Effect of Toll Road Pricing Strategy on Revenue

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Abstract: The research aims to develop standard modal choice probability curves that can estimate the number of toll users for a given toll fare and the level of service of existing main roads. A study was conducted in East Java, Indonesia, where there have been substantial toll road constructions in the region. The study was conducted in three areas having different socio-economic characteristics. We did three types of analyses to achieve the objective: socio-economic factors, ability to pay (ATP) and willingness to pay (WTP), and modal choice analysis. The result showed that the socio-economic condition and service level of the existing road affected the use toll. The ATP/WTP should be combined with the modal choice probability model to determine the toll fare. The probability curve model developed in this study with slight modification can be used in more expansive areas to determine optimum toll fare and its predicted potential toll users.

Keywords: Ability to Pay, Willingness to Pay, toll road pricing, stated preference, modal choice development

1. INTRODUCTION

Toll road construction has been booming in Indonesia in the last five years. It is part of the 4500 km-long toll road that to be constructed by 2024. As of 2019, more than 1500 km of toll road has been built and operated. These toll roads are built and operated either by state-owned companies or private investors. The trend of constructing toll roads in Indonesia as one of the means to improve the transportation infrastructure seems to follow worldwide directions. Recently, toll road became a popular choice to reduce the congestion problems occurring in the big cities due to (a) lack of funding by the State, (b) growing acceptance of the user-pay principle (de Palma, 2000). Also, private toll roads allow drivers to choose between paying extra money to save travel time and continuing to travel free on more congested public roads (4), toll roads can sometimes be built more quickly than public roads. Toll operation tends to have a more transparent accounting that reveals their actual cost (Roth 1996b). A study by Russo (2015) shows that people with higher income have the probability of traveling more; hence time is more important than money

Before investing in a toll road project, one requires a careful analysis to ensure that the large investment put into the project will provide a fair and sound investment. It includes a reasonable estimate of the construction cost and potential revenue. As most toll revenue comes from users using the toll road, a good traffic forecast becomes essential. Unfortunately, many toll roads recently open to traffic in Indonesia have experienced lower traffic volumes than projected (Djakfar, 2018). This phenomenon followed a common trend in toll road operation as reported by Bain and Wilkin (2002), Bain and Plantagie (2003, 2004), Bain and Polakovic

(2005). For instance, traffic from a sample of 104 toll projects was an average of 20–30% lower than forecasted (Bain and Polakovic, 2005). Actual traffic volumes varied from only 15% of the predicted level to more than 150% of the indicated level.

In the case of new toll roads recently operated in Indonesia, the lower than forecasted traffics occurring in the toll roads is hypothesized due to toll rate implementation inappropriateness. According to Vajdic (2012), a reasonable toll rate is the socially acceptable one, encouraging the facility's use. It involves the social perception of the value that a road generates as reflected in the users' willingness to pay and the users' value of time. Factors such as the country's economic profile, road network configuration, fuel prices, and fare prices of alternative public transportation can affect the public perception of what is an acceptable level of toll rates. On the other side, the private sector is looking for a toll rate to ensure the project's financial sustainability and adequate financial returns on the investment.

Studies on pricing and its effects on travel behavior have been extensively studied in the past. Golob (2001), Bhat and Castelar (2002), Brownstone and Small (2005), Loukopolous *et al.* (2005), Bhat and Sardesai (2006), and Hensher and Puckett (2007) studied the changes to travel behavior induced by congestion pricing. Bhattacharjee *et al.*(1997), Verhoef *et al.*(1997), Harrington *et al.* (2001), King *et al.* (2007) have studied the feasibility and acceptability of congestion pricing among road users. In comparison, Kuwahara (2007) studied the impacts of the transportation network on congestion pricing. Eluru et al. (2010) reviewed the extensive literature on the effect of pricing on commuting strategies.

The Willingness to Pay (WTP and Ability to Pay (ATP) are the most used methods to determine the optimum fare for public services. Al-Ghuraiz and Enshassi (2005) stated that the consumer's willingness to pay (WTP) is the maximum amount that a person would be willing to pay for a service rather than do without it or would give up to enjoy a quality improvement. While Deb (2003) dan Musgrave (1075) defined the ability to pay (ATP) as those who can afford to pay more should pay more. Most of the toll studies in Indonesia apply this methodology to evaluate the toll fare system. One of the drawbacks of relying on the toll fare determination to this method is that it did not relate the pricing system to modal choice probability. A limited study showed that relating ATP/WTP with modal choice probability provides better accuracy in forecasting the toll road's traffic volume (Djakfar, 2019). However, it needs to be verified in the area with different socio-economic characteristics.

The paper's objective is to propose a better methodology in determining the optimum toll fare that will provide a good return of investment for the investor. Simultaneously, the public can accept such a rate by relating ATP/WTP analysis with the modal choice probability.

The structure of the paper is as follows. First, we discussed the methodology applied in this research, including the location of data collection, a questionnaire used to collect data, the number of samples, and the analysis method used. The following paragraphs discussed the analysis of data acquired from the field based on the analysis techniques discussed previously. The last sections discussed the recommendations resulting from the research.

2. METHODS

2.1. Location of Study

The study's location was in East Java, where the toll road network has just been constructed or planned to be built shortly. Figure 1 shows the location of the study. Similarly, the data collection was conducted in the area close to the designated toll roads. The following paragraphs discuss detailed data collection methods.

2.2. Data Collection Methods

The following are the types of data required to perform the study: (a) socio-economic characteristics, (b) perception of toll rates, (c) ability to pay and willingness to pay, and (d) revealed preferences of the willingness to divert to toll road from existing roadway. Table 1 presents the socio-economic data to be acquired from respondents.

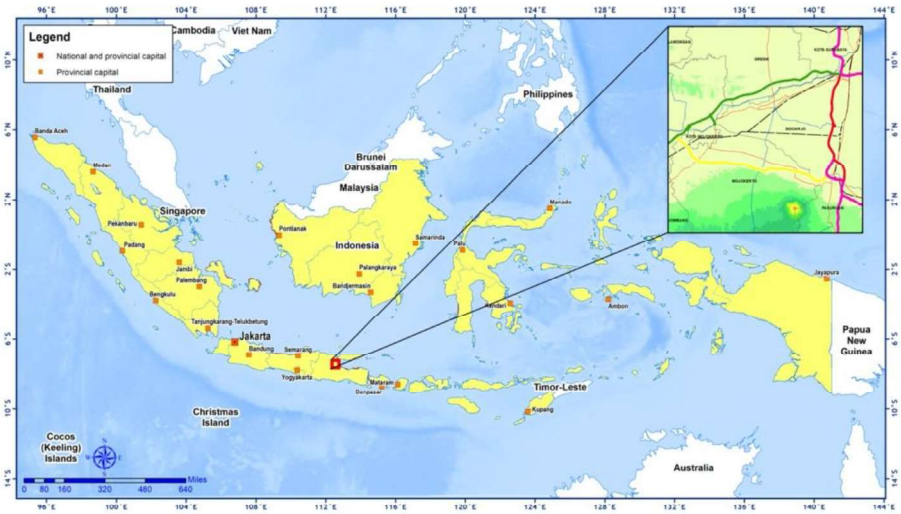


Figure 1. Location of study

Table 1. List of socio-economic data required by the study

No	Description
1	Gender
2	Occupation
3	Vehicle ownership
4	Average monthly expenses for transportation-related
5	Daily transportation expenses
6	Experiences of using the toll road
7	Perception of ideal toll rate
8	Daily or weekly origin-destination of travel

The ability to pay and willingness to pay (ATP/WTP) data was collected through a questionnaire with sample questions, as presented in Figure 2. The simulated preferences of the willingness to use toll road instead of the existing road were also acquired. Previous studies showed that current road conditions and toll fare become the determinant factors for a person to use toll roads or stay on the existing road. Therefore, a stated preference questionnaire was prepared. Five conditions shown in Table 2 (from heavily congested to lighted traffic) were applied to simulate the performance of the existing road condition. The toll rates simulation varies from Rp 600/km to Rp 850/km. Table 2 presents the Stated Preference questionnaire.

1. How much are your monthly household (food, clothes, school fees and meals, electricity, water, and so on) expenses?

☐ Rp 4.000.000 – Rp 4.500.000 ☐ Rp 7.500.001 – Rp 8.500.000
☐ Rp 4.500.001 – Rp 5.500.000 ☐ Rp 8.500.001 – Rp 9.500.000
☐ Rp 5.500.001 – Rp 6.500.000 ☐ Rp 9.500.001 – Rp 10.500.000
☐ Rp 6.500.001 – Rp 7.500.000 ☐ > Rp 10.500.000

2. How much is your daily transportation expense?

Cost Items	Unit (Rp/day)	Remarks
• Fuel:		
• Toll fares:		
• Parking:		
• Others:		

3. In your opinion, what is the ideal toll fares? (average fare in other toll roads: Rp 850/km)

☐ Rp 700/km ☐ Rp 800/km ☐ Rp 900/km ☐ Rp 1.000/km
☐ Rp ……..,-/km (please fill when necessary)

Figure 2. A sample question for ATP/WTP

Table 2. Sample of questionnaire on the probability to divert to the toll road

Simulated condition of existing road	Simulated toll rates (Rp/km)	Your choice*				
		1	2	3	4	5
The road was heavily congested (VCR > 1)	600	☐	☐	☐	☐	☐
	650	☐	☐	☐	☐	☐
	700	☐	☐	☐	☐	☐
	750	☐	☐	☐	☐	☐
	800	☐	☐	☐	☐	☐
	850	☐	☐	☐	☐	☐
Road was congested (0.8 < VCR < 1.0)	600	☐	☐	☐	☐	☐
	650	☐	☐	☐	☐	☐
	700	☐	☐	☐	☐	☐
	750	☐	☐	☐	☐	☐
	800	☐	☐	☐	☐	☐
	850	☐	☐	☐	☐	☐
Road was slightly congested 0.7 < VCR < 0.8	600	☐	☐	☐	☐	☐
	650	☐	☐	☐	☐	☐
	700	☐	☐	☐	☐	☐
	750	☐	☐	☐	☐	☐
	800	☐	☐	☐	☐	☐
	850	☐	☐	☐	☐	☐
Road was in normal condition 0.6 < VCR < 0.7	600	☐	☐	☐	☐	☐
	650	☐	☐	☐	☐	☐
	700	☐	☐	☐	☐	☐
	750	☐	☐	☐	☐	☐
	800	☐	☐	☐	☐	☐
	850	☐	☐	☐	☐	☐

*Notes on choice: **1** = definitely divert to toll road; **2** = might divert to toll road; **3** = cannot decide whether to divert to toll road or keep in existing road; 4 = might keep in existing road; 5 = definitely keep in existing road

2.3. Respondents

Respondents of the study were the existing road users in the area where there is a possibility that they may divert to toll road given incentive by the toll road. In this case, it is time saving due to the shorter travel time expected when using the toll road. Based on the traffic count data, and using the following formula (Yamane, 1967), the number of samples was estimated:

$$n = \frac{N}{1+N\times e^2} \tag{1}$$

In which: n = number of samples
N = number of population
e =level of accuracy

When e = .05, the number of respondents for each area can be determined, as presented in Table 3. The data collection was conducted by interviewing the respondents one by one. It was conducted at the restaurants or rest areas available along the existing roads.

Table 3. Number of respondents of the study

No	Area	Population	Respondents
1	Gempol – Mojokerto	18085	400
2	Waru – Kertosono	14609	400
3	Malang – Pandaan	38448	400

2.4. Analysis Method

There are three types of analyses required for the study: (1) the socio-economic of the respondent, (2) ability to pay and willingness to pay, and (3) development of probability choice curve. Socio-economic analyses were required to determine how the potential toll road users respond to alternative paid infrastructure availability for their movement purposes. For this purpose, a descriptive statistical analysis was applied.

The ability to pay and willingness to pay given such new infrastructure is determined using the following formula:

$$\mathbf{ATP_{resp}} = \frac{\mathbf{I_{rs}\ x\ P_p}}{\mathbf{T_{resp}}} \tag{2}$$

Where:
I_{rs} = respondent's monthly income
P_p =percentage of transportation-related spending over monthly income
T_{rs} = average monthly trip

The willingness to pay analysis was obtained from one of the questionnaire distributed to the respondents. The binary logit model was used to determine the probability for a person to switch to toll road from the existing roadway, as follows (Ortuzar, 2011):

$$P_{ij} = \frac{e^{(U_j-U_i)}}{1+e^{(U_j-U_i)}} \tag{3}$$

Where:

P_{ij} = probability of a person to choose the i route rather than the j route

$(U_j\text{-}U_i)$ = individual response to use a particular route given several options

According to the discrete choice model, personal choice to a specific route usually depends on their socio-economic characteristics, and the relative attractiveness to the alternative candidate. Therefore, this can be modeled as follows:

$$\boldsymbol{U_j - U_i = a_0 - a_1(X_{1j} - X_{1i}) + a_2(X_{2j} - X_{2i}) + \cdots + a_n(X_{nj} - X_{ni})} \quad (4)$$

In which X_1, X_2, …X_i are socio-economic variables affecting the modal choice.

3. Results & Discussions

3.1. Socio-economic Characteristics

Figure 3 presents the main socio-economic characteristics of the respondent for each area. As can be seen from the Figure, most respondents have at least one per week to use a toll road in terms of using toll road experiences.

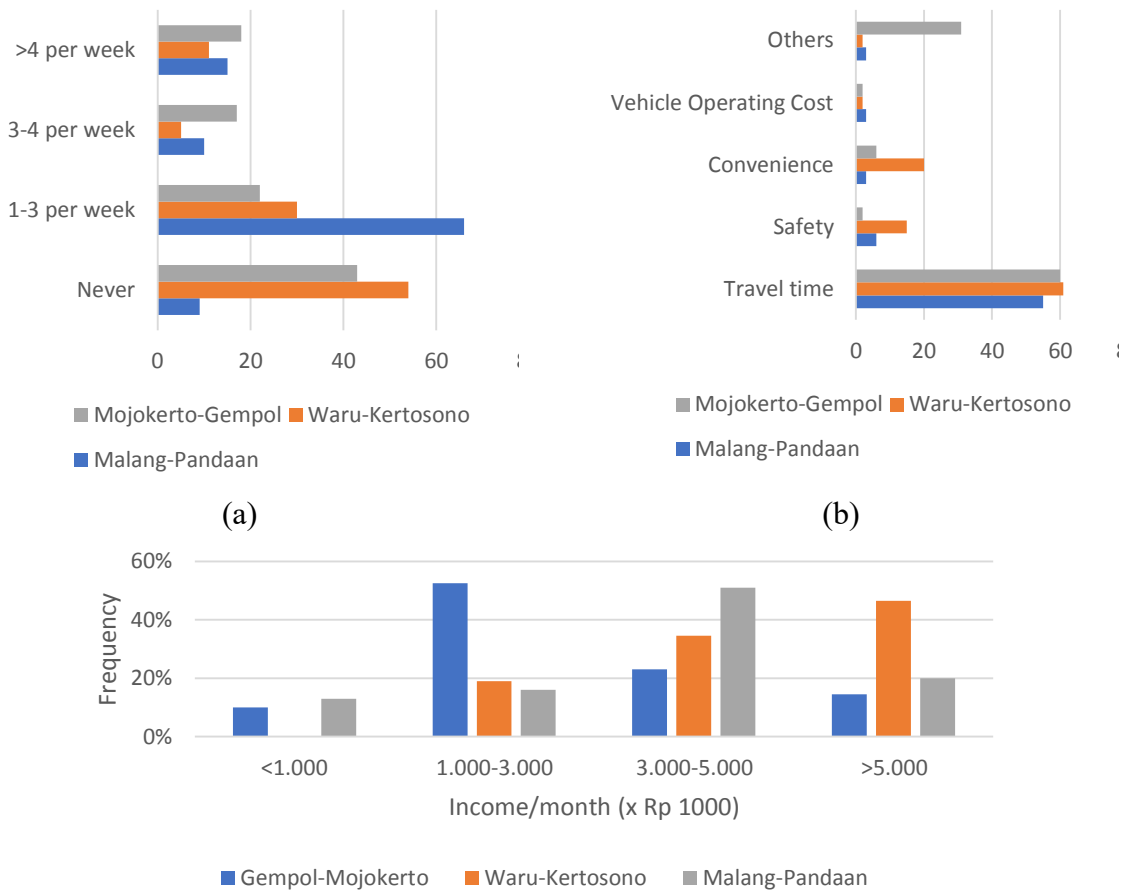


Figure 3. Socio-economic characteristics of respondents; (a) experiences of using a toll road, (b) Reasons for using a toll road, and (c) average monthly income

Respondents in the Malang-Pandaan area have used toll roads more often than those of any other location. Malang – Surabaya is one of the busiest routes in East Java, connecting two significant regions in East Java. Surabaya is East Java Province's capital city, while Malang is the tourist destination and major college towns. While most respondents in the Malang-Pandaan area said they had used toll at least one per week, some of the respondents have not used toll roads in the other study area. This finding may affect their preference for using toll roads.

When asked what the main reasons to use toll, the majority of respondents of all study area concurred that travel time was the primary reason since toll road will benefit them by shortening the travel time of their journey. It implies that toll roads will be most attractive in the area where traffic congestions occur, and the road users feel that it has affected the convenience of their travel. Most of the respondents fall in the Rp 3 – 5 million/month ranges in terms of income. Respondents in the Waru-Kertosono have the highest income, followed by Mojokerto-Gempol and Malang-Pandaan, as shown in Fig 3c. It is understandable since the Waru – Kertosono area is a better-developed area compared with the others.

3.2. Ability to Pay dan Willingness To Pay (ATP/WTP)

Figure 4 presents the ATP/WTP value for each study area. In terms of ability to pay, 80 % or above the cumulative frequency of respondents thought that toll fare should be within Rp 600/km – Rp 800/km ranges, except respondents at Malang – Pandaan, which show higher values.

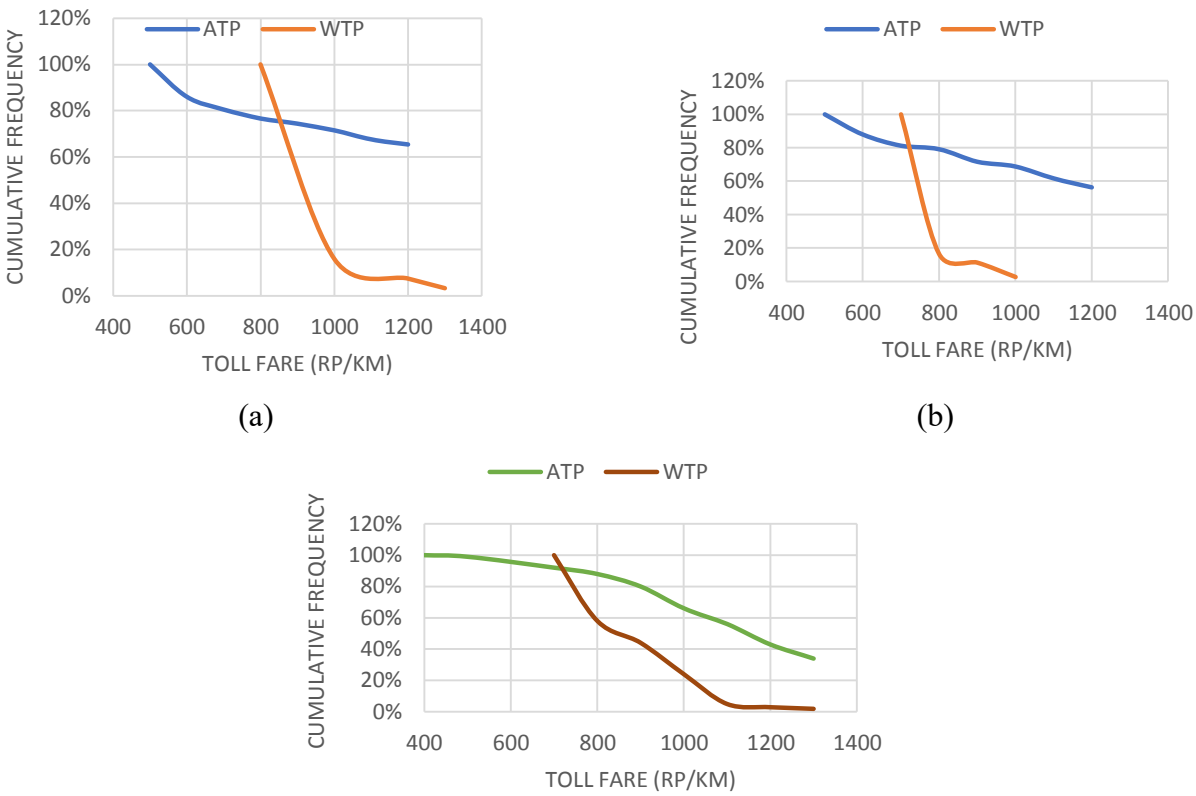


Figure 4. ATP/WTP value; (a) Mojokerto – Gempol; (b) Waru – Kertosono; (c) Malang – Pandaan

Similar trends seem to appear in the willingness to pay curve. Malang – Pandaan respondents tend to be willing to pay a higher toll fare compared to other study areas, followed by those of Mojokerto – Gempol and Waru – Kertosono.

The plausible explanation of this trend is that Malang – Pandaan area has a lower or more insufficient level of service (LOS) of its existing road, which will affect the users' time travel and, consequently, drive more people to use the toll road. In other words, the level of service condition of the existing road will affect how people think about preferring toll road and drive them to have more willingness to use the toll road.

3.3. Probability Model Development for Toll Road

From questionnaires distributed (see Table 1), respondents filled each item of the questions based on their preferences ranging from 1 to 5 on the Lickert scale (1 represents that he/she definitely diverts to toll road; 2 might shift to toll road; 3 cannot decide whether to shift to the toll road or keep in the existing road; 4 might hold in the existing road, and 5 definitely keeps in the existing road). For further analysis, their selections should be transformed into a probability scale using Berkson-Theil transformation (Ortuzar, 2011) and utility-scale, as shown in Table 4.

Table 4. Probability and utility transformation

Lickert Scale	Probability Scale (P)	Utility-Scale $Ln(\frac{P}{1-P})$
1	0.9	2.1972
2	0.7	0.8473
3	0.5	0.0
4	0.3	-0.8473
5	0.1	-2.1972

For example, when for a given level of service of the existing road and simulated toll fare, a respondent thinks that he/she might divert to toll road, then he/she will select scale 2 (on Lickert scale), which transforms to utility scale of 0.8473.

3.4. Development of modal choice probability model.

After the utility-scale transformation, all the responses were then arranged like the one in Table 5. With the help of statistical software, a linear multiple regression equation can be formed, with the utility model for each area of study is presented in Table 6. Using Eq.1, the modal choice probability model for each study area is presented in Table 7. The probability curve can be developed using the model in Table 7, as shown in Figure 6. One should note regarding the R^2 in Table 6 that shows lower values, which means weaker relationship among variables in the regression model. However, this is common value when dealing with modal choice model.

Table 5. Sample of Respondent's response

No	Road Condition (X1)	Toll Fare (X2)	U_j-U_i
1	1.2	29000	2.1972
2	1.2	31000	0.8473
3	1.2	34000	0.000
4	1.2	36000	-0.8473
5	1.2	40000	-2.1972

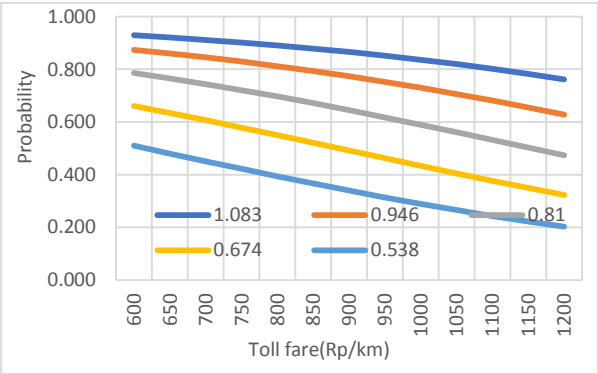
Table 6. Utility model for each area of study

No	Area of Study	Utility Model	Remarks
1	Gempol - Mojokerto	$(U_j\text{-}U_i) = -1{,}052 - 0{,}002\ (X_1) + 4{,}644(X_2)$	$R^2 = 0.171$
2	Waru - Kertosono	$(U_j\text{-}U_i) = 0{,}198 - 0{,}004\ (X_1) + 5{,}139(X_2)$	$R^2 = 0.395$
3	Malang - Pandaan	$(U_j\text{-}U_i) = 2{,}272 - 0{,}004(X_1) + 2{,}683(X_2)$	$R^2 = 0{,}36$

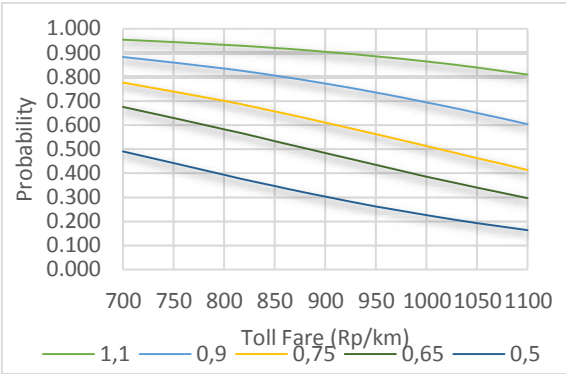
Table 7. Modal Choice Probability Model

No	Area of Study	Probability Model
1	Gempol - Mojokerto	$P_{JT} = \frac{e^{(-1{,}052 - 0{,}002\ (X1) + 4{,}644(X2))}}{1 + e^{(-1{,}052 - 0{,}002\ (X1) + 4{,}644(X2))}}$
2	Waru - Kertosono	$P_{JT} = \frac{e^{(0{,}198 - 0{,}004\ (X1) + 5{,}139(X2))}}{1 + e^{(0{,}198 - 0{,}004\ (X1) + 5{,}139(X2))}}$
3	Malang - Pandaan	$P_{JT} = \frac{e^{(2{,}272 - 0{,}004\ (X1) + 2{,}683(X2))}}{1 + e^{(2{,}272 - 0{,}004\ (X1) + 2{,}683(X2))}}$

Figure 5 shows how the level of service condition of existing road and toll fare affects the road user's decision to keep in the existing road or switch to the toll road. The Figure shows that when the level of service of the existing road is poor, as demonstrated by a high value of volume over capacity ratio, then there is a higher probability that the user will switch to toll road, and vice versa. These figures will help planners and investors predict the number of potential users of toll roads and decide the toll fare. As the figures show, the higher the toll fare, the lower the expected toll users. Setting similar toll fare for a region, a common practice in Indonesia, may reduce the predicted users in some toll, but may overestimate in other toll roads. It can be explained by Figure 9. This figure was constructed using the average volume over capacity ratio of the existing road for each area. As shown in the Figure, each region has a unique curve, depending on each area's socio-economic characteristics. In the area where existing roads have a higher volume over capacity ratio, they tend to have a higher probability of switching to toll roads, and vice versa. Thus, one of the actual uses of this research findings is to propose a better method for the Government in deciding the toll fare (in Indonesia, it is the Government that sets the toll fare).



(a)



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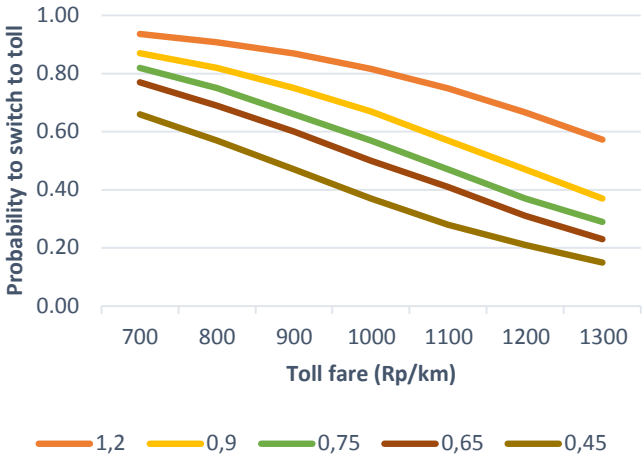

(c)

Figure 5. The probability of switching to toll road at various simulated level of service of the existing main road; (a) Mojokerto – Gempol; (b) Waru – Kertosono; (c) Malang – Pandaan

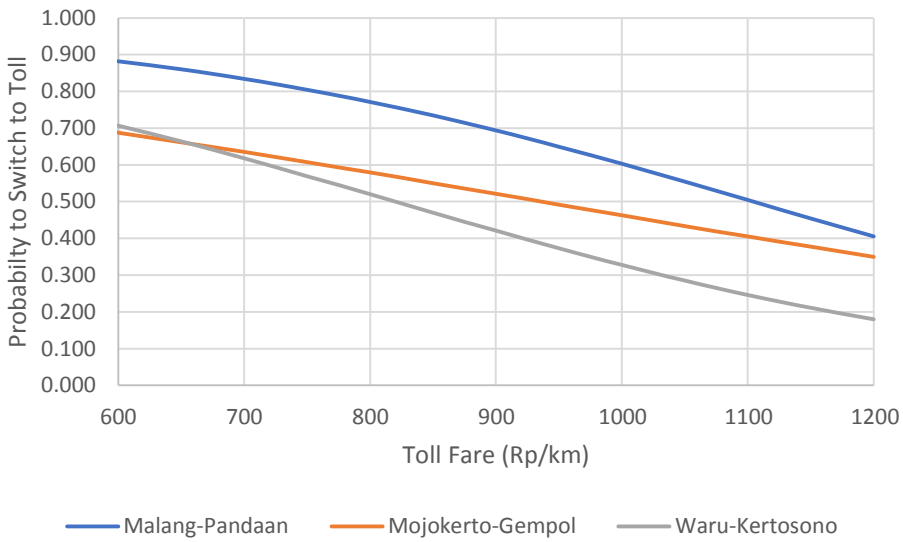

Figure 6. Probability Model for switching to a toll road

3.5. Effects of Toll Fare to Revenue

One of the crucial issues in toll road investment is how much revenue it can receive. Investors will pursue ways to maximize their revenue. One of the standard practices to achieve it is by increasing the toll fare, assuming that increasing the toll fare may maximize the revenue. Using the model developed as discussed above, one can simulate whether this assumption is valid. For illustration, the following paragraph will discuss this assumption.

The total revenue that toll road can be accrued can be expressed as follows:

$$Revenue = \sum_{i=1}^{n} Traffic\_volume_i \times Tol\_fare_i \quad \textbf{(5)}$$

In which:

i = vehicle classification in toll road management.

Using traffic data and related toll fare for each vehicle classification in the area and inputting them into Eq 5, one can estimate the revenue. Figure 7 presents the illustration of the effect of toll fare on the revenue. The figures show that increasing toll fares did not necessarily increase the revenue. For example, in the Waru – Kertosono area, higher revenue could be obtained at the lower toll fare. The maximum revenue could be obtained at the optimum toll fare in the Mojokerto – Gempol, and Malang – Pandaan areas. It is an exciting finding and seems to contradict Indonesia's general view that increasing toll fares would increase revenue.

4. CONCLUSION AND RESEARCH IMPLICATION

a. The modal choice probability model and curve developed in this research will be handy for the parties involved in the toll road policy, whether to decide the toll fares or determine the optimum revenue.
b. The model curve can be used mainly during the initial stage of the toll development plan. It can predict the number of toll users without conducting a detailed survey and analysis.
c. The ATP WTP analysis alone cannot be used when deciding the toll fares since it does not correlate with the predicted toll user. The study showed that at Rp 800, -/km toll fare, the projected travelers who diverted to Toll road were about 80% when using ATP/WTP method, and about 70% when using the proposed model, which was closer to the real data.
d. With a slight modification of all curves, this study's curves can be combined to come with a standard curve used in the broader region. Alternatively, one can modify using a parameter depending on the area.

5. ACKNOWLEDGMENT

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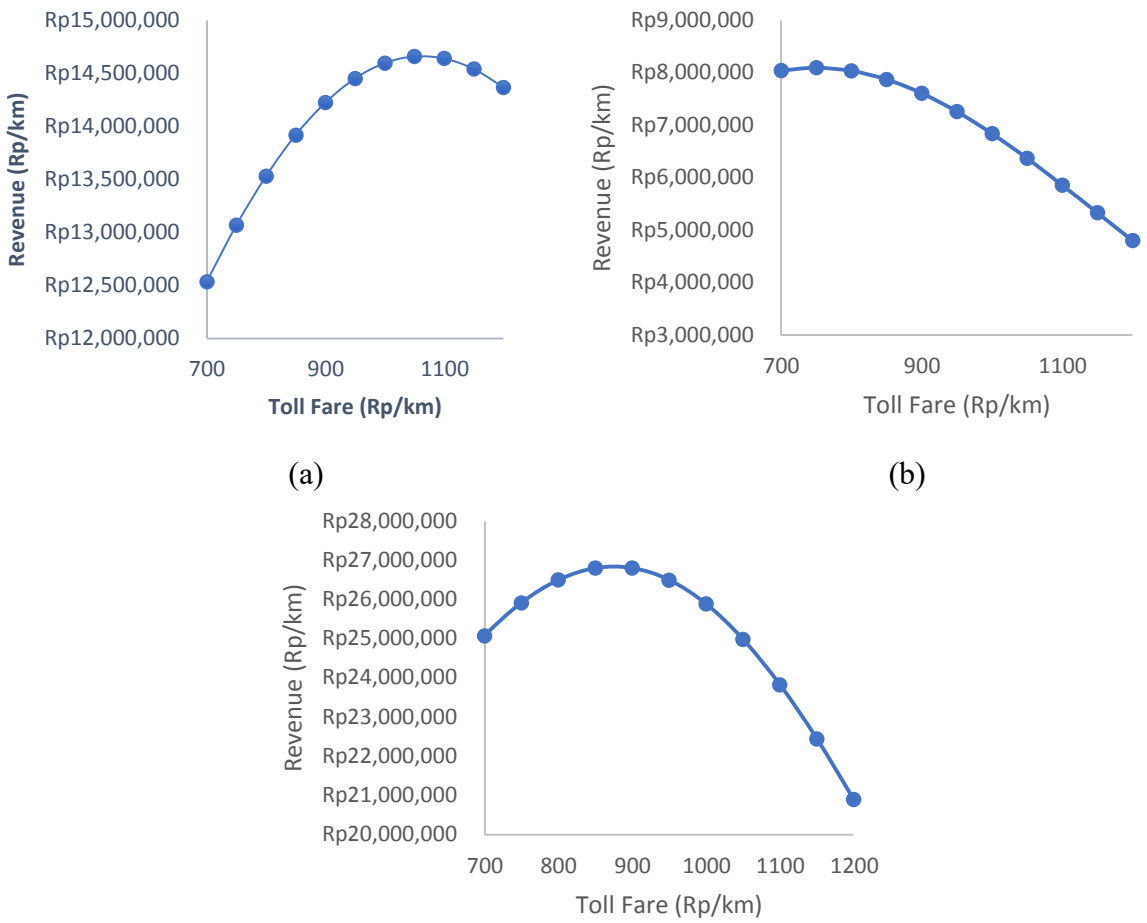

Figure 7. Effect of Toll fare to revenue: (a) Mojokerto-Gempol; (b) Waru-Kertosono; (c) Malang-Pandaan

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