A Lane-changing Model Based on Queue Length at an Urban Signalised Intersection

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Abstract: - The aim of this research is to study and develop models for driver's lane-changing behaviour in an urban area using the logistic regression method. A pilot study was conducted using a videotape recording technique to film an approach road leading to a signalised intersection in an urban road during the morning off-peak period. Inter related coding methods were designed to described and verify the driver's lane-changing manoeuvre. A questionnaires study to analyse the driver's background, experience, attitudes, lane-changing practices and their driving behaviour on the road was carried out in order to develop lane-changing behaviour models using the logistic regression method.

Key-Words: - Lane-changing, Action, Racei, Fast, Queue, Pass

1 Introduction

Nowadays, the consequences of traffic jam issues had become a big concern for community especially in a big city. It is impossible to identify the whole story about it without identify on the specific factor that contribute to the traffic jam. One of many factors that have been identified in contributing the traffic jam is the driver's behaviour. Thus, the purpose of this study was one way to bring up the issues of driver's lane-changing behavior in an urban area.

Previously, numerous researches have been conducted to investigate the driver's behaviour in an urban area. Ikenouek et al. [1] and Botma [2] had developed a model based on the mechanic lane-changing manoeuvre aspects in urban road. In their study, the main aspects is the related forces in lane-changing manoeuvre happened such as acceleration, reaction times, break forces, vehicle signal aspect and others without decision making aspect to make any lane-changing manoeuvre. A comparison study between a car follow model and lane-changing model had been made by Gipps in 1986 [3]. From his study, he concluded that lane-changing is more complex than car follow because lane-changing decision depends on the identified objectives that sometimes can contrary on each other.

Actually, the drivers are not good enough in lane-changing making decision [4] since less of lane-changing discipline was ranked at the third position as the main cause of an accident happen in highway. In another context, one researcher [5] explained that the traffic jam problem caused by the stopping bus in the bus stand. A related study by [6] stated that it is important to make an explanation about the cause of lane-changing. Meanwhile, another study [7] at a traffic light intersection shows many drivers changed to the shortest queue lane at started red. A study made in United States by Mason et. al [8] stated that careless in lane-changing was listed in 10th position out of 25 driver's behaviour as the cause of accident happened in highway,

2 Background

This study was conducted to develop a lane-changing model based on queue length at an urban signalised intersection. In this study, 2230 sets of questionnaires were carried out to the drivers randomly. 384 or 17.22 % sets of questionnaires were returned back by the respondents. The results of the returning questionnaires were recorded to make an analysis. These results were useful in developing a lane-changing model by using computer software named as Statistical Package of Social Science (SPSS) version 10.0. This study convergent on Lembah Klang which is a most development place in Malaysia which have many big city such as Kuala Lumpur, Petaling Jaya, Shah Alam, Klang, Ampang Jaya, Gombak, Selayang and Kajang.

2.1 Logistic Regression Model

Based on SPSS version 10.0 regression model for one independent variable, logistic regression model is written as:

$$\text{Probability (event)} = \frac{e^{B_0+B_1X}}{1+e^{B_0+B_1X}}$$

or same with

$$= \frac{1}{1+e^{-(B_0+B_1X)}} \tag{1}$$

Where B_0 and B_1 are the coefficients or estimated parameters from the data which is a scalar, X is the independent variable which is a vector, and e is the basic logarithm value same with 2.7182818.

For two or more independent variable, logistic regression model is written as:

$$\text{Probability (event)} = \frac{e^Z}{1+e^Z}$$

or same with

$$= \frac{1}{1+e^{-Z}} \tag{2}$$

and

$$Z = B_0 + B_1X_1 + B_2X_2 + \ldots + B_pX_p \tag{3}$$

where $B_0, B_1, \ldots B_p$ are the coefficients or estimated parameters from the data which is a scalar, X_1, X_2, …Xp are independent variables which is a vector, and k is the number of independent variable.

If the value of the Probability (event) is less than 0.5, hence concluded that the event was not occurred but if the probability value is larger than 0.5, hence concluded that the event was occurred.

Finally, probability of the event not occurred can be estimate as:

Probability (not occurred) = 1 – Probability (event) (4)

3 Results and Discussions

3.1 Lane-Changing Model Based on Queue Length

The lane-changing model based on queue was developed by using a dependent variable named as Action. This model refers to a picture posed on question 55 of the questionnaire as shown in Fig. 1. This question related to the driver's action whether to choose lane 2, 3 or 4 when the driver drives on lane 2 and facing on various kind of queue length at lane 2, 3 and 4 at the signalized intersection. The driver direction is straight. Based on the SPSS result, four independent variables were significant in developing this model. These variables were selected refers on their significance level which is less or equal to 5 percent (0.05). The independent variables named as:

Racei = refers to a driver group
Fast = refers on drives fast because late to attend an appointment
Queue = refers on selecting a lane with the shortest queue at the signalized intersection
Pass = refers on given passage to another driver

Table 1 refers to the dependent variable that is constant (Action) included in the model. Table shows that no respondent were predicted true on not changing lane when facing on this scenario (Question 55), meanwhile 269 respondents were predicted true on changing lane. Otherwise, 113 respondents have been misclassified in not changing lane and no one else respondent have been misclassified in changing lane. On the whole, 70.4 % (> 50 %) respondents were predicted true in making decision.

Table 2 presents the dependent variable included in the equation. Otherwise, Table 3 shows the independent variables not included in the equation. Both of the tables display all the independent variables and constant are significant when their significance value are less than five percent.

Table 4 demonstrates the result of Hosmer and Lemeshow test. From the results obtained, it was found that the significance value is more than five percent which is 0.666 or 67 %. Meanwhile, a Chi-square and degree of freedom values are 5.833 and 8 respectively. The null hypothesis which stated that there is no significant difference between the observed and expected value cannot be rejected. So, this model was very suitable with the collected data.

Table 5 displays the overall percentage of the true predicted have increased about 3.7 % from 70.4 % to 74.1 % when all the significance independent variables included in the model. Table shows that 36 or 31.9 % respondents have been classified true in not changing lane (more than 31.9% from Table 1) and 247 or 91.8 % respondents were classified true in changing lane (decrease 8.2 % from 100% in Table 1). Besides that, 77 (from 113 in Table 1) respondents were misclassified as not changing lane, meanwhile an addition of 22 respondents from nil have been misclassified in changing lane. On the whole, we can use this changing model.

Table 6 arrays the variables include in the equation. The Table states that all the independent variables and constant are significant since their significance value is less than five percent except Pass (6 percent).

Based on the results above, the produced lane-changing model is:

$$\text{Probability (Lane - Changing Based on Queue Length (Action))} = \frac{1}{1+e^{-Z}}$$

Refer to the equation (2),

Z = 1.295 – 1.219 (Racei) – 0.235 (Fast) + 1.037 (Queue) – 0.457 (Pass)

3.2 Value of *Z*

The value of Z was identified based on how the variables are recorded in SPSS. Actually, there were two different range used in recoding the respondent's answer such as positive and negative value or yes and no or strongly agree and strongly disagree. For positive range in this case, substituted one (yes) in Racei, Queue and Pass, meanwhile substituted five (strongly agree) to Fast. Hence,

Z =1.295 - 1.219 (1) – 0.235 (5) + 1.037 (1) - 0.457 (1) = -0.519

So,

$$\text{Prob(LaneChangingBasedonQueueLenght(Action))} = \frac{1}{1+e^{-(-0.519)}} = 0.3731$$

Based on the result given in the equation, since the probability value is less than 0.5, hence concluded that the lane-changing does not occurred. On the other word, the driver was predicted not changing lane when facing on various kind of queue length.

3.3 Probability Sensitivity

The probability sensitivity was tested to prove its ability in another day practices. This test was made by including the negative range value in the equation. So, substituted zero on Racei, Queue and Pass meanwhile one to Fast. Hence,

Z =1.295 - 1.219 (0) – 0.235 (1) + 1.037 (0) - 0.457 (0) = 1.06

So,

$$\text{Prob(Lane - Changing Based on Queue Lenght (Action))} = \frac{1}{1+e^{-(1.06)}} = 0.7427 \qquad (5)$$

Since the probability value is more than 5 percent (>0.5), hence we concluded that the event (lane-changing) was occurred. It means that the driver is predicted to change lane when facing on the differences between queue lengths. So, this model is sensitive with the value of the independent variables.

3.4 Predicted Probability Histogram Graph

The scatter probability plot of the event occurred or not is represented by Predicted Probability Histogram Graph in Fig. 2. It shows that many groups of event (Lane-changing) occurred were skewed to the right of 0.5 which is 245 cases compared with 80 cases not lane-changing. There were a few groups of event does not occurred were skewed to the left of 0.5 which is 30 cases (Not Lane-changing) and 20 cases (Lane-Changing). The result produced by the graph was similar with the equation (5).

The suggested Lane-Changing Model Based on Queue Length is:

$$\frac{1}{1+e^{-[1.295-1.219\,(\text{Racei}) - 0.235\,(\text{fast}) + 1.037(\text{Queue}) - 0.457\,(\text{Pass})]}}$$

4 Conclusion

This study limited itself to only one scenario (Question 55) faced by the drivers around the capital city of Malaysia. The suggested model above only gives an estimation of the probability whether the driver was changed lane or not. Since the Lane-changing model based on queue length is sensitive, it can predict whether the driver changed lane or not when facing on the scenario stated in the questionnaires. It can be done by substituted the value of independent variables with the collected range value that have from the current record.

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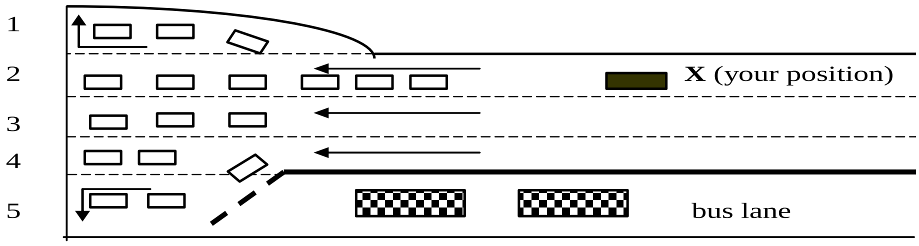

Vehicles stop at the stop line due to red light signal. You are in the 2nd lane and still moving, and perceived lane 4 has the shortest queue. What is your Action? (You are going straight ahead).

[ ] Proceed to lane 2.
[ ] Change lane to lane 3 only.
[ ] Change to lane 3 and then change to lane 4.

Fig. 1 Question 55 about the respondent (driver) action when facing with various queue lengths on the stop line

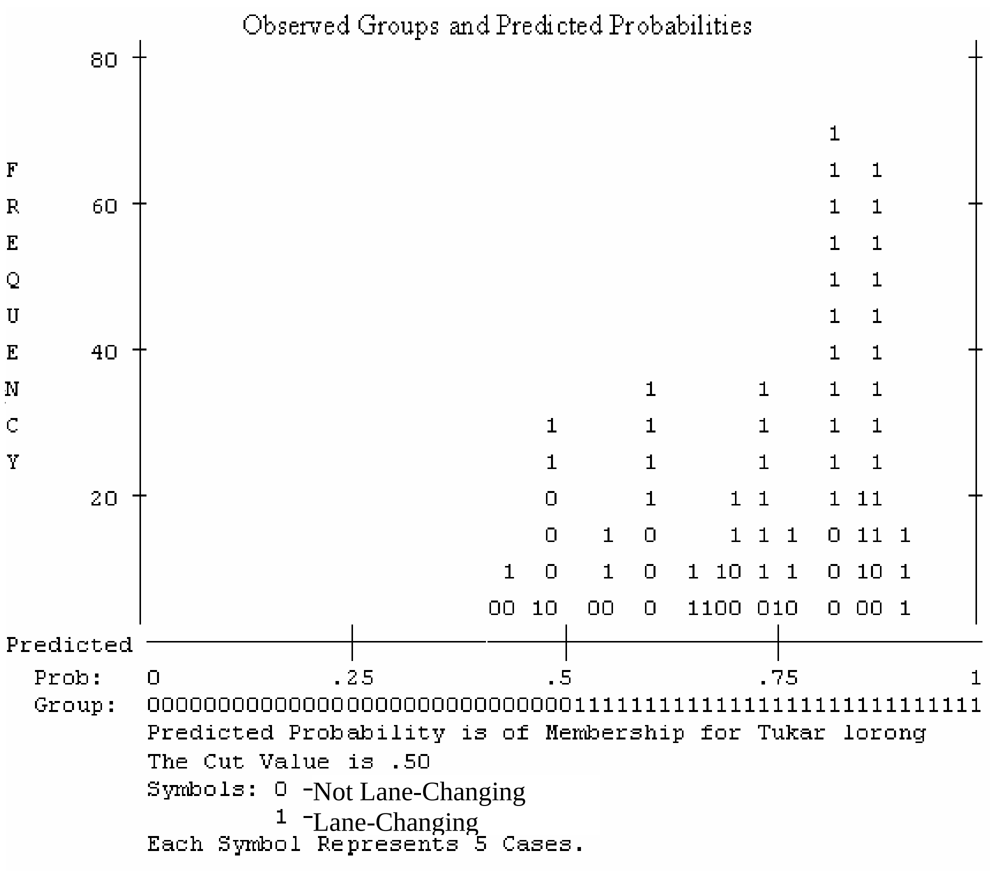

Fig. 2 Predicted Probability Histogram Graph (Data Analysis on SPSS 2001)

Table 1: Classification table (constant in the model)

Observation			Prediction		
			Go straight Changing lane		Right Percentage
			Not changing lane	Changing lane	
Step 0	Go straight Changing lane	Not changing lane	0	113	0.0
		Changing lane	0	269	100.0
	Overall percentage				70.4

Table 2: Dependent variable included in the equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	0.867	0.112	59.859	1	0.000	2.381

Table 3: Independent variables not included in the equation

			Score	Df.	Sig.
Step 0	variables	Racei	9.294	1	0.002
		Fast	9.788	1	0.002
		Queue	23.645	1	0.000
		Pass	6.414	1	0.011
	Overall Percentage		41.858	4	0.000

Table 4: Hosmer and Lemeshow Test

Step	Chi-square	Degrees of Freedom	Sig.
1	5.833	8	0.666

Table 5: Classification table

Observation			Predicted		
			Go straight Changing lane		Right Percentage
			Not changing lane	Changing lane	
Step 1	Go straight Changing lane	Not changing lane	36	77	31.9
		Changing lane	22	247	91.8
	Overall percentage				74.1

Table 6: Variables include in equation

		B	S.E	Wald	Df	Sig.	Exp(B)	95.0% C.I for Exp(B)	
								Lower	Upper
Step 1	Racei	-1.219	0.394	9.564	1	0.002	0.296	0.136	0.640
	Fast	-0.235	0.106	4.940	1	0.026	0.791	0.643	0.973
	Queue	1.037	0.240	18.612	1	0.000	2.820	1.761	4.516
	Pass	-0.457	0.243	3.527	1	0.060	0.633	0.363	1.020
	Constant	1.295	0.388	11.134	1	0.001	3.653		