

# MODELLING THE ROUTE DIVERSION BEHAVIOUR OF MOTORCYCLISTS IN RESPONSE TO VARIABLE MESSAGE SIGNS

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The dissemination of traffic information through variable message signs is expected to minimize congestion effectively by guiding travellers to make better route selections. In light of the fast expansion of motorcycles in developing countries and the gap in the literature, the purpose of this research is to analyze the key attributes that affect motorcyclists' preferences to divert from their original routes. A stated preference experiment was conducted to recognize the en-route decisions in response to VMS messages. A binary logit model was introduced to estimate the parameters associated with the two choices: stay or divert. As a result, it was revealed that motorcyclists prefer to adjust routes when the alternative provides shorter distances, wider roads, less traffic, and lower trip durations. Individual characteristics, including age, occupation, education, and the habit of accessing traffic information sources while riding, also had a significant influence on this behaviour. Motorcyclists showed a strong tendency to divert when route suggestions were presented, leading to the study's implication of spreading traffic to create more balanced networks.

*Key Words* : route diversion behaviour, motorcyclists, variable message signs, route guidance

## 1. INTRODUCTION

Traffic congestion is a severe problem in many cities throughout the world, especially in developing countries. This condition is exacerbated by the rapid growth of motorcycle ownership, the most prevalent mode of transportation in South-East Asian countries, leading to gridlock mechanisms during peak hours. There are numerous causes for these phenomena, in general, the existing infrastructure has become inadequate to accommodate traffic demand. Nonetheless, constructing new roads to increase capacity is not always the foremost solution. This scheme may result in a vicious circle of congestion that is predicted to constitute a feedback loop since the flow of vehicles will also rise to fill the additional space. In fact, it was observed that the distribution of traffic accumulation in road networks is not balanced in occupying the entire links. Some paths are very congested due to their popularity and familiarity among travellers, whereas other sets of roads may not

be completely functional for a variety of reasons, including human perceptions and tendencies. In light of these issues, a number of prior studies suggested traffic information as an effective and efficient method for alleviating traffic congestion<sup>1)</sup> in terms of time, cost, and resources. This method will improve the performance of traffic systems<sup>2)</sup> since travellers will be able to make better-informed route decisions.

A variable message sign (VMS) is a kind of intelligent transportation system (ITS) device installed on the road that can convey information about either traffic conditions or early alerts of incidents. As a result, the utilization of available transportation infrastructure can be optimized<sup>3)</sup> by encouraging travellers to prevent heavily used roads<sup>4)</sup>. The existence of this electronic board device may affect the preferences of travellers in both normal and congested traffic by providing traffic guidance<sup>5)</sup>. However, the significant benefits of VMS cannot be earned by motorcyclists in Indonesia, as VMSs are exclusively in-

stalled on highways and toll roads, which are not accessible to two-wheeled vehicles. Therefore, by modelling and analyzing the route diversion behaviour of motorcyclists, the objective of this research was to assess how the provision of VMS in urban road networks could impact their routing decisions.

## 2. LITERATURE REVIEW

In essence, route choice is a daily decision made by a vast number of travellers who select specific routes based on a variety of attributes of the available alternatives<sup>6)</sup>. As individual characteristics and perceptions contribute significantly to this decision-making process, different vehicles may take diverse routes between the same origin-destination. In addition, even though a pre-trip route choice has been made, the observed circumstances or individual urgency may cause the traveller to alter their original path, which is afterward referred to as en-route route choices. This route diversion behaviour tends to demonstrate the distinction between the current and expected best routes<sup>7)</sup>.

Several existing studies have analyzed the factors that most stimulate road users to deviate from their intended route, however, all are focused on passenger car drivers. A recent study on route diversion was completed by Diop et al. (2020)<sup>8)</sup>. Using a stated preference (SP) survey of drivers in Dalian, China, the effect of driver acceptance of VMS information on this behaviour was examined. The combination of the Technology Acceptance Model (TAM) and the Hybrid Choice Model resulted in the fact that socioeconomic characteristics, including age, gender, income, driving experience, and style of route choice, affect drivers' perceptions of VMS. Moreover, the message should be as comprehensive as possible to assist road users in making better travel decisions.

Another article was by Vacca et al. (2017)<sup>9)</sup>, who compared two different model structures, binary logit, and mixed binary logit models, in order to determine the best-fit model for characterizing the route diversion behaviour. In contrast to prior research, the study did not evaluate the reaction of drivers to the traffic information, but rather their desire to deviate due to a variety of route attributes and personal characteristics, including habit and learning effect variables. Both traffic delay and distance were shown to have negative coefficients, indicating drivers' disutility toward longer and more crowded routes. Younger drivers, males, workers or self-employed, those with less driving experience and lower monthly expenses are more likely to divert from the original path. Additionally, drivers were less favoured to change routes with regard to their travel habits. Previously,

Vacca and Meloni (2015)<sup>10)</sup> used GPS-based data in Cagliari, Italy, to determine the major factors that induce drivers to divert to alternative routes. The study found that gender, age, income, driving age, perception of time, the number of traffic lights, and the proportion of highways had a significant influence.

Ma et al. (2014)<sup>11)</sup> estimated a multinomial logit model to recognize variables that contribute to drivers' compliance in Beijing, China, with the VMS message. From the collected SP data, the model demonstrated that driver characteristics, including gender, driving experience, vehicle type, personality, frequency of travel, and familiarity, influence the tendency for route diversion. Meanwhile, Kattan et al. (2010)<sup>12)</sup> evaluated similar responses, but toward incident information delivered by VMS. The estimate of a latent discrete choice model revealed that driver experience, network familiarity, travel time, distance purpose of travel, and complementary information sources, affect the preferences to divert.

## 3. METHODOLOGY

### (1) Data collection

In view of the fact that VMS is currently unavailable and inaccessible for motorcyclists in Indonesia, a hypothetical choice experiment was required to capture the desired behaviour in this research. Accordingly, the appropriate data collection technique for specifying the preferences in route diversion to be applied is stated preference (SP). In addition to being able to account for the non-existent markets, this method offers many other advantages, including the capability to avoid multicollinearity across attributes<sup>13)</sup>, as well as its time and cost efficiency.

As a combination of selected attributes, the hypothetical scenarios were derived from the discrete choice experiments (DCE) introduced by Aizaki et al. (2014)<sup>14)</sup>. Two primary groups are classifying the determinants of the route diversion propensity: (1) route attributes (i.e., distance, road width, travel time, traffic flow), and (2) individual characteristics, which consist of socioeconomic and motorcycle riding properties. The latter, however, was not adopted to generate the experimental design for the SP survey.

The experiment began by directing respondents to visualize themselves riding a motorcycle from home to the workplace. In the middle of the trip, they were supposed to notice the traffic information from the VMS. In this situation, sampled motorcyclists were asked to decide whether to change routes to the alternative road informed by VMS or to continue along their original path. The underlying assumption in the experiment is that all respondents travel alone in the same origin-destination pair.

In accordance with previous studies identifying the most effective VMS display style<sup>4)</sup>, the traffic information was delivered in the pictogram style, which refers to the combination of graphic and text format content. For the graphical message, the traffic conditions were given as a color-coded map with three distinct colors (green, yellow, and red) indicating each level of the traffic flow (light, moderate, and heavy traffic), respectively, to allow the respondent to comprehend the report quickly. On the contrary, the travel time and delay on the roads were disseminated in text format. Figure 1 depicts the example of VMS presented to respondents in the SP survey.

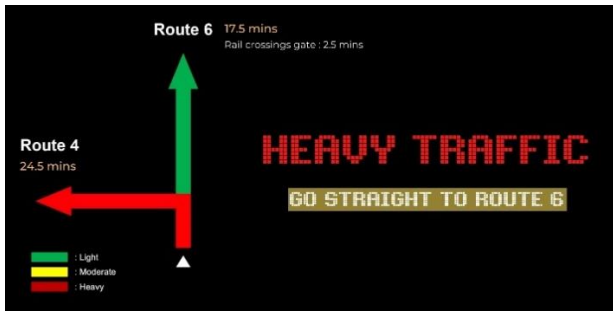


Fig.1 Example of VMS scenario given in the SP survey.

## (2) Modelling approach

In the stated preference experiment, sampled motorcyclists were offered two alternatives given the traffic situation scenarios displayed in the VMS. Respondents had to decide between staying on the present route or diverting to an available alternative route. In light of the sufficiency of the discrete choice model in describing choice probabilities, the identification of this sort of route diversion behaviour with two choices necessitated the estimation of a binary logit model specification.

To derive the logit model, equation (1) represents the general utility function ( $U_{jn}$ ) of the decision maker  $n$  facing alternative  $j$ . The function fundamentally can be decomposed into two parts: the deterministic component of the utility ( $V_{jn}$ ), and the error terms of the model that assume independently and identically distributed (i.i.d.) extreme value type I ( $\varepsilon_{jn}$ ). The former is comprised of the marginal utilities indicated by  $\beta$  and the vector of observable variables is denoted by the variable  $x_{jn}$ .

$$U_{jn} = V_{jn} + \varepsilon_{jn} = \beta' x_{jn} + \varepsilon_{jn} \quad \forall j \quad (1)$$

In this research, the relationship between explanatory variables and the tendency of motorcyclists to deviate from the original path was examined using BIOGEME<sup>15)</sup> by estimating the size and direction of the coefficients. The choice probabilities can then be derived in the binary logit structure, as shown in

equations (2a) and (2b).

$$P_{jn} = \frac{e^{\beta' x_{jn}}}{\sum_{i=1}^J e^{\beta' x_{in}}} = \frac{1}{1 - e^{V_{in} - V_{jn}}} \quad (2a)$$

$$P_{jn} + P_{in} = 1 \quad (2b)$$

## (3) Sample characteristics

In addition to behavioural responses, individual characteristics of respondents, including socioeconomic and motorcycle use properties, have also been acquired through the SP survey. The data overview is listed in Table 1.

## 4. MODEL RESULTS

For the purpose of discovering the most significant variables that motivate motorcyclists to divert from the original path, a binary logit model specification was initially tested for all available variables, including route attributes and individual characteristics. The latter was also taken into account in the model, considering its substantial impact on routing decisions<sup>8)</sup>. However, it was found that not all variables affected riders' propensity for route diversion, leading to the decision to eliminate those variables from the model. As a result, the final model specifying this en-route routing decision is reported in Table 2.

Even though this study gathers data via SP surveys, which typically include multiple hypothetical observations for a single respondent, it is important to note that the serial correlation has been tried to be relaxed by implementing the flattening panel data function technique available in BIOGEME software 3.2.10 version<sup>15)</sup>. Referring to the statistical parameters, it was concluded that the model specification summarized in Table 2 could adequately describe the route diversion behaviour of motorcyclists. It is worth noting that both generic and alternative-specific attributes have been estimated. Thus, a hypothesis test must be conducted to statistically verify a better-fitting model. This resulted in the likelihood ratio test rejecting the null hypothesis with 5 degrees of freedom and a 10% significance level, as denoted by the lower likelihood ratio of 5.479 in comparison to the chi-square distribution value ( $\chi^2 = 11.07$ ).

The alternative specific constant (ASC) represents the average effect on the utility of all variables not accounted for by the model<sup>16)</sup>. Accordingly, for the model to be consistent with the theory, one alternative constant must be normalized to a value of 1. The positive sign of ASC in the estimation results implies that respondents prefer to stay on the existing route rather than divert to another one.

**Table 1** Individual characteristics (proportion in parenthesis).

Socio-economic - Gender		Socioeconomic - Monthly income	
1: male	95 (35.1%)	1: no income	60 (22.1%)
2: female	176 (64.9%)	2: less than Rp 5,000,000	150 (55.4%)
Socioeconomic - Age		3: Rp 5,000,001 – Rp 10,000,000	45 (16.4%)
1: 17 - 24 years old	137 (50.6%)	4: Rp 10,000,001 – Rp 15,000,000	14 (5.2%)
2: 25 - 35 years old	84 (31%)	5: over Rp 15,000,000	2 (0.7%)
3: 36 - 50 years old	38 (14%)	Riding - Type of motorcyclists	
4: 51 - 60 years old	10 (3.7%)	1: commuter	262 (96.7%)
5: over 60 years old	2 (0.7%)	2: non-commuter	9 (3.3%)
Socioeconomic - Education		Riding - Professional (taxis, couriers)	
1: middle school or less	12 (4.4%)	1: yes	100 (36.9%)
2: high school	152 (56.1%)	2: no	171 (63.1%)
3: undergraduate	101 (37.3%)	Riding - Driving license ownership	
4: graduate	6 (2.2%)	1: valid	234 (86.4%)
Socioeconomic - Occupation		2: expired	11 (4.1%)
1: unemployed	11 (4.1%)	3: none	26 (9.6%)
2: student	101 (37.3%)	Riding - Length of experiences	
3: government employee	12 (4.4%)	1: less than one year	32 (11.8%)
4: private sector	119 (43.9%)	2: 1 to 3 years	87 (32.1%)
5: freelancer	27 (10%)	3: 3 to 5 years	70 (25.8%)
6: retired	1 (0.4%)	4: over five years	82 (30.3%)
Socioeconomic - Transport eExpenses		Riding – Daily frequency	
1: less than Rp 1,000,000	188 (69.4%)	1: less than three times	124 (45.8%)
2: Rp 1,000,000 – Rp 3,000,000	73 (26.9%)	2: 3 to 5 times	107 (39.5%)
3: Rp 3,000,001 – Rp 5,000,000	10 (3.7%)	3: over five times	40 (14.8%)

## 5. DISCUSSION

Referring to Table 2, the results of the binary model estimation pointed out the variables that significantly affect the behaviour of motorcyclists with regard to route diversion. The greatest effect on en-route decisions among the route attributes evaluated in the model arises out of the length of the path. As expected, motorcyclists prefer to stick with their present route when the distance of the alternative is larger, which is consistent with the findings of Vacca et al. (2017)<sup>10)</sup> and Kattan et al. (2010)<sup>12)</sup> in the case of passenger car drivers. The degree of traffic flow conditions (light, moderate, or heavy traffic), and the travel time required to reach the destination, also follow a similar trend. The negative signs of these coefficients imply the disutility of motorcyclists toward denser roads and longer trip times. The latter is in line with Khattak et al. (1994)<sup>17)</sup>.

Despite the benefits of two-wheeler vehicles' modest size, which enables them to move freely on all types of roads, including alleyways and narrow

shortcuts, it was found that motorcyclists still prefer wider roads. This may be in consideration of traffic safety and comfortability as a result of fewer disturbances and obstacles compared to roads of lower classes in the hierarchy. Overall, the findings support the a priori belief that the propensity to divert routes is higher when the alternative route saves time, has fewer queues, and is shorter in the distance, so as to enhance their own travel performance and ultimately disperse the severe congestion on the networks.

From the perspective of individual characteristics, the age impact on motorcyclists' tendency to deviate produced intriguing outputs. In contrast to the other age groups, the senior rider, which is defined as being over 60 years old, favours staying on their original path rather than diverting route in response to the VMS message broadcasting information about traffic conditions, as also discovered in Jou et al. (2005)<sup>1)</sup>. Considering the aggressiveness of Indonesian motorcyclists on the road and the slower reaction time of the elderly compared to younger age groups, this may also be attributed to safety concerns. In the same

manner, student motorcyclists are more likely to change routes than public workers, who have a strong marginal utility to remain stationary. Moreover, in the case of respondents who often access traffic information sources while riding motorcycles, the desire for route diversion is more significant. In addition to the habit of updating the pre-trip route choice, this is predictably also likely due to the awareness and familiarity with traffic information delivered from a variety of sources. Nevertheless, in compliance with Vacca and Meloni (2015)<sup>11)</sup>, it was revealed that monthly income and transportation expenses did not influence motorcyclists to divert.

Furthermore, the stated preference experiment in this study also attempted to recognize the effect of VMS route recommendation on the routing decisions

of motorcyclists. The model estimation summarized in Table 2 confirms the hypothesis that when route guidance is transmitted, motorcyclists are more likely to alter the route with higher certainty. This discovery may be interpreted and implemented in the practical field to aid and control the proportion of motorcyclists on the road since they tend to adhere to the offered suggestion. In the end, it is expected that the distribution of vehicles across networks will be more balanced, and the vehicle time spent on the road will decrease. It is also noteworthy that the provision of VMS neither distracts drivers nor jeopardizes traffic safety, since no equipment on the rider's side is necessary<sup>11)</sup>. Therefore, this strategy is good and secure for regulating motorcycles on networks.

**Table 2** Binary logit model estimation results.

Estimated parameters	Utility Interaction	Coefficient	t-test	p-value
<b>Constants</b>				
<i>ASC (stay on the current route)</i>		1.56	4.66	0.00
<b>Route attributes</b>				
<i>Path length (kilometers)</i>	Both	-3.08	-2.80	0.01
<i>Minimum road width (meters)</i>	Both	1.79	2.42	0.02
<i>Traffic flow degree</i>	Both	-0.56	-5.78	0.00
<i>Average travel time (minutes)</i>	Both	-0.08	-1.83	0.07
<i>Provision of route suggestion</i>	V <sub>divert</sub>	0.51	2.97	0.00
<b>Individual characteristics:</b>				
<i>Age from 17 to 24</i>	V <sub>stay</sub>	-0.95	-4.01	0.00
<i>Age from 25 to 35</i>	V <sub>stay</sub>	-1.17	-6.03	0.00
<i>Age from 36 to 50</i>	V <sub>stay</sub>	-1.25	-5.49	0.00
<i>Age from 51 to 60</i>	V <sub>stay</sub>	-0.93	-2.25	0.02
<i>Age over 60</i>	V <sub>stay</sub>	5.87	11.30	0.00
<i>Government employee</i>	V <sub>stay</sub>	1.05	2.19	0.03
<i>Student</i>	V <sub>stay</sub>	-0.42	-1.82	0.07
<i>Lack a valid driving license</i>	V <sub>stay</sub>	0.81	2.66	0.01
<i>Master's degree graduate</i>	V <sub>divert</sub>	1.61	2.71	0.01
<i>Habit of observing traffic information while riding</i>	V <sub>divert</sub>	0.32	1.68	0.09
<b>Model parameters:</b>				
<i>Null log-likelihood (LL<sub>0</sub>)</i>			-982.16	
<i>Initial log-likelihood (LL<sub>ASC</sub>)</i>			-619.67	
<i>Final log-likelihood (LL<sub>β</sub>)</i>			-535.61	
<i>Rho-square (ρ<sup>2</sup>)</i>			0.136	
<i>Rho-square-bar (adjusted ρ<sup>2</sup>)</i>			0.108	
<i>Akaike Information Criterion (AIC)</i>			1105.22	
<i>Bayesian Information Criterion (BIC)</i>			1186.74	

## 6. CONCLUSION

This research explores the propensity of motorcyclists to adjust routes under a VMS environment. A web-based stated preference experiment was conducted in order to evaluate the routing decisions of individuals when encountered with numerous hypothetical choice scenarios. Since respondents were presented with two options, staying on the original path or diverting to an alternative road, the route diversion behaviour of motorcyclists was investigated by estimating a binary logit model.

The model specification revealed that motorcyclists are more likely to divert when the alternative route offers better conditions in terms of traffic volume, travel times, and distance. Nonetheless, it was discovered that almost all motorcyclists favour diverting routes, except those over 60 who prefer to stay on their current route. The provision of route suggestions on the VMS display proved to cause motorcyclists to deviate significantly. As a result, it is considered that broadcasting real-time traffic information is an effective strategy for managing traffic and reducing congestion by guiding travellers to disperse throughout road networks. Thus, a practical recommendation can be made, which is to broaden the implementation of VMS to varying road types that are accessible by a range of vehicles.

Several limitations of this study should be acknowledged. First, the data obtained through hypothetical choice scenarios only accounted for one origin and destination pair, which might restrict the preferences that were recorded. Second, the investigation did not differentiate the level of awareness toward VMS-delivered messages. Adding more attributes to capture this behaviour might result in a more extensive model describing the tendencies of motorcyclists in route diversion. Accordingly, considering the limitations mentioned above, some future work should be done to extend the scope of this research. The threshold of each essential attribute that would motivate motorcyclists to change their current path can be explored to enrich the references for practical implementation. In addition, the different VMS formats should be assessed in order to determine the most appropriate and effective display for travellers in Indonesia. The day-to-day dynamic routing decision-making process must be observed, allowing for gathering varied route patterns, as well as distinct individual urgencies and characteristics.

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