Analysis of Highway Rates Based on Ability to Pay (ATP) and Willingness to Pay (WTP) (Case Study: Plan for Semarang Harbour Highway)

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Abstract. Government plans to build Semarang Harbor Toll road that connects Kaliwungu, West Semarang-Ahmad Yani Airport, North Semarang, Tanjung Emas Port, and Kaligawe to unravel congestion on existing roads where current conditions are not yet available integrated public transportation, this is indicated by high volume of traffic 3,949 pc/hour with a VCR value of 1.25. This study aims to analyze travel time on toll roads, the toll tariffs of Harbor Tolls based on analysis of Ability to Pay (ATP) and Willingness to Pay (WTP) and potential for traffic flow that moves from existing roads to toll roads using binomial logit method. Analysis results obtained Semarang Harbor Toll road rates for group I of Rp. 1,040/km, group II, tariff is Rp. 1,200/km and tariff of Rp. 1,300/km. There is a difference between ATP, WTP analysis and binomial logit analysis based on BOK for class I where toll road mode selection is Rp. 947/km, existing road Rp. 1,583/km. Then for Group II, the selection of toll road mode is Rp. 1,121/Km, the existing road Rp. 1,611/Km and class III obtained the selection of the mode of toll roads 1,206/Km, the existing road Rp. 1,876/km.

Keywords: toll tariffs, ability to pay, willingness to pay, binomial logit method

1. Introduction
The main road that connecting Kendal Regency to Semarang City and Demak Regency is Pantura Road so the vehicle's volume that passes on Siliwangi Road is 8,837 pcu/hour with DS 0.99, it can be concluded that the current Pantura Road condition already congested. Semarang Harbor Toll Road's plan that connected to Urban Toll Road is expected that public road users can switch to using Semarang Harbor Toll Road, but it's possible that in the near future there will be less demand, but Semarang City people lifestyle who choose housing in the suburbs and vehicle ownership preferences cannot create efficient transportation mobilization both in terms of cost, density consequences or vehicle ownership as orientation [1]. Toll roads which are part of the public road network system provided by the government that serve as an alternative to existing roads and toll roads are calculated based on ability to pay, willingness to pay, travel time difference, and investment eligibility later for the amount of tariff to be evaluated every 2 (two) once a year [2].

The government has estimated toll rates based on [3], an ability to pay (ATP) and willingness to pay (WTP) study was conducted to calculate toll rates. As a basis for determining general toll rates are oriented to ability to pay (ATP) and willingness to pay (WTP) to the community as potential toll road users, so in this study determining toll rates is used to compare the ATP and WTP approaches. Besides that, it must also know how much potential the movement of traffic flow from the existing road to the
toll road and how much traffic will continue to use the existing road. In addition, the existence of this research is expected to be a basis for consideration for the government or investors that are financially feasible to carry out.

2. Literature Review

2.1. Volume Capacity Ratio
According to [4] the amount of capacity of urban and out of city roads can be calculated as follows:

\[ C = C_0 \times FC_{LJ} \times FC_{PA} \times FC_{HS} \times FC_{UK} \]  

(1)

Where the C function is capacity (cur/hr), \( C_0 \) is base capacity (cur/hr), \( FC_{LJ} \) is Capacity adjustment factors related to lane width or traffic lane, \( FC_{PA} \) is Capacity adjustment factors related to directional separator only on undivided roads, \( FC_{HS} \) is capacity adjustment factors related to unity price agreement on shouldered or rolling roads, \( FC_{UK} \) is Capacity adjustment factors related to city size.

2.2. Ability To Pay and Willingness To Pay
In determining toll road rates in Indonesia, the calculation used is based on Vehicle Operating Costs (BOK), investment feasibility, ability to pay and willingness to pay toll road users. Based on research using the regression equation model to find out the willingness to pay, WTP rates are obtained based on perceptions of the range of rates offered for each time saving variation ranging from 15 minutes to 60 minutes, then look for the average value of the overall time savings available so that the WTP value obtained Road Medan-Binjai Toll Road per km is Rp. 606.92. While the amount of ATP value is obtained based on the calculation of the allocation of 5%, 10%, 15%, 20%, 25% derived from transportation costs and based on the level of intensity (frequency) traveling from Medan to Binjai, based on the calculation results, the amount of ATP is obtained namely Rp. 753.52 / Km [5].

Analysis result [6] showed that the ideal rate per km based on the perception of Surabaya-Kertosono toll road users is Rp 700.00 / Km (Class I), Rp 1,050.00 / Km (Class II), Rp 1,400.00 / Km (Class III). From analysis results, the value of ATP tends to be higher than the value of the WTP which can indicate the ability of respondents to pay for toll road facilities is greater than the willingness to pay because respondents prospective toll road users have relatively high income but the utility for services is relatively low. Research between [5] and [6] shows that in terms of ATP and WTP every city in Indonesia has different characteristics, there are several factors that influence people's desire to use toll roads (1) direct benefits to respondents (2) relative costs over time (3) public awareness (4) political and environmental liberalism [7].

2.3. Route Selection
Two network models which simultaneously estimate the value of travel time and of travel time reliability based on the risk-averse driver's route choice behavior. The first model is formulated as a utility maximization problem under monotonic and separable link travel times, whereas the second model is formulated as a utility maximization problem under non-monotonic and non-separable link travel times. The proposed models have the same structure as a user equilibrium (UE) traffic assignment problem with elastic demand. It is shown that the first model, which addresses independent stochastic capacity, is formulated as an optimization problem with a unique solution and is solved by using an algorithm for a UE traffic assignment problem with fixed demand. The second model, which addresses both stochastic Origin–Destination (O–D) flow and stochastic link capacity, is formulated as a nonlinear complementary problem. O–D demand functions formulated in the proposed models are derived from the utility maximization behavior of the driver in the network. Therefore, the network models proposed in this study are consistent with those of studies that address the value of travel time and of travel time reliability based on utility maximization behavior without considering the driver’s route choice [8].
3. Method
Flow chart data analysis used as a reference in conducting the research. A good conceptual framework that can explain what the outline of the series will be examined. More details can be seen in Figure 1.

Figure 1. Diagram Alir Penelitian.

3.1. Research Method
In implementation of an ideal toll tariff research, it is necessary to have the stages that must be carried out as in the picture above. The first step in this research is to find out what problems will be examined, then conduct a literature study to support the research, then determine the objectives of the research so that the implementation does not stray too far, then conduct an LHR survey to determine peak hour movement, then compile a questionnaire.

Questionnaire planning refers to the study of literature, variables and the formulation of the problem in the preparation stages of how the respondent's pattern of saving rates and the time the respondent chooses based on conditions that will occur on the route being reviewed. Then you will get a planned hypothesis (the driver will tend to choose the toll road with the toll rate if using the toll road will make
the travel time to be faster and more convenient). With this hypothesis, some characteristics of the questionnaire were examined in the study. The collection of primary data is by interviewing prospective toll road user respondents randomly from the population of existing road users to be reviewed.

### 3.2. Sample Size Determination

In carrying out this research, The Isac Michel approach is a formula used to calculate the minimum sample size if the behavior of a population is not known with certainty. Isac Michel is commonly used in survey research where usually the sample size is quite large, so we need a formula to get a small sample but can represent the entire population.

**Description:**

- \(n\) = sample
- \(p\) = proportion of people
- \(q\) = 1 - \(p\)
- \(Z\) = level of confidence / significance
- \(e\) = margin error

From the above equation, \(n\) is the minimum number of samples, value of \(p\) (proportion of people) using toll roads is 0.5 with a significant level of 90% and a margin of error of 10%.

\[
n = \frac{(1.64)^2 \times 0.5 \times 0.5}{(0.1)^2}
\]

\[
n = 67.24
\]

\[
= 67 \text{ respondents}
\]

So that the number of samples that must be taken for Class I vehicles is 67 respondents and Class II and Class III each are 67 respondents. But to anticipate existence of defective data, number of respondents increased each group to 70 respondents.

### 4. Data Presentation

Respondents characteristics analysis in Group I, Group II and Group III consisting information of the age of the respondent, gender, frequency of travel, type of vehicle that is often used, class of vehicle, road that is often used, travel time, travel and destination of the trip.

**Table 1. Respondents Characteristics Analysis**

| No  | Characteristics          | Explanation                                                                 |
|-----|--------------------------|-----------------------------------------------------------------------------|
| 1   | Respondent Age           | 17-25 years 0 %, 26-30 years 7 %, 31-35 years 18 %, 36-40 years 24 %, 41-45 years 24 %, 46-50 years 16 % and above >50 tahun 10 % percent. |
| 2   | Gender                   | Group II and 3 100% Male, Group I Male 74% and Female 26%.                   |
| 3   | Travel Characteristic    | Work / business 93% and non-business 7%                                     |
| 4   | Travel Frequency         | Trip 1x 15%, Trip 2x 23% Trip 3x 27%, Trip 4x 15%, Trip 5x 12% and Trip 6x 8%. |
| 4   | Travel Time              | 45-60 minutes 17%, 60-90 minutes 11%, 90-120 minutes 8%, 120-180 minutes 15%, 180-240 minutes 15% and more than 240 minutes 33%. |
| 6   | Amount of Work Per Week  | 4 days 8 %, 5 days 35 %, 6 days 56 % and 7 days 1 %.                         |
| 7   | Average Hours of Work Per Day | 7 hours 2 %, 8 hours 25 %, 10 hours 26 %, 11 hours 17 %, 12 hours 29 %, and more than 12 hours 1 %. |
| 8   | Type of work             | Entrepreneur 39%, teacher/lecturer 9%, student 4%, retired PNS/TNI/Polri 4%, housewife 4%, private employee/BUMN employee 26% and government employee/TNI/Polri 14 %. |

Source: analysis results 2019
5. Analysis and Discussion
Analysis using the state preference survey method, which includes ability to pay (ATP), willingness to pay (WTP) and route selection of respondents of potential toll road users (Figure 2).

5.1. Travel Time Analysis
The travel time needed by a private car to go through the Semarang Harbor Toll Road is 14 minutes and for trucks 22 minutes. Then when compared to the existing road there is a difference in travel time for 45 minutes for private cars and for 67 minutes for trucks (Figure 2, Table 2, tabel 3).

![Figure 2. Toll road plan Semarang Harbour. Source: PT. Sumber Mitra Jaya](image)

### Table 2. Speed analysis of existing road kaliwungu-kaligawe.

| No | Vehicle Type | Distance (km) | Average Speed (km/hr) | Travel Time |
|----|--------------|---------------|-----------------------|-------------|
| 1  | Private car  | 24.6          | 45.2                  | 60 minutes  |
| 2  | Truck        | 24.6          | 30.5                  | 90 minutes  |

Source: Analysis Result 2019

### Table 3. Speed analysis of toll road Semarang Harbour.

| No | Vehicle Type | Distance (km) | Speed (km/hr) | Travel Time |
|----|--------------|---------------|---------------|-------------|
| 1  | Private Car  | 22            | 90            | 14          |
| 2  | Truck        | 22            | 60            | 22          |

Source: Analysis Result 2019

5.2. Analysis of Volume, Capacity, Ratio (VCR)
The results of VCR analysis and field observations shows that 3 (three) existing roads, namely Walisongo, Yos Sudarso and Arteri Utara roads have shown congestion during peak hours. (Table 4).

![Map showing Jalan Tol Semarang Harbour, Jalan Tol, and Jalan Nasional with distances: 7.5 km, 4.5 km, 9 km](image)

### Table 4. Volume, capacity, ratio (VCR) analysis during peak hours.

| No | Roads             | Traffic Volume (pce/hour) | Capacity | D1 | LOS |
|----|-------------------|---------------------------|----------|----|-----|
| 1  | Jl. Walisongo T-B | 1.693                     | 3.168    | 0.53 | C   |
|    | Jl. Walisongo B-T | 3.949                     | 3.168    | 1.25 | F   |
| 2  | Jl. Yos Sudarso U-S | 2.064                     | 3.295    | 0.63 | C   |
|    | Jl. Yos Sudarso S-U | 2.232                     | 3.295    | 0.68 | C   |
| 3  | Jl. Arteri Utara T-B | 1.821                    | 3.295    | 0.55 | C   |
|    | Jl. Arteri Utara B-T | 1.428                    | 3.295    | 0.43 | B   |

Source: Analysis Results 2019
5.3. Route Selection
In the transportation system the balance condition can occur at several levels, the simplest level is the balance of the road network system, when every trip always try to find the best route, that can minimize the cost and travel time.

5.4. Route Selection Analysis of Vehicle Type I
Binomial logit analysis is based on assumptions that are free and evenly distributed according to the distribution function. While the function of the utility is using CJT as a toll road VOC and CJE as an existing road VOC with the following equation:

\[ C_{JT} = \frac{e^{(C_{jt} - C)}}{1 + e^{(C_{jt} - C_{je})}} \]  
(3)

\[ C_{JE} = 1 - C_{JT} \]  
(4)

\( C_{JT} \) = toll road user probability
\( C_{JE} \) = existing road user probability

Table 5. Logit binomial differences for vehicle type I.

| CJT | CJE | CJE-CJT |
|-----|-----|---------|
| 747 | 1.583 | 635     |

Source: Analysis Results 2019

Table 6. Logit binomial differences for vehicle type II.

| CJT | CJE | CJE-CJT |
|-----|-----|---------|
| 1121 | 1611 | 489     |

Source: Analysis Results 2019

Table 7. Logit binomial differences for vehicle type III.

| CJT | CJE | CJE-CJT |
|-----|-----|---------|
| 1206 | 1876 | 669     |

Source: Analysis Results 2019

The route selection or the transfer from existing roads to toll road is using logit binomial, the time value here is the time value converted in rupiah based on VOC [9], the time value of each type of vehicle is different. So the binomial logit anlaysis results can be seen in the following tables:

Table 8. Cost analysis toll road Semarang Harbour of vehicle type I.

| CJT | In   | Out | Distance (km) | Cost per km |
|-----|------|-----|---------------|-------------|
| 948 | Kaliwungu | Krapyak | 12          | Rp 11,373   |
| 948 | Kaliwungu | Bandara | 12          | Rp 11,373   |
| 948 | Kaliwungu | Kaligawe | 22          | Rp 20,850   |
| 948 | Kaligawe  | Bandara | 9           | Rp 8,530    |
| 948 | Kaligawe  | Krapyak  | 18          | Rp 17,059   |

Source: Analysis Results 2019
Table 9. Cost analysis toll road Semarang Harbour of vehicle type II.

| CJT   | In       | Out   | Distance (km) | Cost per km |
|-------|----------|-------|---------------|-------------|
| 1121  | Kaliwungu| Krapyak| 12            | Rp 13,455   |
| 1121  | Kaliwungu| Bandara| 12            | Rp 13,455   |
| 1121  | Kaliwungu| Kaligawe| 22           | Rp 24,667   |
| 1121  | Kaligawe | Bandara| 9             | Rp 10,091   |
| 1121  | Kaligawe | Krapyak| 18            | Rp 20,182   |

Source: Analysis Results 2019

Table 10. Cost analysis toll road Semarang Harbour of vehicle type III.

| CJT   | In       | Out   | Distance (km) | Cost per km |
|-------|----------|-------|---------------|-------------|
| 1206  | Kaliwungu| Krapyak| 12            | Rp 14,474   |
| 1206  | Kaliwungu| Bandara| 12            | Rp 14,474   |
| 1206  | Kaliwungu| Kaligawe| 22           | Rp 26,536   |
| 1206  | Kaligawe | Bandara| 9             | Rp 10,856   |
| 1206  | Kaligawe | Krapyak| 18            | Rp 21,712   |

Source: Analysis Results 2019

The probability of the route selection between toll road mode and existing road for Vehicle Type I using the equation $Y = a + b X + c X$, the independent variable is the differences in VOC ($X = CJT-CJE$) which CJT is the VOC of toll road and CJE is the VOC of the existing road and the dependent variable uses linear regression parameters where the $a$, $b$, and $c$ is the results of regression analysis.

$Y = a + b(CJE-CJT) + c(CJE-CJT)$

$Y = 0.546 - 0.0002809549 (948) + 0.0001771184 (948)$

$Y = 0.7062$

$Y = 70.62\%$

The probability of choosing toll road is 0.7062 and the probability of choosing the existing road is $1 - 0.7062 = 0.2938$. Hence, the percentage of each probability is:

- The probability of using toll road = 70.62\%
- The probability of using existing road = 29.38\%

The probability of choosing between the toll road and existing road for Vehicle Type II:

$Y = a + b(CJE-CJT) + c(CJE-CJT)$

$Y = 0.780 + 0.001346168 (1210) + 0.0022533 (1210)$

$Y = 0.6854$

$Y = 68.54\%$

The probability of choosing transportation modes using the toll road is 0.6854 and the probability of choosing the existing road mode is $1-0.6854 = 0.3146$. The percentage of choosing the transportation modes on toll road and existing roads:

- Probability of choosing Toll Roads as transportation mode = 68.54\%
- Probability of choosing Existing Roads as transportation mode = 31.46\%

The probability of choosing a toll road as a transportation modes with existing Vehicle Type III roads is as follows:

$Y = a + b(CJE-CJT) + c(CJE-CJT)$

$Y = 0.780 - 0.00000010036 (1619) + 0.0000001289 (1619)$

$Y = 0.5430$

$Y = 54.30\%$
The probability of choosing transportation modes using the toll road is 0.5430 and the probability of choosing the existing road mode is 1-0.5430 = 0.4570. The percentage of choosing the transportation modes on toll road and existing roads:

Probability of choosing Toll Roads as transportation mode = 54.30 %
Probability of choosing Existing Roads as transportation mode = 45.70 %

5.5. ATP and WTP Analysis of Vehicle Type I

The results of the analysis using ATP and WTP equilibrium charts (Figure 3) indicate that the average respondent ability to pay is Rp. 1,497.00, while willingness to pay only Rp. 1,194.00. Based on Rate analysis by connecting ATP and WTP, the balance of ATP and WTP is obtained with a Vehicle Type I Toll Rate of Rp. 1,040.00 / km, with the percentage of potential users of the Semarang Toll Road 70%.

![Figure 3](source: analysis results 2019)

5.6. ATP and WTP Analysis of Vehicle Type II

The results of the analysis using ATP and WTP equilibrium charts (Figure 4) indicate that the average respondent ability to pay is Rp. 1,620.00, while willingness to pay only Rp. 1,293.00. Based on Rate analysis by connecting ATP and WTP, the balance of ATP and WTP is obtained with a Vehicle Type II Toll Rate of Rp. 1,200.00/km, with the percentage of potential users of the Semarang Toll Road 60%.

![Figure 4](source: analysis results 2019)
5.7. ATP and WTP Analysis of Vehicle Type III
The results of the analysis using ATP and WTP equilibrium charts (Figure 5) indicate that the average respondent ability to pay is Rp. 2,335.00, while willingness to pay only 1,576.00. Based on Rate analysis by connecting ATP and WTP, the balance of ATP and WTP is obtained with a Vehicle Type III Toll Rate of Rp. 1,300.00/km, with the percentage of potential users of the Semarang Toll Road 85%.

![Figure 5. Graphic of connection between ATP and WTP for Type III.](image)

Source: analysis results 2019

6. Conclusion
The following conclusions are based on the research discussion:

1. The travel time difference based on the planned speed of passenger vehicles on the Semarang Harbour Toll Road is 90 km/h and trucks 60 km/h. When compared to the existing road, there is 35 minutes travel time difference for passenger car and 53 minutes for trucks.

2. Based on ability to pay (ATP) analysis and Willingness to Pay (WTP) analysis, suitable rate for Vehicles Type I is Rp. 1,040,- per kilometer, it is Rp. 40,- more higher than the government regulation rate, so it is possible for Vehicles Type I to move from existing roads to toll road. Suitable rate for Vehicles Type II is Rp. 1,200 per kilometer and suitable rate for Vehicles Type II is of Rp. 1,300 per kilometer are lower than the government regulation rate, it is possible that small portion of Vehicles Type II and Vehicles Type III to move from existing roads to toll road .

3. The binomial logit analysis results based on BOK for Vehicles Type I where the selection of toll road as transportation modes is Rp. 1,940/km with a probability of 70.62%, existing road Rp. 3,554/km with a probability of 29.38%, then for Vehicles Type II the selection of toll road as transportation modes is Rp. 4,059/km with a probability of 68.54%, existing road Rp. 5,301/km with a probability of 31.46% and Vehicles Type III obtained the selection of 6,717/km toll road as transportation mode with a probability of 54.30%, the existing road 7.717/km with a probability of 45.70%.

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