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Motorcycles and Passenger Cars Behavior at Unsignalized Intersection in Malaysia Rural Roadways

Fajaruddin Mustakim[a], Azlan Abdul Aziz [b], Motohiro Fujita[c], Mohammad Nazir Ahmad[d]

[a*]Universiti Tun Hussein Onn Malaysia, Institute IR4.0, Universiti Kebangsaan Malaysia and Faculty of Engineering and Technology, Malaysia Multimedia University. fajardin5695@gmail.com
[b]Research Management Center, Faculty of Engineering and Technology, Malaysia Multimedia University azlan.abdaziz@mmu.edu.my
[c]Member of JSCE, Professor, Graduate School of Eng. Nagoya Institute of Technology Gokiso, Showa, Nagoya Aichi, 466-8555, Japan. fujita.motohiro@nitech.ac.jp
[d]Institute IR4.0, Universiti Kebangsaan Malaysia, 43600, Bangi, Selangor, Malaysia. mnazir@ukm.edu.my

***Corresponding author:** fajardin5695@gmail.com

Abstract

Right turn vehicles namely car passenger and motorcycle have been identify causing the risky vehicle maneuverer and attributes which significantly result to road crash and effect to slightly and serious injuries at intersection (unsignalized T-junctions). This paper concentrates on the conflict analysis and gap acceptance of right-turning vehicles (RTV) at three-leg unsignalized intersections on Malaysia Federal Route. The selected intersections were located in Road Sections (RS) 2, 9, and 10. The analysis of gap acceptance behavior models for passenger car, motorcycle and single rider were developed using logistic regression. In relation to the analysis of gap acceptances, we used five gap patterns to consider all the possible gap patterns for RTV from minor to major roads at unsignalized T-junctions. Gap pattern analysis have been carried out for each types of gap and found that gap pattern 3 was a vulnerable gap pattern. Based on this finding, this research further examines the driver and rider behavior of gap acceptance and lane changing due to slightly and serious conflicts using the proposed gap patterns for an RTV. In addition, this paper has determined the critical gap for passenger car, motorcycle and single rider by using Raff method and Logit method. Both methods give a close result for critical gap. Furthermore, this research found that the second vehicle attributes, namely, the vehicle passing the RTV occurrence a motorcyclist, passenger car, lane change due angular conflict, and lane change due nose-tail conflict influenced the RTV to accept a shorter gap. Alternatively, channelization and traffic lights possible the RTV to accept a longer gap. This study proposes to utilize average gap pattern 3 and critical gap as a tool to identifying and improvised the hazardous unsignalized intersection.

Keywords: Conflict analysis, gap acceptance behavior and gap pattern analysis

1. Introduction

Base on police statistic record PDRM [1] in Malaysia, between (18 March 2020- 18 February 2021) number of motorcycles crashes stated 8,932 cases. About 33.8% or 3,020 cases were involved motorcycles fatality, meanwhile 15.1% (1,351 cases) were serious injuries. Motorcycle slightly injuries and damages recorded 47.3% (4,223 cases) and 3.9% (338 cases) respectively.

Abdul Manan & Varhelyi [2] reveals that the highest numbers of motorcycle fatalities happen in Malaysia rural roadways (61%), on primary roads (62%) and on straight road sections (66%). The majority are riders (89%). Abdul Manan et al. [3] found factor associated with motorcyclist fatalities in Malaysia were straight road sections, access points, primary or secondary road, male, 21 – 30 years old, speeding and wet surface or water ponding.

Silcock et al. [4] reveal suitable approach for remedial measures to reduces the probability and causality of road crash by identify hazardous sections of the road network. In industrialized countries it has been recognize as one of the favorite cost-effective method of improving road safety. Hadi et al.[5] summarized, the results of high number of access points was associated with higher accident frequency. The study revealed that increased lane width, median width and outside shoulder width were significance measures in reducing accident. The author applies negative binomial regression analysis to analyses the effect of cross-section design elements on total death and causality crash rates for various types of rural and urban highways. Fajaruddin et al. [6] carried out studied on accident prediction model using regression method. The study concluded that the factors which effect to road crash in rural roadway are, number of access points, approach speed, motorcyclist and passenger cars. Previous studied that has been done by Fujita et al.[7] applied multiple linear regression method to analysis the fatal and serious injuries accident and found that right turn motorcyclist onto main stream from the minor road and quantity of access point has significant effect on the accident, meanwhile installing of traffic signal and road divider can significantly decrease amount of road crash.

Haleem et al. [8] analyzed crash injury severity in state of Florida concentrating on three and four-leg unsignalized intersections by using binary probit model method. Several important factors affecting crash severity was identified. Those attributes included left and right shoulder width, number of left turns on the minor road, traffic volume on the major stream, the number of through lanes on the minor road and number of right and left turn lanes on the major stream. The author found that, the 90-degree T-junction design as the most suitable secure design for flatting number of accident causality. Spek et al. [9] the existence of unsignalized intersection are purposely which is usually provided on minimum road capacity. This encourage the drivers or riders to rise their velocity. The study concludes that increasing vehicle crash between minor road vehicle and major road vehicle due to rise vehicle approach speed in main stream.

Polus et al. [10] found that gap acceptance may be used to predict the relative risk at intersections, where shorter gaps usually involve higher accident risk. Previous research carried out by Jennifer et al.[11] the probability that a driver will have an accident or near miss when turning right across a stream of traffic are depend on size of the gap that a driver will accept in an oncoming stream, velocity, age, sex and type of on-coming vehicles. Gap is defined as the time elapsed between the rear bumper of one vehicle and the front bumper of the following vehicle in the traffic stream of major road at a reference line. Gap acceptance decision involve making a judgment about whether it is possible to complete a maneuverer before an oncoming vehicle arrives Hoffman et al [12].

Brilon et al. [13] has been describes critical gap for occurrence as “the shortest time gap in the importance stream that a minor road driver is prepare to accept for crossing or entering the major road conflict zone. Another definition given by Drew et al. [14] describes the critical gap as the gap for which the percentage of driver or rider that will accept a minimum gap is equal to the percentage of driver or rider that will reject a maximum gap.

Comparison between neural network and binary-logit models in predicting driver’s tendency either to accept or reject the gap at rural roadway have been carried out by Pant et.al [15]. The research reveals that driver decision to accept or reject a gap can be motivated by the following attribute such as fast-moving motorist, size gap, waiting time in minor road, traffic type of control at the intersection and the turning movements in both major and minor road. Ben-Akiva et al.,[16] applied logit model modelling approach for developing gap-acceptance functions. Harwood et al.,[17] similarly implement logit models to model gap acceptance in a search of unsignalized intersection sign distance on the basis of gap acceptance. They are four categories of maneuvers at unsignalized intersection: a left turn from minor road, a left turn on the main road a right turn from minor road and a right turn from main road.

Mannering et al. [18], concluded when analyze motorcyclists behavior likelihood of being involved in accident by repeated speeding and changing weaving between lane of traffic were the critical factors of fatal crashes. Eberhard et al. [19], conducted research merge or lane change crash happen under “normal” driving situation, that is daytime and sunshine condition. It found that types of crashes are that the driver who is ignorant of the other vehicle when he or she makes a lane change fails to immediate respond with a retrieval movement to avoid the crash. Authors identified eight classifications of lane change/merge crashes. They involve: angle hit, angle hitting drifting, rear-end hit, sideswipe and rear-end hitting, both changing lanes, leaving a parking place.

Glauz et al. [20], for example, investigated conflict and historical accident data in the greater Kansas City area at 46 signalized and non-signalized intersections. A procedure namely “abnormal” and “expected” conflict was also developed to identify conflict levels for these intersections. The research found that, overall, traffic conflicts cases and average accident rates produce estimates of nearly as good as those produced from historical accident data.

Caird et al. [21] found motorcyclists are neglected in right-of-way violation crashes in which a vehicle from the conflicting stream encroaches into the path of an approaching motorcycle. Furthermore, drivers tend to over-estimate the motorcycle arrival time approaching the intersection, hence increasing the possibility of a collision. Motorcycle fatalities are more frequent in rural areas due to greater speed and less traffic control by Silva et al. [22].

Alternative approach was necessary to analyze the probability of accident at intersections, however not all accident data have been reported. Thus, traffic conflicts were prefered to overcome this issue. Caliendo et al. [23] have proposed microsimulation technique to generate traffic conflicts at three legged and four legged unsignalized intersections by using AIMSUN simulation software with SSAM software. Time to Collision (TTC) and Encroachment Time (PET) were applied to identify critical conflict. The author has found that the value of TTC and PET lie within the range of 0 to 1.5 seconds and 0 to 5 seconds respectively. Furthermore, it summarized that both traffic conflict method can be implemented as latest approach to estimating crash at unsignalized intersection.

Although human fault, in one side or another, has been identified as the main influential factor to most road crash, road-associated factors are also should not being neglected. There is infrequently one isolated reason of road crash, and human fault will typically always occur alongside engineering-associated deficiencies in the road safety facilities. For example, road crash resulting from motorist crossing onto main stream from minor roads at unsignalized intersections are usually associated with unsafe road safety facilities, such as the without channelization or road median. Thus, accident reduction by considering engineering countermeasures play a vital role.

Several factors significant to traffic accidents have been clarified in previous studies. Nevertheless, most of researchers have been industrialized in countries and situations where driver’s position (left-handed), traffic characteristic, driver or rider behavior, accident collections, infrastructure and safety facilities are very different from those in rural Malaysia roadways. Some unclear conditions associated to lane changing due to slightly and serious conflicts on rural roads in Malaysia are remain poorly clarified. Quite frequent slightly and serious conflicts have been occurred on rural roads in Malaysia. Thus, the analysis of hazardous vehicle movement and their correlation to slightly and serious accidents is essential in order to flatten accident rates as well as social economic damage. Moreover, inadequate attention from preceding research to consider of all traffic movement, traffic flow from all directions, and left and right turning from minor and major roads by type of vehicle at unsignalized intersection. The current research was the only to analyze the factors contributing slightly and serious accidents on Malaysian Federal Road 50 involving unsignalized intersection and various vehicle movements. This research involved comprehensive analysis of hazardous movement, gap acceptance and lane change due slightly and serious conflicts of right-turning vehicles (focusing motorcyclists and passenger cars) from a minor road as critical attribute in slightly and serious accidents.

2. Site Survey

Traffic maneuvers data was collected using video cameras mounted on a tripod at the specific sites. In addition to the traffic maneuvers, site-survey data about the intersections was also recorded, as well as the road measurement, geometric characteristics and photos. Traffic survey data carried out in this paper were based on the hourly traffic volume. Passenger cars, motorcycles, vans, lorries and buses data were counted from the hourly traffic volume (disaggregated by each type of motor vehicles), counted on each Road Section at the selected intersection. The passenger cars (car, per hour) on the rural highway range from 1,017 to 1,830 while for motorcyclist (Mc, per hour) range from 291 to 346. **Figure. 2.1** shows the example time-based frequency in traffic volumes (15 minutes interval) at Road Section (RS) 10. In morning the peak traffic volume was 857 vehicles noted at 8.00a.m-8.15 a.m. Meanwhile the maximum mid-day traffic volumes were 570 vehicles recorded at 1.00p.m-1.15p.m. While in the evening the highest traffic volume was 575 vehicles at 5.15p.m to 5.30p.m.

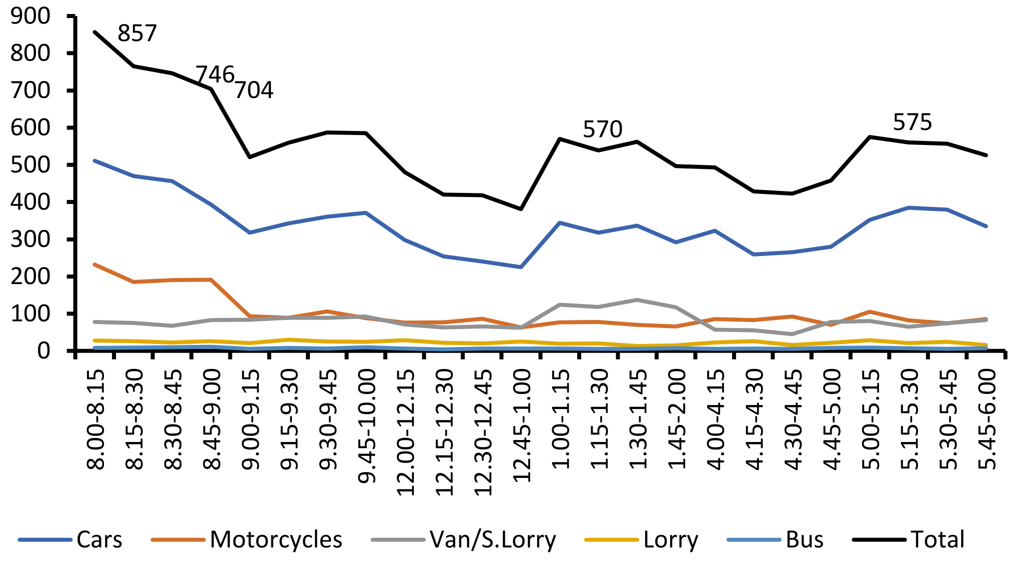

Figure 2.1: The time-based frequency in traffic volumes during a typical weekday

The traffic behavior data retrieved from the video camera as illustrate in **Figure 2.** Meanwhile, the detail of traffic survey was collected and presented in **Table 2.1** at selected intersection located in RS 2,9, and 10. The intersection chosen for the research was an access point (unsignalized single T-junction) joining a 2-lane 2-way minor road with a 4-lane 2-way major road. Four peak hour periods were used to analyze the RTV movements (12:00 to 14:00 and 16:00 to 18:00), involving types of vehicle such as passenger cars, motorcycles, vans, small lorries, trucks and buses were also counted simultaneously. Traffic behavior, approach speed, type of gap, waiting time, and change lane conflict were similarly been analyzes. There are 6 vehicles maneuvers which is vehicles from minor road enter to major road, vehicles from major road onto minor road and vehicles from mainstreams, shows in **Figure 2.2**.

Table 2.1: Traffic maneuvers at Road Section 2, 9 and 10

Movement	Minor Road	Major Road
Right turns	551 *(2)*	208 *(3)*
Left turns	269 *(4)*	506 *(1)*
Eastbound through	-	11420 *(6)*
Westbound through	-	8556 *(5)*

( ) Type of traffic movement, See **Figure 2.2**.*(1)* Left-turning vehicles from major to minor road ,*(2)* Right-turning vehicles from minor to major road ,*(3)* Right-turning vehicles from major to minor road *(4)* Left-turning vehicles from minor to major road.

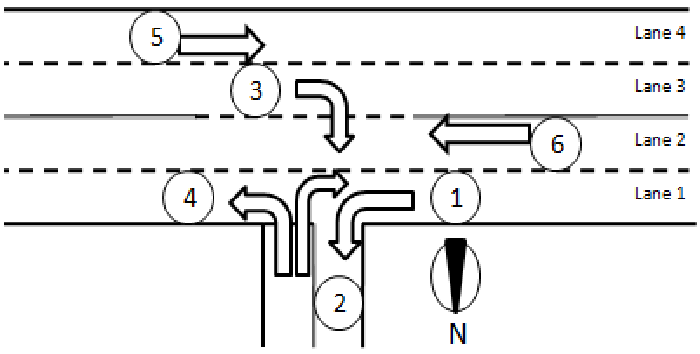

Figure 2.2: The traffic flow count at unsignalized intersection.

Every movement vehicle can be described as type 1: vehicle from major road left turn into minor road, type 2: vehicles right turn from minor road into major road, type 3: vehicles right turn into minor road from major road while type 4: vehicles left turn form the minor road into major road, type 5: vehicles through westbound and type 6: vehicles through eastbound.

3. Change Lane Conflict and Gap Acceptance Analysis

Type of gap patterns for right turning vehicle has been established by Fujita et al [7]. **Figure 3.1** shown four type of gap pattern for right turning vehicle at RS 9 and RS10. Meanwhile **Figure 3.2** shown five type of gap pattern for right turning vehicle at RS 2. The type of gap was explaining as **Gap 1:** It is described as the gap between a pair of vehicles in tracks 1 or 2. The pair of vehicles involves of the first vehicle passing the RTV, and the second vehicle which may allow the RTV to turn right. **Gap 2:** It is described as the gap between a pair of vehicles in tracks 3. **Gap 3:** It is described as the gap between the first vehicle in tracks 1 or 2, which has just passed the RTV, and the second vehicle in track 3. **Gap 4:** It is described as the gap between the first vehicle in track 3, which has just passed the RTV, and the second vehicle in track 1 or 2. **Gap 5:** It is described as the gap between the first vehicle in tracks 1 or 2, passing the vehicle at the head of the queue, and then following the second vehicle in track 5. In this analysis, the accepted gap is the gap pattern and gap time that the RTV accepted for directing a right-turning activity. In contrast, the rejected gap is the longest gap for which the RTV refused to turn right.

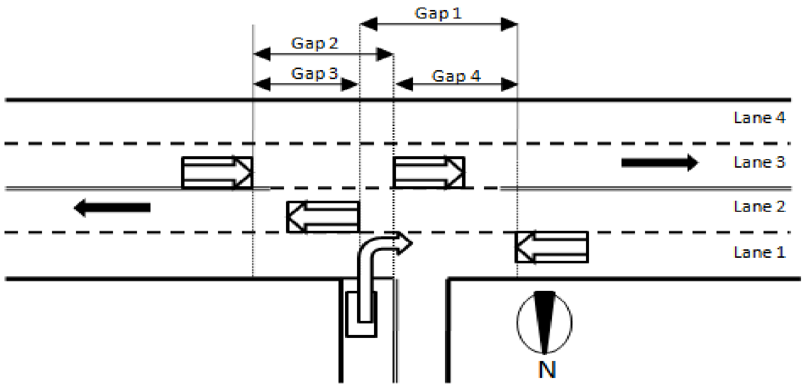

Figure 3.1: Four type of gap patterns for accepted or rejected gap by vehicle - turning at RS 9 and RS 10 unsignalized intersection.

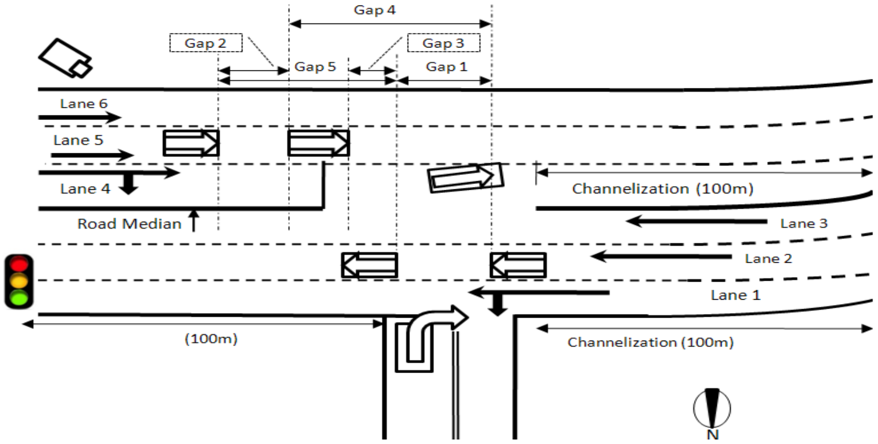

Figure 3.2: Five type of gap patterns for accepted or rejected gap by vehicle - turning at RS 2 unsignalized intersection.

The frequency of the accepted gaps and the number of lane change conflicts by gap pattern at the junctions in three unsignalized intersection as illustrated **Figure 3.3**. The Gap three pattern had the highest frequency of accepted gaps (187) and the highest number of lane change conflict (62). Alternatively, Gap two pattern had the lowest number of lane change conflict with one case.

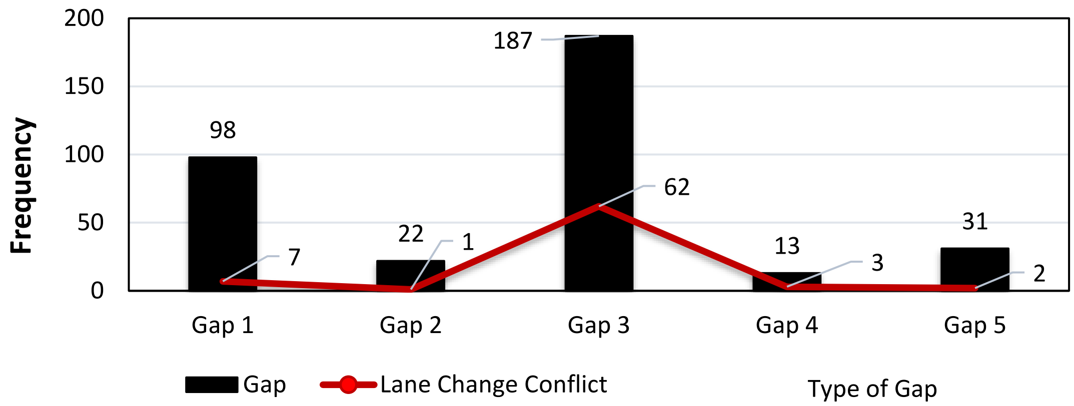

Figure 3.3: Type of gap frequency at unsignalized intersection

3.1 Type of Gap Acceptance Pattern Analysis

They are five different types of gap patterns at the RS 2 intersection as shown in **Figure 3.4**. The Gap three, Gap five and Gap one has longest gap acceptance times recorded, with gaps of 26.85 seconds, 23.81 seconds and 12.15 seconds, respectively. Alternatively, the Gap one pattern, Gap three pattern and Gap five pattern has the lower end of range, the shortest gap acceptance times were recorded with gaps of 4.28 seconds, 4.54 seconds and 6.65 seconds, respectively. Moreover, Gap 5 pattern (11.44 seconds) stated the highest average gap acceptance time, followed by the Gap 3 pattern (10.24 seconds) and Gap 1 pattern (6.85 seconds).

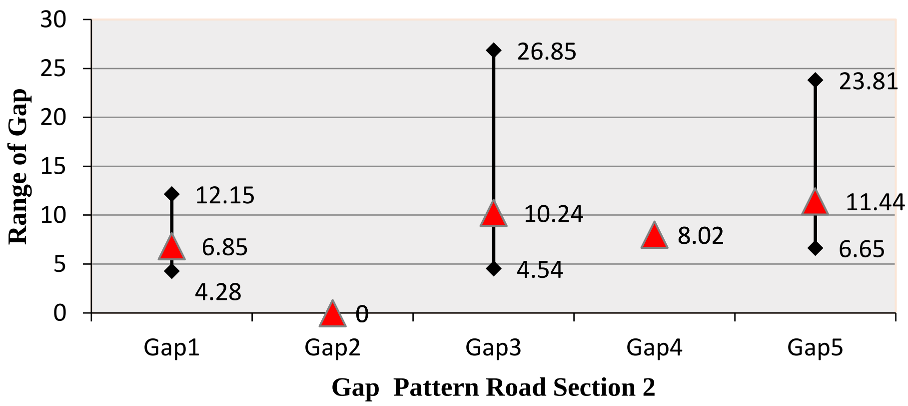

Figure 3.4: RS 2 unsignalized intersection and type of gap pattern.

They are four different types of gap patterns at the RS 9 intersection as shown in **Figure 3.5**. Gap three and Gap four which shared the longest gap of 15.49 seconds, meanwhile gap pattern one stated 14.78 seconds. The lower end of range for gap pattern was Gap three, Gap two and Gap four with gap times of 3.00 seconds, 3.04 seconds and 3.82 seconds, respectively. Gap three stated highest average gap acceptance times followed by Gap one with 8.84 seconds and Gap two obtained 6.95 seconds.

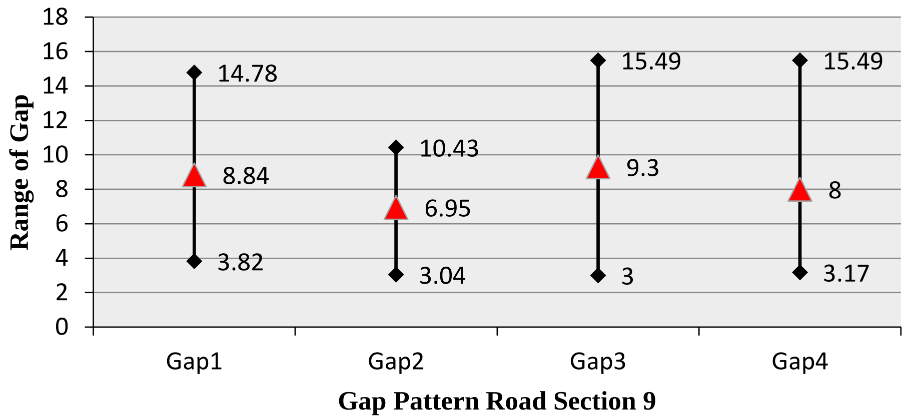

Figure 3.5: RS 9 unsignalized intersection and type of gap pattern.

The different types of gap patterns at the RS 10 intersection as shown in **Figure 3.6**. Gap One recorded the longest gap acceptance which 12.46 seconds, followed by Gap Three 11.06 seconds and Gap Four 6.70 seconds. Alternatively, Gap three, Gap two and Gap one stated the shortest gap times, with gap times of 3.02 seconds, 4.01 seconds and 4.53 seconds, respectively. From shortest to longest, the average gap acceptance times were Gap two (4.44 seconds), Gap three (6.60 seconds), Gap four (6.79 seconds), and Gap one (9.62 seconds).

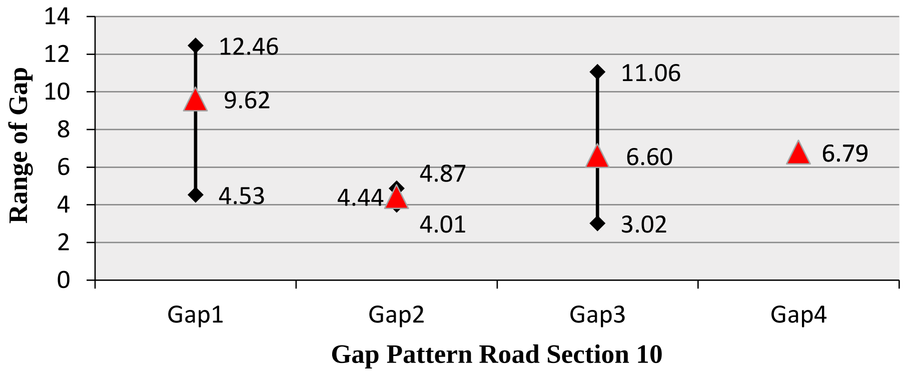

Figure 3.6: RS 10 unsignalized intersection and type of gap pattern.

3.2 Conflict Situation

The accident risk is possibly associated with both driving behavior leading vehicles and following vehicles. Traffic conflicts are interactions between two or more vehicles or drivers take evasive action, such as braking or weaving, to avoid a collision. Type of conflicts in these studies were simplifies into two types namely change lane due rear-end conflict and change lane due angle conflict as shown in **Figure 3.7**. Conflict was chosen in this study to correlate the effect of right turn vehicle from the minor road. Conflict in this paper was classified as; rapid deceleration, suddenly lane change or stopping to avoid collision (near-missed situation); emergency braking or violent swerve (near-missed situation) and emergency action followed by collision. In this paper, change lane due to nose-tail and angle conflict categories in three events. Firstly, change lane due rear-end conflicts situation occur at the time when minor road right-turn move on to the main stream road. Those vehicles from lane three will allowed the right turn vehicle by slowing down the speed, meanwhile the followed vehicle have a potential rear-end conflict circumstance and immediately by changing lane maneuver from lane three to lane four as shows in **Figure 3.7**. Secondly, angle conflict event happens during the time when minor road right-turn vehicle crossing on to main stream, those vehicles from left side line three have conflicts potential, change lane conflict situation occurred due to angle conflict as shows in **Figure 3.7**. Thirdly, change lane conflict situation occurred due to nose to tail conflict when the right-turn vehicle from minor road enter the major road. Those vehicles in lane one from right side may have physical-conflict potential by immediate change the lane due to nose to tail conflict between first and second following vehicles as illustrate in **Figure 3.7**.

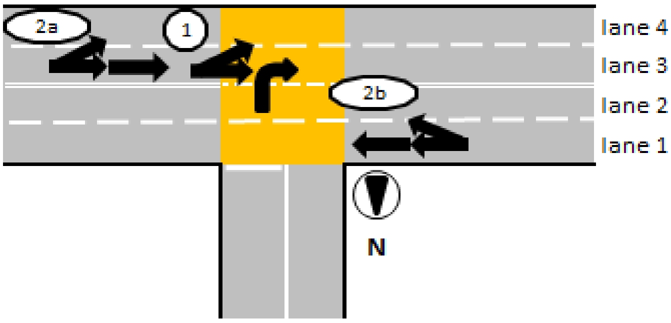

Figure 3.7: Types of traffic conflicts at un-signalized T junction.1= lane change due angular conflict, 2a and 2b= lane change due nose to tail.

3.3 Analysis of Change Lane Conflict and Gap Acceptance Frequency

Figure 3.8 represent the classes of right-turning vehicle frequency by gap size at the all road section unsignalized intersections. The highest numbers of RTVs were recorded for the accepted gap times of 6 and 7 seconds. This intersection has experiences 35 cases of change lane with serious conflicts that occurred in the gap of less than 6 seconds, while 42 cases of change lane with slightly conflict that happened in the gap of less than 11 seconds.

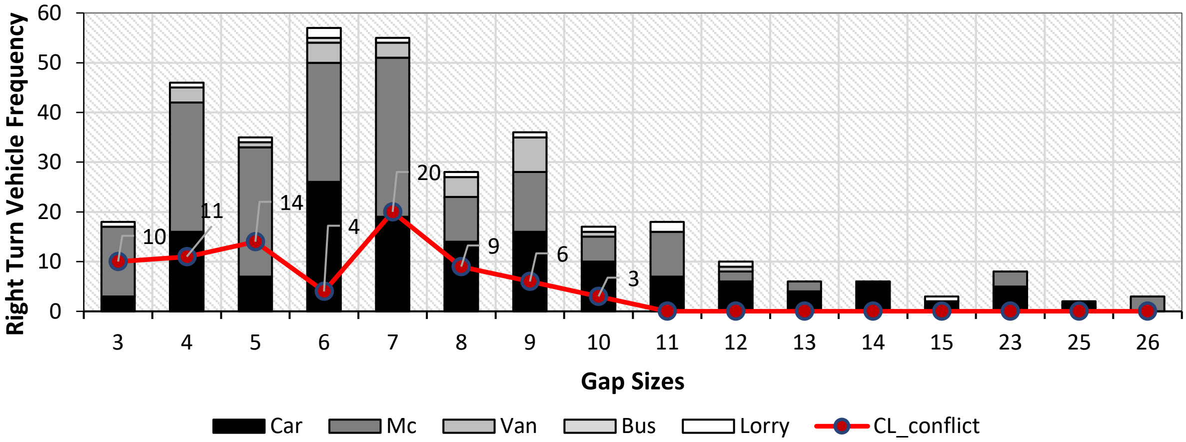

Figure 3.8: Accepted gap frequency for right turning vehicle involved in lane change conflicts at the unsignalized intersection.

Figure 3.9 shows the frequency distribution of accepted gaps for right-turning motorcycles (single riders) involved in lane change due to nose-tail and angular conflict. The accepted gaps of 4 and 7 seconds shared the maximum occurrence of right turn riders. Those single riders have experiences 23 cases of change lane with serious conflicts that occurred in the gap of less than 6 seconds, while 21 cases of change lane with slightly conflict that happened in the gap of less than 11 seconds.

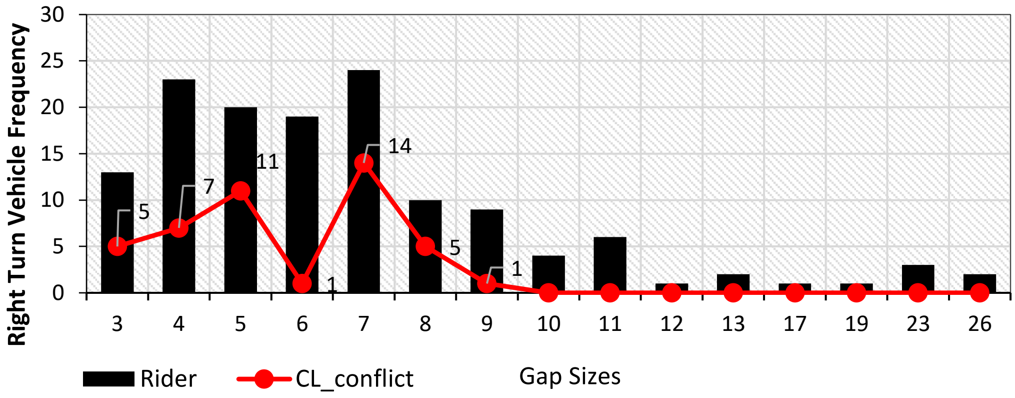

Figure 3.9: Accepted gap frequency for right-turning motorcycles (single rider) involved in lane change conflicts at the unsignalized intersection.

Figure 3.10 represents the distribution of the gap acceptance for right-turning motorcycles pillion rider involved in change lane conflicts. The accepted gaps of 7 seconds had the highest RTV frequency, followed by gap accepted 5 seconds and 6 seconds share the second highest frequency. Those pillion riders have experiences 4 cases of change lane with serious conflicts that occurred in the gap of less than 6 seconds, while 7 cases of change lane with slightly conflict that happened in the gap of less than 11 seconds.

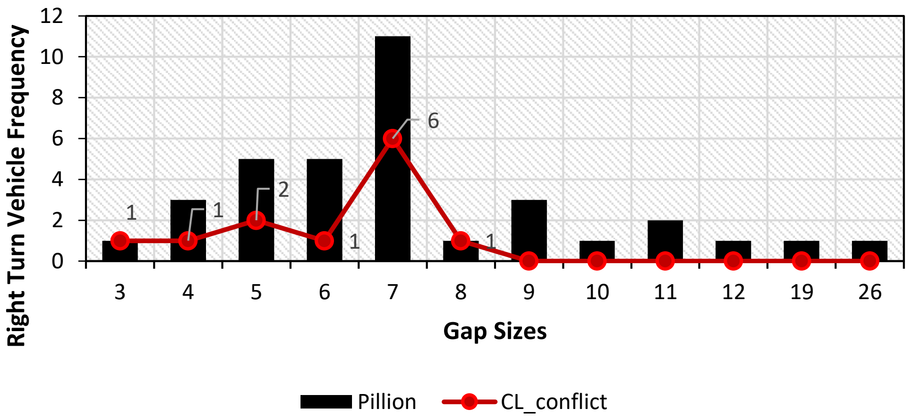

Figure 3.10: Accepted gap frequency for right-turning pillion riders involved in serious conflicts at the Unsignalized Intersection.

4. Analysis of Critical Gap using the Raff Method

Raff`s method was used in many countries because of its simplicity, graphical presentation and easy to understand. It is still relevant and being applied widely in some research projects. The rejection curve was gained by accumulating the total number of rejected gaps that were longer than the given gap. The acceptance curve was gained by accumulating the total number of the accepted gaps that were shorter than the given gap. By implementing the Raff method to both the accepted and rejected gaps from the total number of 276 cases, as shown in **Figure 4.1**. The accepted and rejected gaps for motorcycle single riders were 138 and 138 has been analysis respectively. Intersection point of the rejection and acceptance curves were defining as the critical gap. The critical gap for selected intersection was 4.75 seconds for motorcycle single riders.

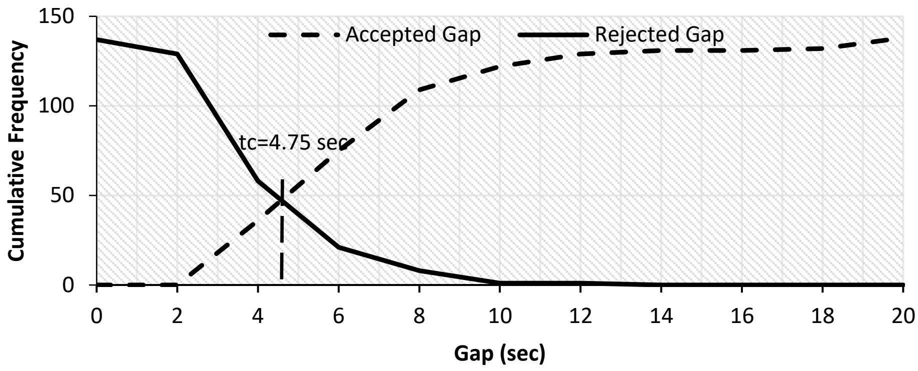

Figure 4.1: Motorcycle single rider's cumulative distributions of accepted or rejected gaps versus gap at the unsignalized intersections.

By using the Raff method to both the accepted and rejected gaps from the total number of 389 cases, as shown in **Figure 4.2.** The accepted and rejected gaps for motorcycle were 170 and 218 has been analyzes respectively. Applying the same calculation explained above for motorcycle singles riders. The critical gap for motorcycles was 5.00 seconds which is longer than riders.

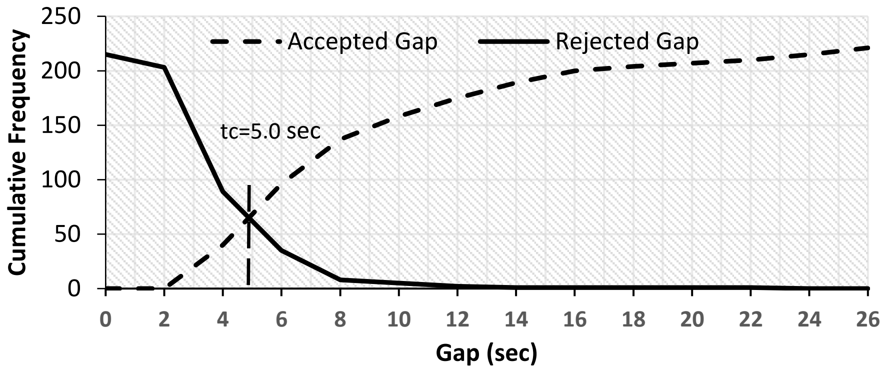

Figure 4.2: Motorcycles cumulative distributions of accepted or rejected gaps versus gap at the unsignalized intersections.

By applying the Raff method to both the accepted and rejected gaps from the total number of 346 cases, as shown in **Figure 4.3**. The accepted and rejected gaps for passenger cars were 143 and 203 has been analyzes respectively. Applying the same calculation explained above for motorcyclist and riders. The critical gap for passenger cars was 5.90 seconds which is longer than motorcyclist and riders.

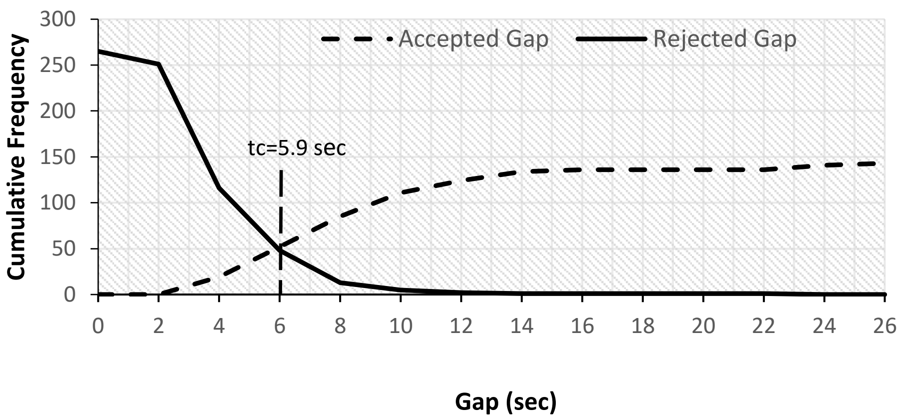

Figure 4.3: Passenger cars cumulative distributions of accepted or rejected gaps versus gap at the unsignalized intersections.

5. Gap Acceptance Behavior Model

5.1 Construction of model

This research focuses on two type of vehicles which are motorcycle and passenger car. They have two decisions whichever to received or refused the gap to cross onto the unsignalized T-junction. It is essential to select the models relevant to the type of data being analyzed. Logistic regression has been chosen in the research to model these types of discrete choice behavior and is appropriate technique for this research. The driver's or rider result might rest on, length of the gap given, approach speed of the oncoming vehicle and vehicle maneuverer at the unsignalized T-junction. All the result for right turn driver or rider called the value of the decision. The practical equation can be represented as follows:

$$U_i = V_i + \varepsilon_i \qquad (1)$$

Where U_i = the chance of a randomly elected vehicle to accept gap i or total value. V_i = experiential value and ε_i = value error or a random error component.

V_i, experiential value, is a function of difference variable factor that of the randomly chosen driver's or rider chance to accept gap i is represented as:

$$V = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \qquad (2)$$

Where β_0= is constant, β_1, β_2.... β_n= are the regression constants, $X_1, X_2 \ldots. X_n$ = other explanatory variables. (P_{rtv}) is given by the logit function was expressed in equation (3). The probability of driver or rider will accept gap randomly.

$$P_{rtv} = \frac{1}{1+ e^{-(\beta_0+ \beta_1 X_1+ \beta_2 X_2+\cdots+ \beta_n X_n)}} \qquad (3)$$

Base on logit function in equation (3) can be transformed into a linear equation as stated below:

$$\text{In}\left(\frac{p_{rtv}}{1-p_{rtv}}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \qquad (4)$$

Where P_{rtv}= Right turn vehicle probability. The critical gap is the *x*-value, obtained by substituting P_{rtv} with 0.5. The parameters in equation (4) are estimated using the maximum likelihood estimation method.

As discussed earlier, the data collection involved three intersection efforts contributed in a sum of 1011 data experiential. Among, 451 right turn vehicles (RTVs) were presented and three type of transportation involved in the analysis were passenger cars (143), motorcyclists (170), single riders (138). Furthermore, logistic regression method was developed to fit the data and in order to relate the effect of various factors on the gap acceptance behavior model. SPSS Statistic 23 software was utilized to developed the model by using logistic regression approach. In addition, a stepwise selection method was applied to determine the significance level at 0.01, 0.05 and 0.10. Gap acceptance behavior model variables was described in **Table 5.1**.

Table 5.1 Attributes for gap acceptance model.

Abbr.	Description
RT	RT=1 if vehicle turns right at a gap, and 0 otherwise
Gap	Gap which is rejected or accepted (sec)
Car	Car=1 if the RTV is car, and 0 otherwise
Mc	Mc=1 if the RTV is motorcyclist, and 0 otherwise
Rider	Rider=1 if the RTV is motorcyclist of single rider, and 0 otherwise
PRider	PRider=1 if the RTV is Pillion Rider, and 0 otherwise
Van	Van=1 if the RTV is van, and 0 otherwise
Conf	Conf=1 if serious conflict occurred (i.e., angular or nose-tail), and 0 otherwise
Nose-tail	Nose-tail=1 if nose-tail of serious conflict occurred, and 0 otherwise

Lc_Ac	Lane changing due to Angular conflict = 1 if lane changing due to angular conflict occurred, and 0 otherwise.
Lc_NTc	Lane changing due to Nose to Tail conflict = 1 if lane changing due to Nose to Tail conflict occurred, and 0 otherwise.
Gap1	Gap1=1 if the gap is the gap pattern 1 in Fig. 5.1, and 0 otherwise.
Gap2	Gap2=1 if the gap is the gap pattern 2 in Fig. 5.1, and 0 otherwise.
Gap3	Gap3=1 if the gap is the gap pattern 3 in Fig. 5.1, and 0 otherwise.
Gap4	Gap4=1 if the gap is the gap pattern 4 in Fig. 5.1, and 0 otherwise.
Gap5	Gap5=1 if the gap is the gap pattern 5 in Fig. 5.2, and 0 otherwise.
Chnlz	Chnlz=1 if the RTV stops for a while at the channelization before continuing the turning on the major road and 0 otherwise
Chnlzfy	Chnlzfy= 1 if channelization facility in Road Section 2 and 0 otherwise
TL	TL=1, if all vehicles in the RS 9, and 0 otherwise.
FPC, FMc, FLorry, FBus	FPC, FMc, FLorry or FBus=1, if the first vehicle passing the RTV in the major road is a passenger car, motorcycle, lorry, or bus, respectively, and 0 otherwise
SPC, SMc, SRider, SP Rider, SLorry, SBus	SPC, SMc, SRider, SLorry, or SBus=1, if the second vehicle passing the RTV on the major road is a passenger car, motorcyclist, single rider, lorry, or bus, respectively, and 0 otherwise.

The results of the parameter estimation are shown in **Table 5.2**. Models 1, 2, 3, 4, 5 and 6 were calibrated for right-turning passenger car, motorcyclists and motorcyclists (single riders), right-turning, respectively. The Model were categorized into two-part which are detailed model and simplified model. Detailed Model explain the significance behavior for passenger cars, motorcyclists and single riders meanwhile the simplified Model used to calculate the critical gap T-critical (tc) for passenger cars, motorcyclist and riders.

Table 5.2: Passenger cars, motorcyclists, and single riders for gap behavior models

Attributes	(Car) Detailed	(Mc) Detailed	(Rider) Detailed	(Car) Simplified	(Mc) Simplified	(Rider) Simplified
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	-5.07 (76.26)***	-10.45 (40.83)***	-5.82 (57.11)***	-4.99 (94.96)***	-3.81 (101.50)***	-3.51 (66.90)***
Gap	0.95 (84.80)***	0.84 (89.71)***	0.89 (70.52)***	0.85 (88.73)***	0.74 (99.82)***	0.74 (72.25)***
SPC	-	1.53 (13.30)***	2.12 (16.87)***	-	-	-
SMc	1.40 (4.24)**	1.99 (7.80)***	2.62 (10.71)***	-	-	-
SRider	-	5.32 (14.68)**	-	-	-	-
SP Rider	-	5.31 (13.89)**	-	-	-	-
Lc_Ac	-	3.03 (7.25)***	2.93 (6.53)***	-	-	-
Lc_NTc	2.69 (3.25)*	-	-	-	-	-
Chnlz	-2.15 (11.21)***	-	-	-	-	-
TL	-0.71 (3.27)*	-0.91 (8.17)**	-	-	-	-
N	346	389	276	346	389	276
NagelkerkeR^2	0.73	0.70	0.66	0.69	0.55	0.55
H.R-Right Turn	84%	84%	84%	83%	75%	78%
H.R-Total	89%	86%	89%	88%	81%	81%

***, **, *= Confident level at the 99%, 95% and 90% level, respectively

The gap acceptance shown in **Table 5.2** consisted of six separate behavior models for passenger cars, motorcyclist and single riders. Models 1, 2, and 3 were calibrated for right-turning passenger cars, right-turning motorcyclist, and right-turning single rider, respectively. Alternatively, models 4, 5 and 6 are the simplified models for passenger cars, motorcyclist and single rider of RTVs, respectively. The R^2 values obtained for Model 1,2,3,4,5 and 6 were adequate high, at 0.73, 0.70, 0.66, 0.69, 0.55, and 0.55, respectively. More than 80% of the total hit ratios in all models, indicated that the models represent the data quite well.

After frequent efforts to validate the gap acceptance model, the attributes (Table 5.2) that remained in Models 1, 2, 3, 4, 5 and 6 were gap, the SPC (second vehicle passing the RTV was a passenger car), SMc (the second vehicle was motorcyclist passing the RTV), SRider (the second vehicle was a single rider passing the RTV), SP Rider (the second vehicle was pillion riders passing the RTV), AC_Lc (angular conflict by lane changing), NTc_Lc (nose-tail conflict by lane changing), TL (traffic light), Chnlz (channelization). Those attributes were significant factors in the rider' and driver's choices to turn right. The gap attributes for motorcyclists were smaller than the gap attributes for passenger cars, from which it can be understood that the motorcyclists were possibly to accept a shorter gap. The positive sign of the lane changing due to angular and nose-tail conflict attributes indicated that the RTVs that caused serious conflict tended to start turning right in a short gap. Conversely, it was shown that a conflict was possibly to occur in a shorter gap. Meanwhile, the negative sign for traffic light and channelization (Chnlz) parameter specified that the RTVs were possibly to accept a longer gap.

The attributes of traffic light and channelization have a negative sign in Model 1, which indicated, the RTVs were likely to accept a longer gap. Alternatively, positive sign of the second passenger car (SPC), the second motorcyclist (SMc), the second single rider (SRider), the second pillion rider(SPillion) and angular conflict due change lane (AC_Lc) attributes in Model 2 indicated the right turn vehicles were likely to accept a short gap. Alternatively, the attribute of the second passenger cars (SPC), the second motorcyclists and angular conflict due change lane (AC_Lc) were a positive sign, specified that RTVs were likely to accept a short gap. The simplified model 4,5 and 6 developed for passenger car, motorcyclists, and riders representively to determine an average critical gap. The detailed calculation was discussed in the following section.

5.2 Critical Gap for Right Turning Vehicles (RTVs)

The estimated of critical gaps for RTVs, were defined by gap accepted with probability equal to 50% as shown in **Table 5.3**. Model 4,5 and 6 were used to calculate the critical gap for passenger cars, motorcyclists and single riders by including P_{rt}= 0.5 for each of the models. The result of critical gap for passenger cars, motorcyclists and single riders were 5.85 seconds, 5.15 seconds and 4.75 seconds, respectively. Meanwhile the critical gaps with conflict for passenger cars and single riders were calculate using Model 1 and Model 3 by setting Prt=0.5 for each model and if with conflict=1 and 0 otherwise. As a result, passenger cars and single riders with conflict obtain critical gap 2.51 seconds and 3.25 second respectively.

Considering with **Figure 3.7** and **Table 5.3**, passenger cars that obtain quick gap (3 sec.) probably to cause serious conflict. Although, accepted gap for single riders is a bit lengthier than passenger cars, gap accept 4-5 seconds, is occasionally inefficient for single riders to turn right safely. Likewise, passenger car drivers might simply over-look motorcyclists in traffic flows on major roads (Conflict type 1 in **Fig. 3.7**) those riders suddenly change lane (from lane 3 to lane 4) or although the first vehicle might achieve to stop securely then such immediate break cause consequence conflicts to the subsequent cars (Conflict types 2a and 2b) those cars abruptly change lane. In **Figure 3.9**, nearly fifty percent of single riders accepted gaps of less than or equal to 6 seconds might produce serious conflicts. Conversely in **Fig. 3.10** half of pillion rider accepted gaps more or equal to 7 seconds have caused slightly conflicts.

All critical gaps for passenger cars, motorcyclists and single riders obtained at the unsignalized intersection are shorter than those from the Malaysia Standard (ATJ 11/87) [24] and United State Highway Capacity Manual 2000 (USHCM 2000) [25] stated 7 seconds and 7.5 seconds, correspondingly. Additionally, the variance between the standards and the outcome of critical gap for passenger cars and single riders considering serious conflict due lane change were quite large. Passenger cars with serious conflict accepts a too short gap to turn right securely. RTV drivers appear to purposely start turning right in a very short gap with facts of the danger or with expectation for main stream drivers to reduce speed automatically. Especially to motorcyclist or single riders, the right-turn motorcyclists has higher potential to experiences serious accidents. Thus, in this research can classified that motorcyclists and single riders as vulnerable RTVs.

Table 5.3: Comparison of the critical gaps

	Critical Gap (tc)	
	Logit Method	Raff Method
Passenger car critical gap	5.85	5.90
Motorcyclist critical gap	5.15	5.00
Single rider critical gap	4.75	4.75
Passenger cars change lanes, due nose-tail conflict	2.51	-
Single riders change lanes, due angular conflict	3.25	-
Malaysian Standard	7.0	
United State Highway Capacity Manual 2000	7.5	

6. Conclusion and Recommendation

This research has carried out the factors relevant to serious and slightly accident due to change lane in order to clarify the hazardous right turning vehicles maneuverers. The outcomes were summarized as follows:

(1) Logistic regression was used to developed gap acceptance models at access points. Implementing the models to the passenger cars, motorcyclist and single rider behaviors on RS 2, 9 and 10, the variables of gap, second vehicle passing the RTV was a passenger car, motorcyclist, single rider, pillion rider, change lane due angular conflict, change lane due nose-tail due conflict, traffic light, and channelization were found to be significant factors in drivers' decisions to turn right.

(2) The combination of RS 2, 9, and 10 revealed that the positive signs of the change lane due to angular conflict, nose-tail conflict, second vehicle was a motorcyclist, single rider, motorcyclist of pillion rider and passenger car variables indicated that the RTVs tended to start turning right in a short gap. The positive sign of the variables in Model 1 indicated that the RTVs were likely to accept a short gap. Alternatively, the negative signs of the traffic light and channelization parameters indicated that the RTVs were likely to accept a longer gap.

(3) This paper has classified two categories of conflict, they are if lane change due conflict were less than or equal 6 seconds (0-6 seconds) were category as serious conflict meanwhile lane change due conflict less than or equal 11 seconds (7-11 seconds) were namely slightly conflict.

(4) Base on passenger cars (Model-1) and motorcyclists (Model-2 and Model-3), lane change due to nose to tail conflict associate with passenger car behavior meanwhile lane change due to angular conflict associate with motorcyclist behavior at unsignalized intersection.

(5) Single rider tends to be the most vulnerable vehicle making right turn from minor road to major roads with critical gap 4.75 seconds compare with passenger cars and pillion riders obtained critical gap 5.85 seconds and 5.15 seconds respectively. If rider experience serious conflict the gap acceptance become shorter 3.25 seconds. Probability of serious injuries or fatalities accident could be occurred. Thus, proper intention needs to be providing such as installing traffic light and construct right turn channelization on the high risk unsignalized intersection.

(6) Since Gap pattern 3 has accepted the higher number of serious conflict (**Figure 3.3**) during the RTV for all unsignalized intersection, and average gap pattern 3 in Road Section 10 were less than 7 seconds compare with other intersection. An appropriate countermeasure needs to be addressed.

(7) This research proposes to utilize average gap pattern three and critical gap as a measurement or tool to identifying the hazardous unsignalized T- intersection especially on rural roadway.

This research has intention to extend the study involving vehicle to vehicle communication (V2V) consist of wireless data transmission between motor vehicles. Scanlon et al. [26], there are several additional methods being explored for preventing possible accident at unsignalized intersection. These approaches can be divided into two categories: vehicle-to-infrastructure base communication (V2I) and vehicle to vehicle (V2V). Although V2I and V2V are capable accident avoidance solutions, these technologies are still being developed and verified.

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