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Submission date: 07-Jun-2021 03:57PM (UTC+0700)

Submission ID: 1602031122

File name: iors_of_the_evacuees_during_emergency_evacuation_using_a_LRM.pdf (738.09K)

Word count: 3337

Character count: 18475

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To cite this article: S Sugiarto ¹ *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **523** 012032

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Characterizing mode choice behaviors of the evacuees during emergency evacuation using a Logistic regression model

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Abstract. The most crucial transportation components in studying individual decision-making behavior are mode choice that used by evacuees. Especially in typical emerging countries which private motorized transport is mostly used in daily activities. Mode choice evacuation behavior is viewed as one of the essential aspects in a transportation disaster planning. This study is aiming to investigate an individual's preferences for selecting motorized and non-motorized modes for their evacuation during imaginary tsunami evacuation. The Stated Preference (SP) experimental data were collected in Kuta Raja sub-district, one of the most exposed sub-district in Banda Aceh. Binary logistic regression was conducted to evaluate the effects of several factors quantitatively and to identify the dominant factor that affected evacuation mode choice. The empirical result depicts that mode choice used by evacuee during an emergency evacuation is suggestively associated to the socio-demographic attributes such as male gender, age, government employee, low-income household, household member and motorcycle owned. It found that the medium-income households substantially rely on motorcycle mode for their evacuation. The more motorcycle owned within the household, the more likelihood of using motorcycle for their evacuation. The male gender and government employee also has a statistically positive correlation to the explanatory power of motorized transport used to evacuate.

1. Introduction

Indian Ocean Tsunami on December 26, 2004 event, the magnitude was 9.0 and epicenter is 255 km from Banda Aceh, the provincial capital of Aceh. The earthquake itself caused damage and Casualties. The subsequent tsunami killed at least 108,100 people and left 127,700 people missing in Indonesia [1]. Indonesia has a lack of disaster information and familiarity caused a postponement in the response of citizens to the tsunami and had led to abundant casualties and missing people. In contrast to developed countries, for instance in Japan, a study conducted by [2], they had a significant effort in the response of citizens, and it caused a substantial effect on reducing casualties by taking advantage of what they learned from disaster prevention education. It was called the "Kamaishi Miracle," and the story spread around the world. Further investigation of the evacuation behaviors by [3], they concluded that the fatality ratio in convinced region was predominantly affected by the force of the tsunami and the residents' characteristics.

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The most crucial transportation components in studying individual decision-making behavior are mode choice that used by evacuees. Especially in typical emerging countries which private motorized transport is mainly used in daily activities. A study by [4] argued that excessive car evacuation could cause severe traffic congestion, and could lead to large numbers of casualties during tsunami disasters. They investigated the possible factors that lead to unnecessary car evacuation can ensure smoother tsunami evacuations and mitigate casualty damages in future tsunami events. The result advised that the distance of evacuation acted as a principal factor in selecting car evacuation relative age and sex variables. Further explorations on car usage behavior during the evacuation were done by [5, 6]. They revealed that car usage, which exceeded the road capacities of local communities, caused severe traffic congestion and tsunami casualties.

In the context of the emerging world, the problem with a high demand for private-motorized transport in tsunami evacuations created traffic wrongly and intended to the complexity of evacuation behaviors. Seeing the rapid urbanization and problem of private-mode dependency, the investigation of factors that influencing mode choice is crucially need to be deliberate. It is, therefore, this study is aiming to investigate an individual's preferences for selecting motorized and non-motorized modes for their evacuation during imaginary tsunami evacuation. The Stated Preference (SP) experimental data were collected in Kuta Raja sub-district, one of the most exposed sub-district in Banda Aceh. The modeling framework used in this study is a binary logit (BL) regression model. The BL model is a simple and open form discrete choice model that widely used the behavioral arena. In the behavior modeling, the BL has been commonly used to analyze behavioral research relating travel and transport behaviors. For example in Thailand [7] used BL to examine tsunami evacuation behavior related to transportation disaster response.

Further implementation BL model by [8, 9] to explore travel behavior related to individual preferences in voting congestion charging policy in Jakarta. Perhaps a more recent study by [4] conducted BL analysis to assess the effects of numerous factors and to identify the leading factor that exaggerated evacuation mode choice in Tohoku, Japan. Thus, in this study, the BL model is implemented to examine the effects of individual travel behavior factors and household's socio-demographic characteristics and to determine the most significant influencing factors that affected evacuation mode choice. The empirical result from this work might be of specific help in the plan of a more effective policy for the evacuation planning in particular for the Banda Aceh region. Furthermore, a better understanding of local characteristics is essential for successful transportation-mobility management policy implementation to gain a better life for society [10, 11].

The rest of this report is structured as follows. In the next section gives a brief description of the SP survey, the distribution of SP survey and describe the formulation of the BL model. In section 3 and 4, we then present model estimates and discuss the findings. Lastly, the conclusions of this work are obtainable at the end of this report.

2. Study Area

This study focuses on tsunami evacuation based on a hypothetical scenario. The tsunami heavily struck in the city of Banda Aceh. The Stated Preference (SP) method is used in this study. The SP method is widely used in travel behavior studies [see for example 10, 11, 12]. The questionnaire survey was conducted in March 2018, approximately fourteen years after the 2004 event.

Table 1. Summary of SP questionnaire

Description	Detail
Time of survey	March 2018
Target location	Kuta Raja sub-district of Banda Aceh, Aceh Province
Distribution methods	A paper-pencil based direct interviews and Collected by the enumerator
Number of questionnaires	100

The target respondent was residents who have experienced the 2004 event. A paper-pencil based on the direct interview was distributed to respondents in Kuta Raja sub-district, one of the most exposed sub-district in Banda Aceh as shown in Figure 1.

The respondents were asked general features of evacuation behaviors if they will face a tsunami event in the future such as departure times, evacuation mode, ²² evacuation place (e.g., escape the building, tall building). Furthermore, the question related to individual socio-demographic characteristics such as gender, age, income, marital status, household's membership, the number of a car owned and the number of motorcycles owned. The questionnaires were distributed to 100 and used in this study. The SP survey is summarized in Table 1, which gives the time of the surveys, target locations, distribution methods, number of samples and sampling distribution.



(a) Banda Aceh city (map data © 2018 Google)

(b) Kuta Raja ²³ sub-district



(c) Kuta Raja sub-district and its villages

Figure 1. Study area

Table 2 shows the distribution of respondent’s socio-demographics. It can be seen that young people (≤ 30 years) is accounting for few sample set, accounting for less than 5% of respondents. The gender distribution is slightly skewed toward females (65%). As regards employment status, our sample indicates 68% of employed respondents, and less than 10% of the sample consists of students. As for the income, it is found that up to 49 % has a low to medium monthly income. Additionally, the distribution of samples reveals that close to 50% of respondents are renting their house.

Table 2. Description of respondents’ socio-demographics

Item	Category	Share	Item	Category	Share	
Gender	Male	35%	Monthly Income (in million)	IDR 1 or less	1%	
	Female	65%		IDR 1 - 2	5%	
Age	20 years or less	2%	Income (in million)	IDR 2.1 - 4	43%	
	21-30 years	3%		IDR 4.1 - 6	36%	
	31-40 years	19%		More than IDR 6		15%
	41 years or more	76%				
Occupation	Working	68%	Driver's license	Renting house	49%	
	Student	9%		Owned house	51%	
	Unemployed	23%				

3. Measurement

The SP questionnaire were employed to capture the effect of socio-demographics respondent to the their mode choice behavior towards emergency evacuation. The dependent variable of the mode choices used by respondents to evacuate if a tsunami will happen in the future. Two choices of the mode are offered to the respondent to select one between two choices (i.e., motorized transport and non-motorized transport).

Table 3 Distribution of the dependence variable (mode choice for evacuation)

Variable	Distribution of a 4-point Likert score (%)	
	Motorized	Non-Motorized
Mode Choice Set	89	11

Table 3 depicts that the dependent variable looks like to be normally distributed. A Kolmogorov-Smirnov test is conducted to ensure the data normally distributed with 5% significant level of error. The mean intention to select motorized in the sample set was 0.89 (SD = 0.31). It depicts that people in Banca Aceh have a strong intention to use motorized transport for their evacuation.

4. Binary Logistic Model

A modeling approach of discrete choice model in used to explore the behavioral characteristic among variables of socio-demographics and mode choice selected for emergency evacuation. A simple formulation of binary logistic (BL) regression is used to delve more deeply related respondent’s intentions to choose their mode during evacuation.

The modeling BL choice behavior is formulated for the following choices: respondent to select one between two choices, that is motorized transport and non-motorized transport for their evacuation. The probability that evacuee i chooses motorized π_i is modelled based on the random utility maximization theory as shown in Equation (1) and (2). More advance and detail of the binary choice and maximum likelihood formulation can be referred to [9]. In this study unknown parameters are estimated using maximum likelihood estimator and implemented in NLogit 5.

$$\text{logit}(\pi_i) = \log\left(\frac{\pi_i}{1 - \pi_i}\right) = \beta x_i \quad (1)$$

$$\pi_i = \text{Pr}(Y_i = 1 | x_i) = \frac{\exp(\beta x_i)}{1 + \exp(\beta x_i)} \quad (2)$$

Table 4 Distribution of the dependence variable (mode choice for evacuation)

Variable	Classification of variables (parameter coding)
Mode Choice (MC)	Binary choices ○ 1 used motorized transport ○ 0 otherwise
Gender (GD)	Dummy of gender ○ 1 male ○ 0 otherwise
Age (AG)	Nominal ○ 1 if 20 years or less ○ 2 if 21-30 years ○ 3 if 31-40 years ○ 4 if 41 years or more
Occupation (OCP)	Dummy variable of government employee ○ 1 if government employee ○ 0 Otherwise
Income (INC)	Dummy variable of monthly household' income ○ 1 if low income household (income < 2 million IDR/month) ○ 0 Otherwise
Household Member (HM)	Nominal ○ 1 if has <3 household members ○ 2 if has 3-5 household members ○ 3 if has 6-10 household members ○ 4 if has more than 10 household members
Motorcycle Owned (MO)	Dummy of having motorized transport within household ○ 1 if has motorcycle ○ 0 otherwise

5. Result and Discussion

The BL regression is conventional method to determine the best of fit model among dependence variable and predictors using calibration data set. The exogenous variables was set as binary choice as $Y_i = \{1: \text{used motorized transport}, 0: \text{used non-motorized transport}\}$. According to the equation (2) Y represents response variables, and x_i is a vector of explanatory variables such as socio-demographic characteristics and individual travel behaviors. Variable notation, definition and empirical settings for both response and regressor used in this study are summarized in Table 4.

The stepwise calibration method is used to select the best fit of the model. The maximum likelihood estimator (MLE) is implemented to calibrated BL parameters. To ensure our model is a statistically acceptable the 5 % level of error is applied for t-test significantly. However, several variables still be selected within 10% level of error as it is for behavioral analysis rather than for predicted model. The result of the calibrated parameters and its significant level can be seen in Table 4 including the Goodness of Fit (GoF) calibrated model.

Table 5 exhibits the parameter results of estimation of mode choice model considering socio-demographic attributes. Calculated indicates of model performance include log-likelihood at convergence (LL (b)) and McFadden Pseudo R-Squared. The McFadden Pseudo R-Squared indicate shows substantially the best fit to our data set, as shown at the bottom of Table 5.

Table 5 Calibrated parameters and Goodness of Fit of mode choice model

Predictors	Coefficient	T-value	P-Value
GD	4.52	2.58	0.009
AGE	1.78	2.29	0.020
OCP	2.29	1.72	0.085
INC	-11.17	-2.67	0.007
HMEM	0.78	1.72	0.084
MO	3.44	1.84	0.066
Dependent Variable			MC
Number of Sample			100
LL (0)			-34.65
LL(β)			-15.72
χ ² (df)			37.86
χ ² Significance level			0.000
McFadden Pseudo R-Squared			0.546

Examining the calibrated parameter results presented in Table 5, the parameter of the male gender dummy has a positive sign for the selected motorized transport mode. This indicates that the male gender plays an important role in influencing an individual’s decision. That is, the male gender the more likely they are to use motorized transport compared to the female gender. It seems that the positive correlation also linked to others individual’s socio-demographic attributes such as age, government employee dummy variable and a number of household member.

Interestingly, the variable of dummy low-income household has a statistically negative association to the motorized transport mode. It seems that low-income household tends to used non-motorized transport as they may not have owned motorcycle or car in the household. However, the mobility attributes of motorcycle held have a substantially positive correlation to the motorized transport mode. This tendency is found to be larger medium-income households (monthly income range from 2 – 4 million IDR) has at least one or two motorcycles. It is presumed that such household finds it necessary to use a motorcycle for their evacuation.

6. Conclusion

This paper reports on investigation and characterizing of an individual choice behavior relating to the mode choice used to evacuate during emergency evacuation. Using data from a Stated Preference survey collected in 2018, a binary logistic model is used to capture the impact of observable such as demographics, household characteristic and mobility attributes in examining mode choice. We find that there is strong association between choice of motorized transport and observable regressors.

The specific empirical finding performed by Logistic model reveals that the male gender plays an important role in influencing an individual’s decision to choose motorized transport. A positive correlation also linked to the attributes of age, government employee dummy variable and a number of household member. Low-income household has a statistically negative association to the motorized transport mode. It seems that low-income household tends to used non-motorized transport as they may not have owned motorcycle or car in the household. While the mobility attributes of motorcycle held have a substantially positive correlation to the motorized transport mode. It is presumed that such household finds it necessary to use a motorcycle for their evacuation.

Indonesia has lack of disaster information and familiarity caused a postponement in the response of citizens to the tsunami and had led to abundant casualties and missing people. An investigation of the evacuation behaviors plays the most crucial components decision-making behavior. Our result confirmed previous research by [4] that typical emerging countries which private motorized transport is mainly used in daily activities. An excessive motorized transport evacuation could cause severe traffic congestion, and could lead to large numbers of casualties during tsunami disasters. Therefore, the

empirical findings of this work may offer general assistance in efforts to the government for the suggested establishment the guidance for evacuation planning, especially deal with complex transport problem. There are widely used statistical approaches that can analyze engineering phenomena such as the probabilistic applications for seismic hazard study done by [13]. Furthermore, a better understanding of local characteristics is vital for successful engineering policy implementation to gain a better life for society [14-17].

7. Acknowledgments

The Syiah Kuala University financially supported this study under Contract No. 289/UN11/SP/PNBP/2018. Furthers thanks go to the staff and students of Transportation System Laboratory, Civil Engineering Department of Syiah Kuala University for their substantial help with the data collection.

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