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ESTIMATING THE OPTIMAL FARE FOR A TOLL ROAD IN INDONESIA USING STATED PREFERENCE METHODOLOGY

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Abstract

Investing in an infrastructure project requires an understanding of the potential market share of future demand to ensure that the assumed economic benefits of the project can be reaped by those who use the infrastructure. Investing in an infrastructure project also requires an understanding of potential revenue flows so that investors can make a rational decision to invest.

In this paper, we attempted to provide useful insights on economic concepts related to market demand and revenue flows through an analysis of human behavior and the decision-making process. We applied a route choice model, using discrete choice theory, for a greenfield transport investment in Indonesia. To estimate such a model, we also developed a stated preference survey and conducted interviews along a segment of the Trans-Sumatra Toll Road. Results indicate that travel time, toll fare and driver comfort are significant variables that determine the probability of using the toll road. We also estimated the car drivers' value of time and the value they assign to driver comfort, as well as the optimal toll fare that is expected to maximize potential revenues on the toll road. We conclude that the application of the stated preference methodology on an infrastructure investment with a competing alternative is useful for robust project preparation and can inform infrastructure officials of the incentives needed to maximize the economic and financial benefits of a potential investment.

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1. Introduction

Transport infrastructure is capital intensive, and governments face significant constraints to fund these much-needed investments. Such constraints call for the participation of other stakeholders including private sector and state-owned enterprises in the financing, construction, operations, and maintenance of such infrastructures. Yet, non-government stakeholders would be reluctant to participate if a potential infrastructure investment is unlikely to generate robust revenue flows to contribute to the sustainability of certain aspects of the infrastructure, such as civil works and operations and maintenance.

Revenue flow estimation requires an understanding of the transportation demand, which is based on the behaviors of the users of the transport infrastructure. The traveler makes decisions based on various characteristics of the transport services and infrastructure (e.g., whether to use a toll or non-tolled road, whether to use public transport or drive, when to leave home). These decisions are affected by various factors, such as travel time, transport cost and comfort. Therefore, a robust understanding of revenue flow estimates for a transport infrastructure requires the potential investor to anticipate changes in demand brought about by changes in the choices of the transport users.

In this paper, we estimate and apply a route choice model for a segment of the Trans-Sumatra Toll Road in Indonesia. The estimation is based on primary data collected through a stated preference survey. With the application of this model, the objectives of this paper are fourfold, namely: (i) to estimate transport demand for the Jambi-to-Rengat segment; (ii) to calculate the elasticities of transport demand in relation to toll fare, travel time and driver comfort; (iii) to determine the value of transport time and driver comfort; and (iv) to identify the optimal toll fare that will maximize potential revenues on this toll road segment.

The rest of the paper is organized as follows: Section 2 provides an overview of the Trans Sumatra Toll Road. Section 3 elaborates on the stated preference survey, discusses the route choice estimation model, and the model's application to estimating the value of time and comfort and the optimal toll. Section 4 provides the analytical results, including the policy implications and study limitations. Section 5 presents the conclusion.

2. Trans-Sumatra Toll Road

The Trans-Sumatra Toll Road is a network of toll roads in Indonesia's Sumatra Island. It is one of Indonesia's key infrastructure projects under development.

Sumatra Island is Indonesia's second largest island in terms of both population and gross domestic product. The island's economic growth demands significant improvements in its intra-island connectivity—95% of its inter-provincial trade rely on roads; yet the national road network is highly congested, heavily damaged due to severe rainfalls and droughts, and the site of many accidents; moreover, many of the roads remain unconnected to the main network. The toll road is expected to address some of these challenges by providing an alternative transport mode for road users.

The toll road consists of 17 main or backbone segments with a total length of 2,048 kilometers (km) spanning from Sumatra's northern tip (Banda Aceh) to its southern tip (Bakauheni), as well as seven supporting segments with a total length of 770 km linking Sumatra's east and west coasts. This paper particularly examines a planned 198 km backbone segment connecting Jambi in Jambi Province to Rengat in Riau Province.

3. Methodology and Data

3.1 Stated Preference Survey

This paper describes a study where the optimum toll level for a segment of the toll road was estimated using the stated preference methodology. We carried out a stated preferences survey, on users of the existing national road, conducted in Indonesia's local language. This existing road is expected to be the competing alternative to the Jambi-to-Rengat segment of the Trans-Sumatra toll road once it is constructed. Therefore, the intercepted users are travelling along the competing section of the existing national road. The survey was designed to serve as a basis for the estimation of a route choice model for users of the existing national road where in the future they may choose the new toll road.

The respondents are exclusively private car drivers, and not accompanying passengers. The respondent or their household is also a private car owner. The drivers, who have control over their route choices, were intercepted along the national road in rest service areas, gas stations and shopping centers where they can spend at least 20 minutes with the surveyor. To intercept a sample as representative as possible, the drivers are intercepted at several places along the road.

The first part of the survey included socio-economic questions for the driver, including gender, age, number of cars owned, and household income. The second part included questions relative to the driver's trip, such as origin and destination, total travel time, and distance, for example. The third part of the survey included the stated preference experiments where the driver was presented with several alternatives that vary three variables (namely, toll value, travel time, and driver comfort)[1] adapted to the trip the driver is carrying out. The last part of the survey aimed to establish some valuation of the comfort elements that the driver implicitly considers in the comfort variable. The comfort variable is a discrete variable, such as (i) better or (ii) same with respect to the existing driver comfort experience. The driver was asked to rank several comfort elements by order of importance to the driver, such as (i) illumination; (ii) rest areas;

[1] Fuel consumption is not considered since it is not practical, i.e., a car driver would not necessarily know how much fuel has been consumed for the trip and thus is unlikely to be a consideration when choosing a route.

(iii) service stations; (iv) safety rails; (v) patrol cars; and (iv) restrooms. The ranking exercise will serve the project design to determine which elements should be included as a priority.

3.1.1 Design of the Stated Preference Experiments

Stated preference experiments describe how respondents behave (i.e., make choices) depending on the hypothetical situations presented to them. In designing the experiments, key variables are identified (i.e., alternative, attributes, and levels) following which the choice tasks (experiments) are developed based on these variables. In these choice tasks, respondents are asked to make a choice between alternatives depending on the changes in the attributes (characteristics) of the specific choice task at hand. Such changes can be preferred or not preferred by the respondent, and this can then affect their choice between alternatives. Once a choice is made, the respondent 'reveals' which attributes are most pertinent to them. In this survey, respondents are indirectly asked, through these experiments, to 'state' how much they are willing to pay to gain a unit of time (or comfort).

There are two alternatives in our survey. The status quo (no choice alternative) is the national road, and the alternative is the toll road. The attributes (i.e., reflecting the characteristics of the road) used include travel time, toll fare and driver comfort. Travel time and toll fare are quantitative/numerical attributes, whereas driver comfort is a qualitative/categorical attribute. The attributes are chosen based on existing literature which shows that these characteristics are pertinent for respondents' decision-making when choosing between different types of roads. The levels of each of these three attributes are determined based on expert discussion with the Ministry of Public Works and Housing and PT Hutama Karya (PT HK), a state-owned enterprise and toll road operator in Indonesia, the current situation of the Jambi-to-Rengat segment, and prior commissioned studies by PT HK. The levels are curated using actual experiences and current trip details to enable more realistic decision-making on hypothetical choice tasks.

For travel time, it currently takes 4.4 hours to traverse the 264 km Jambi-to-Rengat segment of the national road at an average speed of 60 km per hour. In contrast, it is expected that it will take about 1.98 hours to travel the 198 km of the future toll road at an average speed of 100 km per hour. Hence, once the toll road is constructed, toll road users can expect a 55% reduction in travel time. The levels of the travel time attribute for the toll road are as follows: 45%, 55% and 65% faster than the national road. The national road is expected to neither have an improvement nor dis-improvement in travel time.

For toll fare, the estimation of the range of tariffs used in the experiment is based on expert discussion and prior studies on the segment. Currently, PT HK-operated and managed toll road segments charge no lower than Indonesian rupiah (IDR) 1,000 per kilometer. Nonetheless, per communication with the toll road operator (PT HK), existing studies for the Jambi-to-Rengat segment calculated the fare to be about IDR250 per kilometer using the ability-to-pay methodology for the toll road. The levels of the toll fare attribute for the toll road are between IDR250 per kilometer and IDR2,000 per kilometer (this is to account for inflation and the fact that construction will take about six years to complete). The toll fare levels increase by increments of IDR250 per kilometer. Use of the national road incurs no cost.

For driver comfort, the levels of this attribute for the toll road take on a dummy for same as current national road experience (0) and better than current national road experience (1). Implicit in this variable are comfort attributes such as clear lighting on the toll road, availability of rest areas, availability of gas stations, safety rails on the toll road, patrol cars roaming at the night, clean toilets in rest areas or gas stations, and smooth driving surface on the toll road. Theoretically, the respondent is making the choice based on these attributes bundled together. The analysis will attempt to distinguish a rating and a ranking of these comfort attributes separately.

Table 1 describes the alternatives, attributes and levels of the stated design experiment.

Table 1. Alternatives, Attributes and Level of the Study

Alternatives	Toll Road	National Highway (NH)
Attribute 1: Travel time	45% faster than NH	As is
	55% faster than NH	
	65% faster than NH	
Attribute 2: Tariff	IDR 250/km	IDR 0/km
	IDR 500/km	
	IDR 750/km	
	IDR 1,000/km	
	IDR 1,250/km	
	IDR 1,500/km	
	IDR 1,750/km	
	IDR 2,000/km	
Attribute 3: Comfort	Same as current NH experience	Current NH experience
	Better than current NH experience	

In theory, respondents can be asked to respond to the choice tasks based on the whole universe of the combination of attributes. The total number of combinations will arrive at 48 experiments. However, this can be overly burdensome to the respondent. Hence, 16 choice tasks are determined in the experimental design. The number of choice tasks $|S|$ follows the threshold of the minimum size of the design that satisfies the following (Bliemer and Rose, 2021):

$$|S| \geq \frac{K}{|J| - 1}$$

Where K refers to the number of parameters and J refers to the number of alternatives.

In this survey, K equals four considering that the driver comfort attribute is a dummy (therefore, it has two parameters) and travel time and cost each has one parameter considering that these are continuous variables. Given that there are two alternatives for each choice task, the minimum number of choice tasks is 4, i.e., $|S| \geq 4$. Nevertheless, (Bliemer and Rose, 2021) suggested that the choice tasks can be increased to boost the variety in the design data. In this survey, the design is set at 4 times the minimum design size at 16 choice tasks.

An efficient design, with a D-error of 0.030377, varies the combinations of the levels of the attributes shown for each experiment (choice task) using the Ngene software. Note that (Bliemer and Rose, 2021) indicated that a lower D-error is better (to maximize the volume of Fisher information) and that a finite D-error of smaller than 1 provides confidence that the data is suitable for model estimation. (Bliemer and Rose, 2021) also identified the main advantages of using an efficient design, namely that estimates can be generated accurately at smaller sample sizes, and that such designs can avoid dominant alternatives and unrealistic attribute levels.

The 16 choice tasks are considered to be appropriate. Given 16 experiments, 16 observations are collected from each respondent. The 16 choice tasks are randomly presented to the respondents during the survey interview, and respondents had to choose their most preferred option. An example of the choice task, as developed from the Sawtooth software, is shown in Annex 1.

3.1.2 Pilot Survey

Prior to conducting the actual survey, a pilot survey was carried out from June 8 to 10, 2023 comprising 26 respondents (14 in Jambi province and 12 in Riau province) along the Jambi-to-Rengat segment. The objectives of the pilot survey are (i) to help the surveyors become familiar with the respondent criteria and the choice tasks, including how to explain to the respondents why the choice tasks are being asked and the caveats involved (e.g., the respondent has to assume that the choice tasks pertain to their current trip); and (ii) check whether the pilot respondents understood the questions being asked and the choice tasks.

The pilot survey confirmed that the survey was understood by the target audience and the levels of tariffs presented in the choice tasks are reasonable. The surveyors also used their prior experiences in the pilot survey to identify interview strategies for the actual survey and enable a more seamless interview experience for the respondents. The actual survey was conducted from June 30 to July 4, 2023 in rest service areas, gas stations and shopping centers along the Jambi-to-Rengat segment comprising a total of 379 valid respondents.[2] On average, each of the interviews were completed

[2] With a sample of 379 respondents, a z-score of 1.96 for a chosen confidence level of 95% obtained from the Normal Distribution table, an infinite car owner population (considering that the population in Jambi and Rengat are greater than 100,000), and a population proportion of 50%, the sampling error is calculated to be 0.0503. This is statistically representative of the car owner population in Jambi and Rengat.

in 25 minutes. The estimated route choice model based on the pilot survey showed the expected signs for toll fare and travel time.

Both surveys were web-based and conducted using the Sawtooth survey software. There were a few considerations in carrying out the web-based survey. First, a computer-adaptive design was used to provide the driver a context that resembled their present trip as much as possible. Second, the alternatives in the choice tasks were presented randomly across respondents (not within a respondent) to control for any presentation bias (left to right bias) of the alternatives (Bliemer and Rose, 2021). Survey results were geotagged or matched with field photo documentation.

3.2 Route Choice Model Estimation

The route choice model is based on discrete choice theory. In this set-up, transport users are asked to make a choice between mutually exclusive alternatives. Therefore, if the respondent makes one choice, the remaining alternatives can no longer be selected. In making such a choice, it should be noted that the environment that influence the respondent choice is random and specific to each context (Aloulou, 2018). This is in contrast to the neoclassical choice theory which assumes that consumers can buy continuous quantities of goods and that “the chosen environment is static, stable, and transparent and that the individuals’ decisions are rational and typical, so that the individual choice is deterministic and repetitive” (Aloulou, 2018).

The discrete choice model assumes that respondents maximize their utility (objective function) from a discrete set of choices (such as choosing between a non-tolled national road and a toll road for this paper). Since respondent choice is made under a random situation, the utility function is random, and the choice estimates have a probabilistic distribution.

Therefore, we can estimate the probability of choosing a non-tolled national road and a toll road based on the characteristics of the choice attributes, V_j . The utility function of the toll road alternative j, U_j, has both a deterministic component V_j and a random component ε_j:

$$U_j = V_j + \varepsilon_j$$

The deterministic component for the toll road is shown in linear form for ease of estimation:

$$V_j = \alpha_j + \beta_{traveltime} * X_{jtraveltime} + \beta_{tollfare} * X_{jtollfare} + \beta_{comfort} * X_{jcomfort}$$

The utility function (dependent variable) is a discrete variable and vary depending on the number of alternatives that comprise the choice set of the respondent. Since there are two alternatives, the discrete variable takes a value of 1 for the toll road and 0 for the national road (status quo).

The utility function depends on the three attributes (explanatory variables) that characterize the route choice: travel time, toll fare and driver comfort. The first two variables are continuous while driver comfort is expressed as a dummy. These attributes change for the same respondent from one route choice to another. The logit model can be performed to calculate the constant α_j and the coefficients β_l . The constant reflects the impact of other explanatory variables not included in the logit model and the heterogeneity observed between respondent choices, e.g., there can be more respondents who select one choice than those who select the other choice (Aloulou, 2018). The coefficients do not vary according to the route choice of the respondent. A positive coefficient suggests that the variable positively affects the probability of choosing the toll road relative to the national road.

Socio-economic characteristics (such as gender, age, and income) and trip features (such as distance and trip purpose) can also affect the route choice of the respondents. For example, higher-income respondents are more likely to choose the toll road. However, these were not included in the route choice model as explanatory variables as it was not possible to apply the model using those variables. That is, the trip matrices issued from the transport modeling exercise, which are in terms of vehicles, do not distinguish between these characteristics. Furthermore, from a practical perspective, it is impossible to set toll levels by income level or by trip purpose.

We estimate a well-known discrete choice model, namely the binomial logit model (Pearmain, Swanson, Kroes, and Bradley, 1991), using the results of the stated preference survey data for private vehicle drivers. If the random component, which reflects the unobserved behavior of the respondents,[3] is independently and identically distributed, the choice probability function P_j can be defined. The respondent will choose the toll road (alternative j) over the national road (alternative n) if and only if $U_j > U_n$:

$$P_j = Pr\,(U_j > U_n)$$

The probability that the toll road alternative is chosen compared to the national road (where j and n comprise the set of alternative J) can be expressed as:

$$P_j = \frac{e^{V_j}}{\Sigma_{j=1}^{J} e^{V_j}} = \frac{e^{V_j}}{e^{V_j} + e^{V_n}}$$

Since the probabilities of the set of alternatives sum to one, the probability connected with the national road can be measured from the calculated probability of the toll road. This means that the probability of the national road alternative does not need to be specified. The excluded national road alternative will serve as the reference case that

[3] Given that the utility function includes the unobservable, and hence random, it should be noted that the value of such function is unknown and what can be observed is only the choice of the respondents.

is compared with the observed case (i.e., toll road alternative) in the model. Therefore, the coefficients of the national road alternative will be zero.

Since $e^{V_n} = e^0$ = 1, the probability that the toll road alternative is chosen can be shown as follows:

$$P_j = \frac{e^{V_j}}{\Sigma_{j=1}^{J-1} e^{V_j} + 1} = \frac{e^{V_j}}{e^{V_j} + 1}$$

The probability that the national road alternative is chosen is:

$$P_n = 1 - P_j = \frac{1}{e^{V_j} + 1}$$

The ratio of the probabilities of the toll road and national road can be expressed as:

$$\frac{P_j}{P_n} = e^{V_j}$$

Taking logs on both sides, the expression is equal to:

$$log\left(\frac{P_j}{P_n}\right) = V_j = \alpha_j + \beta_{traveltime} * X_{jtraveltime} + \beta_{tollfare} * X_{jtollfare} + \beta_{comfort} * X_{jcomfort}$$

Given that the utility function is linear, dividing the coefficient of travel time by the coefficient of toll fare reflects the marginal rate of substitution of toll fare for travel time. The respondent is willing to pay a certain toll price to save a unit of travel time. This price is the value of time (VoT) as shown below:

$$VoT = \frac{\beta_{traveltime}}{\beta_{tollfare}}$$

Correspondingly, dividing the coefficient of travel time by the coefficient of toll fare reflects the value of comfort (VoC), i.e., the price that the car driver is willing to pay to gain a unit of comfort.

$$VoC = \frac{\beta_{comfort}}{\beta_{tollfare}}$$

The estimation results are presented in Section 4.

3.3 Model Application and Estimation of the Optimal Toll

The route choice model allows for the share of toll road users to be predicted in order to ascertain the possible market share of the potential investment prior to its construction and use. When the market share is known, potential toll revenues can be calculated for each assumed toll fare, and an optimal toll fare (the point at which revenue is maximized) can be ascertained.

Optimal toll estimation requires the value of the variables from a prior transport modelling exercise as inputs, apart from the results of the route choice modeling exercise. These values include the car driver trip matrix, travel time matrix and distance for the respective origins and destinations for the Jambi-to-Rengat segment.

The car driver trip matrix, containing 19 zones of which 11 are internal, is expressed for the year 2030 following a four-step transport modelling exercise. In 2030, over 120,000 cars per day are expected to travel between these zones irrespective of route choice. The travel time and distance matrices are also obtained from the transport modelling exercise. The travel time matrix, expressed in hours for each origin and destinations in the zones, includes both travel times on the toll road and on the connecting roads. The distance matrix is a conditional skim for the toll road and expressed in kilometers for each origin and destination. It is conditional because the matrix only includes the path on the toll road, having assumed the shortest path of traveling from each origin and destination.

The estimated route choice model which contains the coefficients of travel times, toll values and comfort is applied using the values from the aforementioned modelling exercise. The route choice model, with its respective coefficients and constant, is applied for an array of possible toll levels ranging from IDR 0 to 2,000. The probability of choosing the toll road alternative is then calculated, following which this probability is multiplied with the car trip matrix for each origin and destination.

The resulting number of cars on the toll road and the resulting revenue is constructed for each origin and destination. For example, summing up the revenues at every toll fare point from IDR0 to IDR2,000, a toll fare to revenue curve can be constructed for the passenger car driver. This curve is presented in Section 4.

4. Results

4.1 Respondent Profiles

The survey data comprised a total of 379 valid respondents. Two respondents were removed from the study since the experiments were not completed. Given 16 choice tasks, this is equivalent to 6,064 valid observations for the route choice modeling exercise.

Table 2 shows the demographics data of the respondent. Data were collected mainly from male car drivers (90%) belonging from the active population (97%) and owning one vehicle (86%). The average monthly household income of the respondents ranged between IDR2 million and IDR8 million (84%) considering about 1.6 working individuals in the household.

Table 2. Respondents' Demographics

Demographic	Frequency	Percentage
Gender		
Women	37	9.76
Men	342	90.24
Age group		
58 y/o+ retirees	10	2.64
17-57 y/o active pop	369	97.36
Cars owned		
more than one	54	14.25
one	325	85.75
Mean monthly household income		
Less than 1 million Indonesian rupiah	1	0.26
1 to <2 million	25	6.6
2 to <4 million	140	36.94
4 to <6 million	118	31.13
6 to <8 million	59	15.57
8 to <10 million	23	6.07
10 to <12 million	9	2.37
12 to <14 million	2	0.53
>=14 million	2	0.53
Number of working individuals		
Mean = 1.599		
Standard Deviation = 0.657		

4.2 Route Choice Model Estimation results

Table 3 shows the route choice model estimates using a binomial logit model. The coefficients for travel time and toll fare have the expected negative signs, meaning that a longer travel time and higher toll negatively affect the use of the toll road relative to the national road. The coefficient for driver comfort, a perceptive variable, is positive indicating that a more comfortable driving experience enables the use of the toll road.

The constant explains the heterogeneity observed in the respondents' choices.[4] All the coefficients are statistically significant at the 1% level.[5]

Table 3. Route Choice Model Estimates

Variable	Coefficient	Odds ratio
Travel time	-0. 239862***	0.786737
	[0.067]	
Toll fare	-0. 0000145***	0.999986
	[0.000]	
Driver comfort	0. 2717456***	1.312253
	[0.066]	
Constant	2.697302***	
	[0.196]	

Robust standard errors in brackets
Significance level: *** p<0.01, ** p<0.05, * p<0.1
Observations: 6,064
Log likelihood: -2822.0723
Prob>chi^2: 0.0000
Pseudo R^2: 0.2933

To explain the magnitude of the coefficients, the odds ratio (i.e., exponential value of the coefficient) provides an intuitive explanation. The odds ratio of 0.7867 for travel time indicates that when travel time increases by 1 hour (keeping all other explanatory variables constant), the probability of choosing the toll road alternative instead of the national road alternative decreases by 21.33% (i.e., 0.7867-1). For the toll fare variable, the odds ratio implies that when the toll increases by IDR1,000, the probability of choosing the toll road alternative than the national road alternative decreases by 1.40%. Comparing the probabilities of travel time and toll road indicates that the car driver is more sensitive to changes in travel time than the toll fare.

For driver comfort, a dummy variable, the odds ratio of 1.3123 can be explained as follows: when driver comfort experience improves from the status quo experience to a better comfort experience on the toll road, the chances of choosing the toll road compared to the national road increases by 32.23% (i.e., 1.3223-1).

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[4] One factor is whether the appearance of the toll road alternative (i.e., whether on the left or the right) on the computerized survey questionnaire can affect how respondents answer the choice tasks. Therefore, we randomized the appearances of the toll road and national road across respondents (i.e., either on the left screen for one respondent, and right on the other for another respondent). Controlling for this factor on the route choice model, we find that the coefficient for this factor is insignificant.

[5] The standard errors are clustered by respondent to adjust for the correlations of observations within respondents (given that there are 16 observations for every respondent). Clustering does not affect the coefficient estimates.

4.3 Value of Time

Obtaining the ratio of the coefficients of travel time (numerator) and toll fare (denominator) reflects the marginal rate of substitution of toll fare for travel time (i.e., value of time). Therefore, the value of time is estimated to be IDR16,542 per hour for the driver. This indicates that the respondent agrees to pay IDR16,542 more to save an additional hour on their trip.

4.4 Value of Comfort

Correspondingly, the ratio of the coefficients of driver comfort (numerator) and the toll fare variable (denominator) reflects the marginal rate of substitution of toll fare for comfort (i.e., value of comfort). We estimate the value of comfort to be IDR18,741 per unit of driver comfort.

Now, the comfort variable is a perceptive variable, i.e., dependent on how the respondent describes it. The survey attempted to elicit a definition of comfort by asking respondents to rank and determine the importance (using a rating/scale) of seven factors that can potentially describe comfort, including clear lighting on the toll road; availability of rest areas; availability of gas stations; safety rails on the toll road; patrol cars roaming at the night; clean toilets in rest areas or gas stations; and smooth driving surface on the toll road. This exercise also allows the respondent to understand and think about the objective elements that determine driver comfort, extracting them from a merely subjective perception.

The results of the ranking exercise indicate that factors affecting the road safety experience on the toll road (i.e., smooth surface, clear lighting, safety rails, availability of patrol cars at night) are most important for the car drivers. The availability of facilities such as gas stations, rest areas and clean toilets are less important to the respondents. A similar observation can be made when the rating/scale is used as seen in Table 4. The results imply that under a situation of financial constraints, the design of the toll road can prioritize the most important factors related to smooth driving surface, clear lighting and safety rails, instead of rest areas and their associated facilities.

The nominal values for each of the comfort factors can also be calculated using the results of the ranking exercise. A simple ranking proportion is generated for each comfort factor by assigning a value of 7 for the most important factor, a value of 6 for the second most important, and so on, and then normalizing these values by the sum of the values ranging from 1 to 7 (i.e., 28). Multiplying this ranking proportion with the value of comfort of IDR18,741 shows the resulting values for each comfort factor (Table 4). For example, smooth driving surface has a comfort value of IDR4,685, indicating that the respondent agrees to pay this much to obtain a smooth driving surface on their trip.

Table 4. Comfort Factors

Comfort factor	Ranking	Scale value	Value of comfort
Smooth driving surface	1 (most important)	4.5358	4,685.3
Clear lighting	2	4.4244	4,015.9
Safety rails	3	4.2414	3,346.6
Patrol cars	4	3.3979	2,677.3
Gas station availability	5	3.3926	2,008.0
Rest area availability	6	3.2997	1,338.6
Clean toilets	7 (least important)	2.8806	669.3

Note: The scale value assigned a value of 5 for the most important and 1 for the least important factor.
Source: Authors' own calculation.

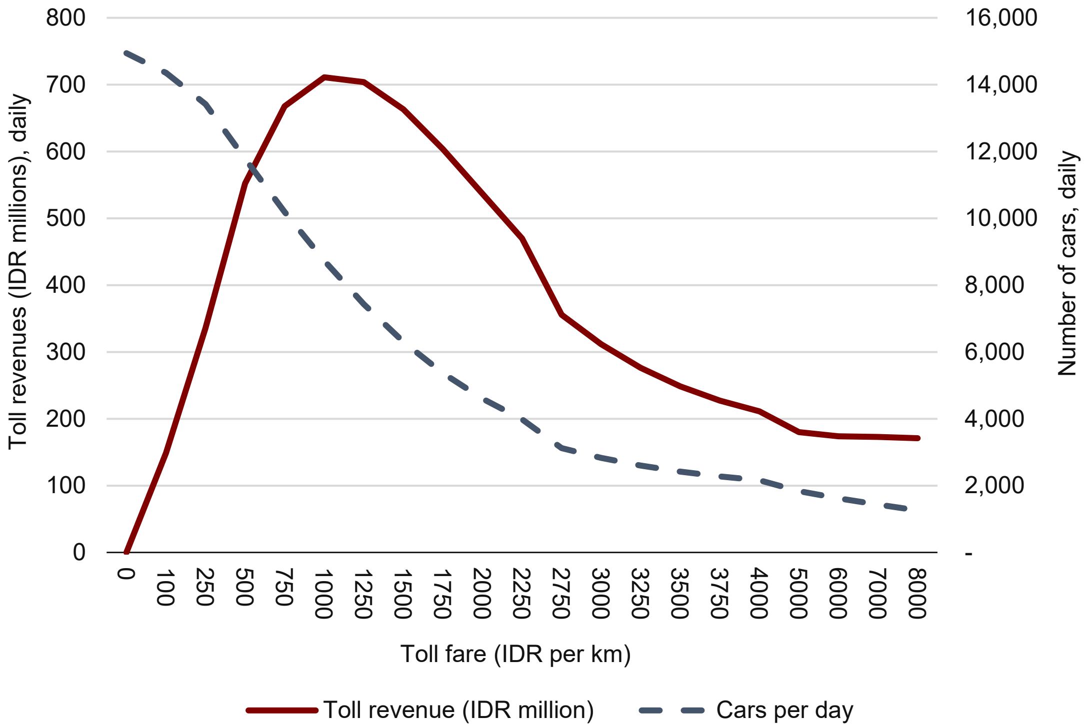
4.5 Optimal Toll

The resulting toll fare to revenue curve shows that the optimal toll for individual cars is IDR1,000/km on the Jambi-to-Rengat segment. With about 8,700 cars per day, the toll revenue is expected to total over IDR700 million per day. Charging a higher toll fare would imply lower traffic volumes and therefore suboptimal toll revenues. For the sake of presentation, charging an exceptionally high toll fare of IDR8,000/km would result in a meagre use of the toll road by car drivers, which would imply that the supposed economic benefits of the toll road (e.g., travel time savings on the toll road compared to the national road) would not benefit most car drivers.

Conversely, charging a lower toll fare would result to a larger market share but at the expense of suboptimal and lower aggregate revenues. In fact, not charging any toll would maximize the cars on the road, and consequently the economic benefits to the community, but affect the financial sustainability of the investment.

Note that the optimal toll calculation accommodates the factors that can affect the probability of choosing the toll road, namely travel time, toll fare and driver comfort. The constant, which is significant and captures other explanatory variables not included in the logit model (e.g., income), is also accounted for.

Figure 1. Toll Fare to Revenue Curve and Transport Demand on the Jambi-to-Rengat Segment of the Trans-Sumatra Toll Road, 2030



IDR = Indonesian Rupiah.
Source: Authors' own calculation.

4.6 Study Limitations

In this paper, we focus on the transport demand of passenger car drivers while ignoring those of commercial vehicles such as trucks, and buses and minivans. Given that there is no route choice model estimation for these vehicle categories, optimal tolls for this vehicle type are not calculated. This is an area of future research.

Moreover, the binomial logit model has a strong assumption that the unobserved behavior of the respondents is independently and identically distributed, so as to facilitate model estimation from binary choice data (i.e., toll road vis-à-vis national road alternatives). This assumption implies that the probabilities between the toll road and national road alternatives do not depend on other variables. For example, the trip generation itself, the origin or destination, or the time of day are independent of the route choice. Given the research purpose, the binomial logit model and its independently and identically distributed assumption are valid. However, a different model and further research methods beyond binomial logit may be necessary to overcome this constraint.[6]

[6] For example, a nested logit model allows for substitution between alternatives, and that respondent choice is allowed to change when another alternative is added to the choice set.

5. Conclusion

In this paper, we analyzed transport behavior by applying the stated preference methodology and resulting route choice model based on a discrete choice estimation for the Jambi-to-Rengat segment of the Trans-Sumatra Toll Road in Indonesia. To the best of our knowledge, this is the first time this methodology is being applied for a toll road investment in the country. We estimated the potential market share of the toll road segment, calculated the elasticities of transport demand in relation to toll fare, travel time and driver comfort, determined the value of transport time and driver comfort, and identified the optimal toll fare that will maximize potential revenues on this toll road segment. The value of time is estimated to be IDR16,542/hour, whereas the value of comfort is estimated to be IDR18,741/unit of driver comfort. The optimal toll for individual cars is IDR1,000/km on the Jambi-to-Rengat segment.

We believe that the analytical framework and methodology presented in this paper provides a firm foundation and is applicable for any infrastructure investment with a competing alternative during project preparation stage. Its application and corresponding estimation results can further provide practical advice to infrastructure officials, both policymakers and implementing agencies, of the incentives needed to maximize economic and financial benefits of a potential investment. For example, it is possible to calculate the optimal toll fare of a potential investment, and this can guide toll road officials in developing toll road regulations. It is also possible to analyze various factors that can define driver comfort, including their relative importance, and such information can help highway officials in prioritizing which comfort elements to invest in, especially if faced with financial constraints.

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Annex

Annex 1. Example of a Choice Task as Presented to the Respondents