

Traffic Accident Cost Analysis Using Willingness-to-pay Method in Surabaya

Ahmad Utanaka, Hera Widyastuti

Abstract—There are some methods to determine accident cost, one of which is the willingness-to-pay method. Willingness-to-pay method use in this research because this method more recommended by developed countries than gross output method which is still used in developing countries, especially Indonesia. Road traffic accident is one of the top 10 causes of death because motorcycle drivers are vulnerable and have a high-risk probability for traffic accidents. Location of this study is at Surabaya City which is the second biggest city in Indonesia because the frequency of accidents is increasing every year. This research began by collecting accident data, demography of Surabaya, price and lifetime of motorcycle tires, and perform stated preference survey to receive the willingness-to-pay value. Selection of decisions in replacing and maintaining tires can determine different willingness-to-pay value. This research analyzes willingness-to-pay value using the discrete choice method and reduces the risk probability of traffic accidents for themselves.

Index Terms— Accident cost, discrete choice, road traffic accident, Surabaya, willingness-to-pay

I. INTRODUCTION

Surabaya is the second biggest city in Indonesia after DKI Jakarta. The development of Surabaya City especially in the economic sector is influenced by road development. Currently, the road network in Surabaya has been too complex, the mobility of the population was very high as well [1]. According to traffic accident data by Directorate of Traffic and City Resort Police of Surabaya (the year 2014 – 2016) shows an increase of the frequency of road traffic accidents each year. In 2014 there are 716 accidents, in 2015 there are 879 accidents, and in 2016 there are 1126 accidents. Accidents can occur due to several factors i.e. human, vehicles, and roads factors [2]. Road traffic accident is one of the leading cause of death, even it is one of the top 10 causes of death in the world beside medical factor (such as heart disease, stroke, diabetes, etc.) [3–5]. This is because motorcycle drivers are vulnerable and have a high-risk probability of traffic accidents [6–9]. Of all the victims of traffic accidents, the most victims are motorcycle driver. Based on traffic accident data in one year (for example in 2017), the number of accident victims who are motorcycle

drivers are 1813 people, where almost 4 times accident victims who are car drivers, i.e. only 509 people. Because of the high accidents that occur, it is necessary to do a study to find out the level of driver's awareness to reduce the risk of accidents. In this study, it is using the willingness-to-pay (WTP) method. WTP method is selected because this method already used in developed countries and it is recommended to be used in developing countries to calculate accident costs [6, 10].

II. LITERATURE REVIEW

The willingness-to-pay approach looks at the ways in which individuals are willing to pay to avoid accidents [11]. This approach is preferable because at this time many countries have moved to the willingness-to-pay approach than gross output approach and the willingness-to-pay approach has been done in Indonesia [6].

In this study, analysis using the discrete choice method to model the willingness-to-pay approach. The result from the discrete choice that used describes preferences and choices in terms of the probability of choosing each alternative [10]. These probabilities reflect the population probability that people with certain characteristics and facing the same set of alternatives by choosing each alternative [12].

The utility functions can be formulated as follow [10]:

$$U = V + \varepsilon = \beta'x + \varepsilon \quad (1)$$

U = the utility of willing to pay the amount for severity reduction

V = the systematic (deterministic) component of the utility of willing to pay the amount for severity reduction

ε = the random (disturbance or error) component of the utility of willing to pay the amount for severity reduction

x = the vector of attributes that are related to the willingness to pay the amount for severity reduction

β' = the vector of unknown parameters

Ben-Akiva and Lerman approach (1985) see the utility of each alternative as a random variable where if any alternative i choose by person n from the choice set C_n , the probability P_{in} given by [13] :

$$P_{in} = P(U_{in} \geq U_{jn} \quad \forall j \in C_n, j \neq i) \quad (2)$$

P_{in} = probability that the individual n chooses alternative i

U_{in} = utility function of the individual n chooses alternative i

Ahmad Utanaka is with The Department of Civil Engineering, Institut Teknologi Sepuluh Nopember, 60111, Surabaya, East Java, Indonesia

Hera Widyastuti is with The Department of Civil Engineering, Institut Teknologi Sepuluh Nopember, 60111, Surabaya, East Java, Indonesia (e-mail: herawidyastuti@yahoo.co.uk)

$\forall j =$ all the cases, J , in the choice set C_n : chooses alternative n

Applying the formula into binary choices which symbolize the choice sets C_n as i and j , then the probability of people choosing alternative i is

$$P_n(i/C_n) = P_r(U_{in} \geq U_{jn}) \quad (3)$$

And the probability of people choosing alternative j is

$$P_n(j) = 1 - P_n(i) \quad (4)$$

Logistically distributed, the choice probability of alternative i binary logit is

$$P_n(j) = P_r(U_{in} \geq U_{jn}) \quad (5)$$

$$= \frac{1}{1 + e^{-\pi(V_{in} - V_{jn})}} \quad (6)$$

$$= \frac{e^{\pi V_{in}}}{e^{\pi V_{in}} + e^{\pi V_{jn}}} \quad (7)$$

The choice probability of the binary model is estimated based on

$$p = \frac{\exp^{\text{logit}(p)}}{1 + \exp^{\text{logit}(p)}} \quad (8)$$

In other words

$$p = \frac{\text{probability}}{1 + \text{probability}} \quad (9)$$

The choice probability for the willingness to pay the amount for severity reduction can be written as follows:

$$P_n(i) = P_{yes} = \frac{e^{\beta^1 x_{yes}}}{e^{\beta^1 x_{yes}} + e^{\beta^1 x_{no}}} \quad (10)$$

Which:

$P_n(i)$ = the probability that individual n has chosen the option to pay the specified amount for severity reduction

III. MATERIALS AND METHOD

Location of this study is at Surabaya City. Data used in this study are the number of the traffic accident, demography of Surabaya City, price and lifetime of motorcycle tires, and willingness-to-pay value from stated preference survey.

In outline, the stages in this study are divided into 4 stages, preparation and literature review, data collection, analysis and discussion, and conclusion. Method of collecting data using stated preference method. Which involves surveys to determine the individual's willingness to pay for products or attributes in a hypothetical situation [11]. Respondents are the citizen of Surabaya City who were interviewed randomly. Interview the interview is done in the center of the crowd of Surabaya City i.e city park, food court, etc. Variables taken are age, income, number of children, and willingness-to-pay choices. After the data collected, then performed data analysis. Data analyzed using the discrete choice method using binary logit model.

IV. RESULTS AND DISCUSSIONS

A. Characteristic of Respondents

Data collected by performing stated preference survey to citizens of Surabaya randomly. the characteristics obtained based on survey results are as follows.

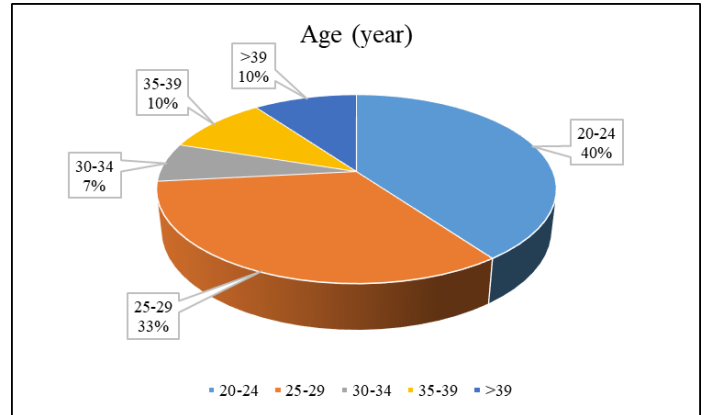


Fig. 1. Characteristic of respondents based on age

The figure above shows the percentage of respondents dominated by age 25-29 years as big as 35% and the smallest percentage is age more than 39 years old as big as 10%.

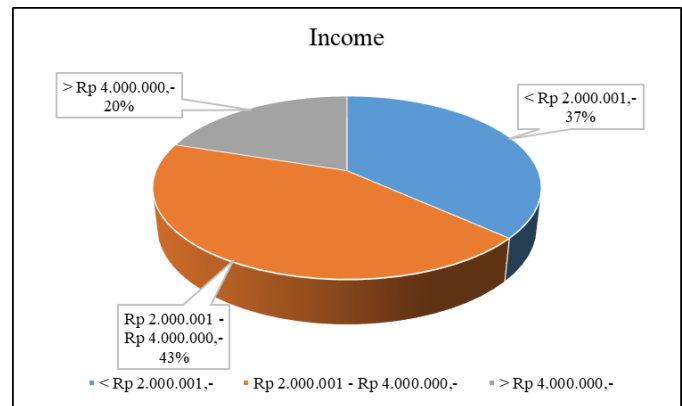


Fig. 2. Characteristic of respondents based income

The figure above shows the percentage of respondents dominated by income between Rp 2.000.000,- and Rp 4.000.000,- as big as 43%. It means the minimum wage for workers in Surabaya City has been fulfilled.

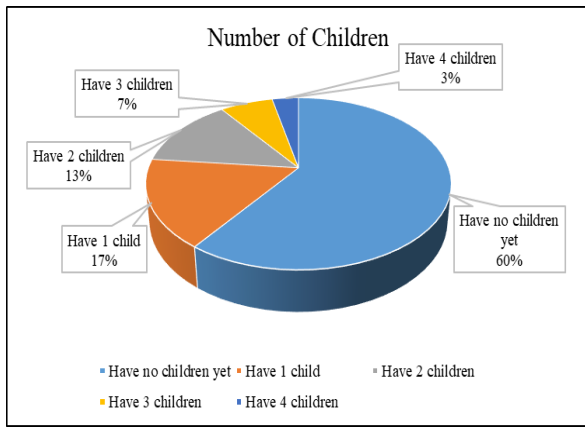


Fig. 3. Characteristic of respondents based number of children

The figure above shows the percentage of respondents dominated with have no children yet as big as 60%. This is caused by age of respondents is still relatively young.

B. Willingness to Pay Choices

Two hypotheses option to reduces traffic accident given to the respondents to be selected. Two options that are given are the reduction of accident risk by 25% and 50% which can be seen in Table I.

TABLE I
WILLINGNESS-TO-PAY CHOICES OR ACCIDENT REDUCTION

Willingness-to-pay choices	Additional cost	
25% reduction	Rp 2.300,-	Rp 0,-
50% reduction	Rp 4.600,-	Rp 0,-

An example of one willingness-to-pay choice that given to respondents can be seen in the following table.

TABLE II
QUESTIONNAIRE WILLINGNESS-TO PAY CHOICE

Criteria	Option A	Option B
Maximum possible speed (km/jam)	70	60
Change tire in every (month)	54	60
The probability for the slight injury	56/100.000	74/100.000
Additional cost (Rp)	2.300	0
Selected alternative		

C. Analysis of The Discrete Choice Model

Many previous studies mention that income, age and number of children are the variables that influence the individual's willingness to pay and the model [10], [14-17]. But, in this study age variable is not significant, so it only uses income and number of children variable. According to survey results, all respondents choose the same option for 25% reduction and 50% reduction so it gives the same result. Data survey results are analyzed using the SPSS program and give the values as the table below.

TABLE III

THE RESULT OF THE MODEL FOR 25% AND 50% SLIGHT INJURY PREVENTION

Variable	Parameter	p-value	Exp (β)
Income	2.720	0.025	15.176
Number of children	-1.797	0.014	0.166
Constant	-2.414	0.111	0.089

Based on the above table, all independent variables p-value < 0.05 it means that each variable has a significant partial effect on y in the model. Income has p-value 0.025 < 0.050 and number of children has p-value 0.014 < 0.050, thus rejecting H₀ or which means a significant partial effect.

According to Exp (β) value, the probability of willing to pay from respondents with higher income is 15.176 times higher than respondents with lower income. While for the probability of willing to pay from respondents with the lower number of children in 0.166 higher than respondents with the higher number of children.

Based on the parameter values obtained, then the equation model formed as follows :

$$\text{Logit}(p) = \ln\left(\frac{p}{1-p}\right) = -2.414 + 2.720 \text{ Income} - 1.797 \text{ Number of children}$$

From model above, it can be interpreted that every single unit change of income variable will increase willingness-to-pay log probability as big as 2.720, while for each one unit change of the number of children variable will decrease willingness-to-pay log probability as big as 1.797.

It can calculate the probability from the model above of a person willing to pay to reduce the risk by 25% and 50% slight motorcycle injuries. For example, if a person has income Rp 3.580.000,- which is the minimum wage of Surabaya City [18] and has 3 children, substitute the values of income and number of children in the equation. Then the probability of a person willing to pay to reduce the risk can be obtained.

$$\text{Logit}(p) = \ln\left(\frac{p}{1-p}\right) = -2.414 + 2.720 \text{ Income} - 1.797 \text{ Number of children}$$

$$\text{Logit}(p) = \ln\left(\frac{p}{1-p}\right) = -2.414 + 2.720 \times 3580000/1000000 - 1.797 \times 3 = 1.933$$

Then the probability is

$$p = \frac{\exp^{\text{logit}(p)}}{1 + \exp^{\text{logit}(p)}} = \frac{\exp^{1.933}}{1 + \exp^{1.933}} = 0.874$$

The interpretation is if a person would be willing to pay for their own safety to reduce the risk of the motorcycle accident, then the probability is 87.4%. But, if with different income and number of children value, it will obtain different probability.

$$\text{Logit}(p) = \ln\left(\frac{p}{1-p}\right) = -2.414 + 2.720 \text{ Income} - 1.797 \text{ Number of children}$$

$$\text{Logit}(p) = \ln\left(\frac{p}{1-p}\right) = -2.414 + 2.720 \times 4000000/1000000 - 1.797 \times 3 = 3.075$$

Then the probability is

$$p = \frac{\exp^{\text{logit}(p)}}{1 + \exp^{\text{logit}(p)}} = \frac{\exp^{3.075}}{1 + \exp^{3.075}} = 0.956$$

If with higher income and the same number of children, then the probability will increase. In the equation above, if a person has income Rp 4.000.000,- and have 3 children, then obtained the probability value as big as 0.956. From its value, it can be interpreted the probability of a person willing to pay to reduce the risk will increase to 95.6%.

$$\text{Logit}(p) = \ln\left(\frac{p}{1-p}\right) = -2.414 + 2.720 \text{ Income} - 1.797$$

Number of children

$$\text{Logit}(p) = \ln\left(\frac{p}{1-p}\right) = -2.414 + 2.720 \times 3580000/1000000 - 1.797 \times 4 = 0.136$$

Then the probability is

$$p = \frac{\exp^{\text{logit}(p)}}{1 + \exp^{\text{logit}(p)}} = \frac{\exp^{0.136}}{1 + \exp^{0.136}} = 0.534$$

But, if with the same income and a higher number of children, then the probability will decrease. In the equation above, if a person has income Rp 3.850.000,- and have 4 children, then obtained the probability value as big as 0.534. From its value, it can be interpreted the probability of a person willing to pay to reduce the risk will decrease to 53.4%.

V. CONCLUSIONS

This study gives one equation in the discrete choice model. From age, income, and the number of children variable that obtained from the survey, the significant variables are just income and number of children variables after being analyzed in SPSS program. This shows the difference from the previous study where the age variable included in one of the significant variables.

The p-value of the income variable is 0.025 and the p-value for the number of children variable is 0.014, where both variables are significant at the 5% level (less than 0.05). The higher income generates higher probability than the lower income, and the lower number of children generate higher probability than the higher number of children.

From the model obtained, it can be interpreted if with higher income and the same number of children it will increase the probability of a person willing to pay to reduce the risk, but if with the same income and a higher number of children it will decrease the probability of a person willing to pay to reduce the risk.

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