibrahim, W. H. W., and Sulaiman. N. (2009). Exploration of Merging Traffic Flow at Malaysian Urban Expressway. *Presented at 8th International Conference of Eastern Asia Society for Transportation Studies*.

[9] Queensland Government. Changing lane and merging. Merging.www.qld.gov.au/transport/safety/rules/road/lanes. Accessed April. 3, 2017.

[10] Zabidi, M. H., Adnan, A., Radin Umar, R. Z., Samuel, S., Ani, M. H., and Hamid, M. (2016). Evaluation of Head Check Behavior of Motorcyclists during Merging in Traffic. *Human Factors and Ergonomics Journal*, Vol. 1, No. 2, pp 28-39.

[11] Abu Hassan, A. T., Adnan, A., Radin Umar, R. Z., Samuel, S., Ani, M. H., Hamid, M. (2017). Motorcyclists Head Check Behavior during Merging in Traffic: Effect of Different Ranges of Merging Lane

Length. *Human Factors and Ergonomics Journal*, Vol. 2, No.3, pp 39-45.

[12] Adnan, A., Ismail, H., Radin Umar, R. Z. Samuel, S., Hamid, M. (2018). Effect of Merging Lane Length on Motorcyclist's Head Check Behavior during Merging in Traffic: Urban Expressway. *Transportation Research Board 97th Annual Meeting (TRB Committee ANF30 Standing Committee on Motorcycles and Mopeds).* Washington DC.

[13] Department of the Environment. Traffics Sign Manual: Road markings, Study and Delineators. www.trafficsigns .ie/wp-content/uploads/2015/12/7-Road-Markings.pdf. Accessed April. 10, 2017.

[14] Department of Transport. Traffic Signs Manual: Road Markings.www.07-traffic-signs-manual-2010-chapter7-road-markings.pdf. Accessed April. 10, 2017.

[15] Pei Y., Qi W., Fu C. (2011) Characteristics of Risky Merging Driving Behavior on Urban Expressway. In: Lin S., Huang X. (eds) Advances in Computer Science, Environment, Ecoinformatics, and Education. CSEE 2011. Communications in Computer and Information Science, Vol 215. Springer, Berlin, Heidelberg

*For correspondence; Tel. + (60) 189794123, E-mail:ammarcloud@gmail.com

**For correspondence; Tel. + (60) 132665576, E-mail: abdmalek@iium.edu.my