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DIFFERENCE IN THE BEHAVIOR OF RIGHT-TURNING VEHICLES AND THEIR EFFECT ON SAFETY AT UNSIGNALIZED INTERSECTIONS IN MALAYSIA

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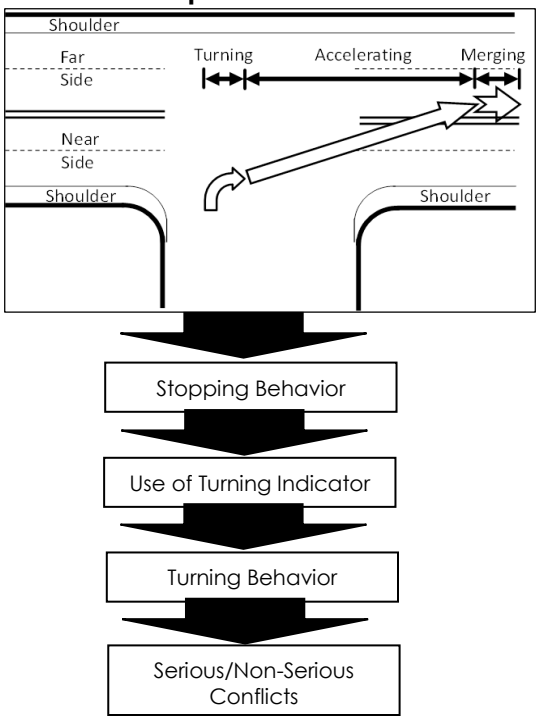
Graphical abstract



Abstract

Intersections are more prone to accidents as compared to straight road segments and vehicles that make right-turning maneuver are the ones which are more likely to be involved in an angle collision. Therefore, this study investigates their behavior at unsignalized intersections in Malaysia. The aim of this paper is to evaluate the compliance with the stop rule, use of turning indicator and right-turning behavior of minor road vehicles. All the behavioral observations were made with respect to two vehicle types which were 'motorcycles' and 'others'. Descriptive analysis was presented and χ^2-test was performed to investigate the association between the variables. It was found that most motorcyclists in Malaysia do not abide by the stopping rule at the intersection before making a right-turn. Moreover they seldom use their turning indicators and tend to make the indigenous 'Weaving Merging Right-Turn' (WMRT) more often as compared to other vehicles. Not complying with the stopping rule and keeping the indicator switched off while making a right-turn was found to be hazardous and resulted in the decrease in the safety of intersection and increase in the risk of accident. However, WMRT was found to be a safer maneuver as compared to the conventional right-turn. For vehicles other than motorcycles, the analysis concluded the same results. It is recommended that the methodology proposed in this research should be extended to other studies with a larger sample size.

Keywords: Conflicts, stopping behavior, turning indicator, right-turning maneuver, hypothesis testing

1.0 INTRODUCTION

Intersections are more prone to accidents as compared to straight road segments as the total numbers of conflicting movements on them are higher than straight roads. Statistics on studies at primary roads in Malaysia [1&2] have revealed that angle collisions are higher as compared to other types. In a study involving data from Georgia, USA; angle crashes were found to be the highest among all types of accidents occurring at unsignalized intersections [3]. Since vehicles that make right-turning maneuver are the ones which are prone to angle collisions, therefore this study investigates their behavior at unsignalized intersections in Malaysia. The analysis was performed by bisecting the traffic mix into two groups, which were, motorcycles and other vehicles. This approach is similar to the one adopted by Harnen 2003a & b [4&5] for the modeling of accidents at unsignalized intersections in Malaysia. The difference being that in place of accidents, traffic conflicts are used in this research to

evaluate the safety at unsignalized intersections. Conflict technique proposed by Hydén, 1987 [6] was adapted for this study for the classification of conflicts into serious and non-serious. The definition coined for serious conflict was "all incidents in which one of the two road vehicles involved is required to stop to avoid a collision", while all other conflicts were termed as non-serious.

This paper aims to evaluate whether

- Motorcycles and other vehicles comply with the stopping rule or not and what is their effect on the type of conflicts at unsignalized intersections in Malaysia
- Motorcycles and other vehicles use their turning indicator while making a right-turning maneuver or not and what is their effect on the type of conflicts at unsignalized intersections in Malaysia
- Motorcycles and other vehicles use the conventional right-turning maneuver or the indigenous weaving merging right-turning maneuver and what is their effect on the type of conflicts at unsignalized intersections in Malaysia

2.0 METHODOLOGY

The data which was collected for this study comprised of three behavioral parameters which were stopping behavior, use of turning indicator and right-turning behavior. A total of 279 observations were made on six different sites in the state of Penang, Malaysia during January to June 2014. All the sites were three-legged unsignalized intersections with no stop sign, that is, they were uncontrolled. Unsignalized intersections were selected because they constitute a huge number among all the fixed control facilities provided on the Road Infrastructure of Malaysia [7]. The sites were similar in terms of basic geometry as none of them had channelizing island or auxiliary lanes to guide the traffic movement. All the behavioral observations were made with respect to two vehicle types which were 'motorcycles' and 'others'. A total of 32 conflicts were observed which included serious as well as non-serious conflicts. Right-turning behavioral observations were made for both conventional as well as the indigenous right-turning maneuver termed as 'WMRT'. This unique maneuver increases the driver comfort by breaking the tasks of turning, accelerating and merging; which otherwise are required to be performed simultaneously as shown in Figure 1. For further explanation the reader can refer to Ahmed *et al*., 2015a [8].

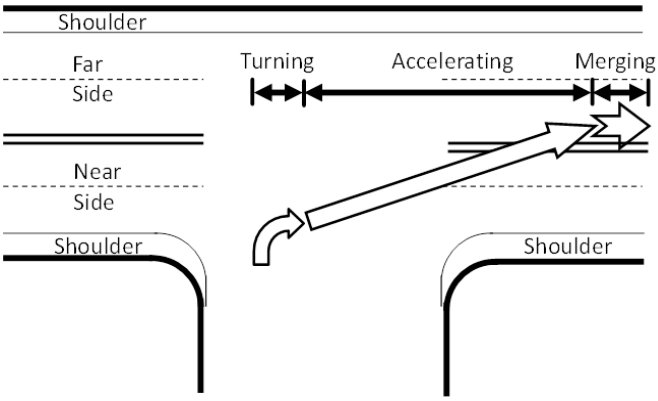


Figure 1 Weaving Merging Right-Turn (WMRT)

Two types of analysis were performed on the data. One was the descriptive analysis and the other was the test of hypothesis. The stopping behavior comprised of two categories which were 'Stop' and 'Didn't Stop'. The second variable which was the use of turning indicator also comprised of two categories which were 'On' and 'Off'. Finally the third variable which was the turning behavior also comprised of two categories namely 'WMRT' and 'Non-WMRT'. Since, all the three variables were categorical in nature; therefore, χ^2-test was selected in order to test the association between them.

3.0 RESULTS AND DISCUSSION

3.1 Descriptive Analysis

3.1.1 Stopping Behavior

Among all the observations made with respect to the stopping behavior for motorcycles and other vehicles, it was found that motorcycles tend to violate the stopping rule more often as compared to their counterparts. Out of all the observations made with respect to motorcycles, the percentage that stopped before making a right-turn was only 42% (5 motorcyclists that stopped out of total motorcyclists which were 12) as calculated from the values presented in Figure 2. This result is similar to a previous study which reported that 39% of the motorcyclists stopped at the stop sign [9]. The probable reason behind this could be their greater maneuverability and small size which makes them capable of turning quickly and adjust in smaller gaps. Due to less inertia they can accelerate more rapidly as compared to other motorized vehicles. Hence, it is possible for motorcyclists to attain the speed of mainstream vehicles much faster and become part of the platoon. This capability urges the motorcycle drivers to take risk and shapes their behavior. Out of all the observations made with respect to 'other vehicles', the percentage that stopped before making a right-turn was 80% (16 'others' that stopped out of total

'others' which were 20) as calculated from the values presented in Figure 2. This result is similar to previous researches which reported that drivers stopped 73.4%, 76.9%, 66% and 61% at different intersections [9-12]. Analyzing further, it was observed that the motorcycles which didn't stop experienced more number of serious conflicts as compared to those who obeyed the stopping rule as shown in Figure 2. Contrary to it the 'other vehicles' who followed the stopping rule experienced more serious conflicts as compared to the ones who didn't. This is due the higher frequency of 'other vehicles' that followed the stopping rule. Since the number of 'other vehicles' who stopped at the intersection were higher, their share in the number of conflicts, including both serious and non-serious, was also greater. On an average the vehicles, that includes the motorcycles as well as 'other vehicles', which didn't complied with the stopping rule had a higher percentage of serious conflicts, which was calculated to be 58.93% by taking the mean of the percentages of serious conflicts of motorcycles and 'others' that didn't stop [{((3÷7)X100)+((3÷4)X100)}÷2] as compared to those who complied with the stopping rule, which was calculated to be 51.25% by taking the mean of the percentages of serious conflicts of motorcycles and 'others' that stop [{((2÷5)X100)+((10÷16)X100)}÷2] from the data presented in Figure 2. This proves that following the stopping rule reduces the risk of accidents for all types of vehicles. Subsequently it improves the safety of the unsignalized intersections.

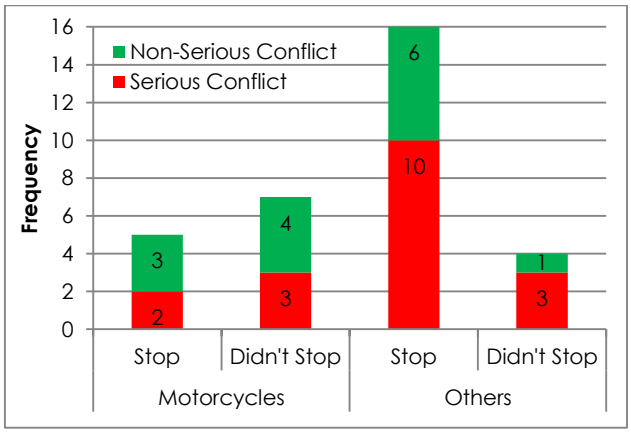


Figure 2 Stopping Behavior of Motorcycles versus Other Vehicles

3.1.2 Use of Turning Indicator

Motorcyclists were found to be very lethargic in terms of use of their turning indicators. None of the motorcyclists switched on their turning indicators while making a right-turn. This result is similar to a recent study conducted on unsignalized intersections in Malaysia [13], from which it was inferred that 93-94% of motorcyclists that made conventional right turn didn't use their turning indicators. The probable reason for this could be the reduction in vehicular control caused due to the thumb movement required for switching on the indicator button, which is usually provided on the handle of the motorcycle. As discussed in the previous section, most motorcyclists do not wish to stop at the intersection, therefore turning the handle and moving the thumb simultaneously can result into loss of balance. Similar to the findings presented in the previous section, among the motorcyclists which kept their turning indicators off, the ones who experienced serious conflicts were less as compared to those who experienced non-serious conflicts. The reason lies with the physical attributes of the vehicle, such as its greater maneuverability and higher acceleration, as explained earlier. 'Other vehicles' were found to better comply with the use of turning indicators. 55% of 'other vehicles' kept their turning indicators switched on while making a right-turn as compared to 45% who kept their turning indicators switched off (9 'others' that kept their turning indicators switched off out of total 'others' which were 20) as calculated from the values presented in Figure 3. In general the vehicles, that includes the motorcycles as well as 'other vehicles', that kept their turning indicators switched off experienced a higher number of serious conflicts, which was observed to be 10 vehicles as shown in Figure 3, as compared to those who kept their turning indicators switched on, which was observed to be 8 vehicles. This proves that use of turning indicator reduces the risk of accidents for all types of vehicles.

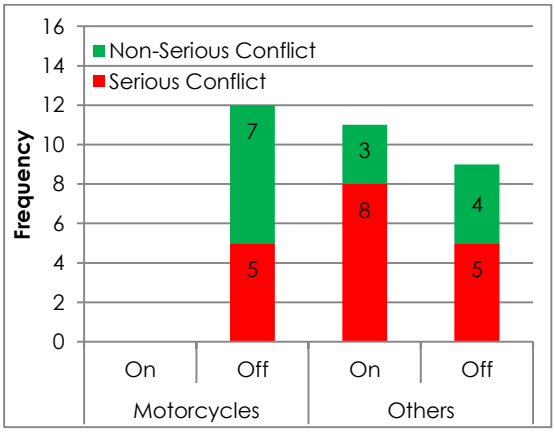


Figure 3 Use of Turning Indicator by Motorcycles versus Other Vehicles

3.1.3 Turning Behavior

Both motorcycles as well as 'other vehicles' were observed to make the two types of right-turning maneuver, which were, the WMRT and the non-WMRT. The total numbers of movements recorded for vehicles making a right-turn from minor to major road on all the six sites were 279 as mentioned in section

2.0. The number of motorcyclists that made the WMRT was 54 while those who preferred non-WMRT were 55. As compared to motorcycles, the number of 'other vehicles' that made the WMRT was 32 while those who preferred non-WMRT were 138. The percentage of vehicles that performed the WMRT was 31% while the ones which performed the non-WMRT were 69%. But upon segregation with respect to vehicle type it was found that the percentage of motorcycles and 'other vehicles' that performed the WMRT was 49.5% and 18.8% respectively. This indicated that WMRT was the maneuver of choice for motorcyclists, because their physical features enable them to complete this maneuver more efficiently as compared to 'other vehicles'. Out of the total number of observations made, that were 279, the ones which were involved in conflict were 32. Irrespective of their type, the numbers of conflicts were found to be higher for vehicles that performed the non-WMRT as compared to those who performed the WMRT as shown in Figure 4. Analyzing further the motorcyclists which performed the non-WMRT experienced more serious conflicts as compared to the ones which performed the WMRT. Similarly the 'other vehicles' which performed the non-WMRT experienced more serious conflicts as compared to the ones which performed the WMRT. This proves that the indigenous right-turning maneuver (WMRT), made by the drivers in Malaysia, is less risky as compared to the conventional right-turn.

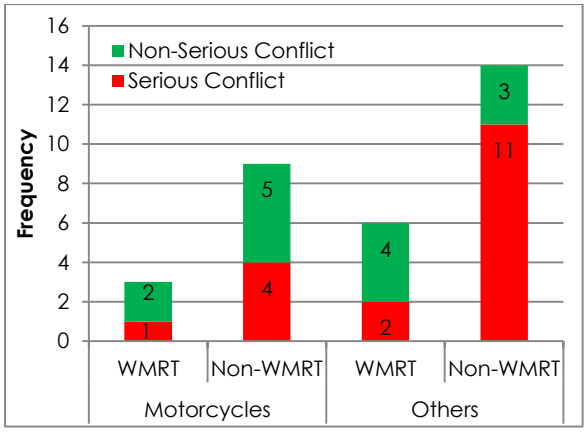


Figure 4 Turning Behavior of Motorcycles versus Other Vehicles

3.2 Hypothesis Testing

In order to determine whether statistically significant difference exists between the behaviour of vehicles and type of conflict as well as type of vehicle and type of maneuver/conflict, hypothesis testing was performed. A very small rejection region of 0.05 was selected so that the null hypothesis could be rejected with 95% confidence [14]. Four null hypothesizes were declared which stated that "there exists no significant difference among stopping behavior and type of conflict", "there exists no significant difference among turning indicator and type of conflict", "there exists no significant difference among type of maneuver and type of vehicle", "there exists significant difference among type of conflict and type of vehicle". Their alternate hypothesizes stated that "there exists significant difference among stopping behavior and type of conflict", "there exists significant difference among turning indicator and type of conflict", "there exists significant difference among type of maneuver and type of vehicle", "there exists significant difference among type of conflict and type of vehicle". All the null hypothesizes were accepted because their respective p-values were greater than 0.05 as shown in Table 1. The reasons behind these results were the low cell counts which arouse due to the smaller number of observations available for each category. However the results of the descriptive statistics stand true as they reflect the practical situation on site rather than the theoretical inferences made through hypothesis testing.

Table 1 Hypothesis testing of Stopping/Turning Behavior versus Type of Conflict and Type of Maneuver/Conflict versus Type of Vehicle

		Type of Conflict	
		Serious	**Non-Serious**
Stopping Behavior	Stop	12[a]	9[a]
	Didn't Stop	6[a]	5[a]
Turning Indicator	On	8[b]	3[b]
	Off	10[b]	11[b]

[a]No significant difference among stopping behavior and type of conflict as per χ^2-test ($p > 0.05$)
[b]No significant difference among turning indicator and type of conflict as per χ^2-test ($p > 0.05$)

		Type of Vehicle	
		Motorcycle	**Others**
Type of Maneuver	WMRT	3[c]	6[c]
	Non-WMRT	9[c]	14[c]
Type of Conflict	Serious	5[d]	13[d]
	Non-Serious	7[d]	7[d]

[c]No significant difference among type of maneuver and type of vehicle as per χ^2-test ($p > 0.05$)
[d]No significant difference among type of conflict and type of vehicle as per χ^2-test ($p > 0.05$)

4.0 CONCLUSION

The behavior of traffic is different in different countries. Especially in low and middle-income countries where traffic rules are seldom followed and drivers are unruly. As a result the indigenous behavior is unique to each type of fixed and flow facility in a transportation network. This study has highlighted the difference in behavior of right-turning vehicles with respect to their compliance of the stopping rule, use of turning indicator and type of turning maneuver. It was found that most motorcyclists in Malaysia do not abide by the stopping rule at the intersection before making a right-turn. Moreover they seldom use their turning indicators and tend to make the WMRT more

often as compared to other vehicles. Not complying with the stopping rule and keeping the indicator switched off while making a right-turn was found to be hazardous and resulted in the decrease in the safety of intersection and increase in the risk of accident. However, WMRT was found to be a safer maneuver as compared to the conventional right-turn. For vehicles other than motorcycles also the analysis concluded the same results. The test of hypothesis failed to produce statistically significant outcome due to the low sample size (n=32) however the results of the descriptive analysis remain valid. Another explanation to the above point is that the values presented in Table 1 indicate the conformity of the relationship between stopping behvaiour and serious/non-serious conflicts, and use of turning indicator and serious/non-serious conflicts with the results presented in sections 3.1.1 and 3.1.2 respectively.

It is recommended that the methodology proposed in this research should be extended to other roadway facilities such as roundabouts, weaving-merging sections, entry/exit ramps, etc. with a larger data set having a greater sample size.

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