Analysis of potential diverted of passenger car to the new toll road (case study: Cileunyi – Sumedang, West Java)

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Abstract. This study aims to determine of potential of passenger car divert from national road to on-construction Cisumdawu Toll Road. The study was conducted by traffic count survey and followed by a roadside interview survey. Stated Preference method was used in order to analyse trip forecasting value. Mode choice model of new trip mode plans (Cisumdawu Toll Road) and current intercity road for Cileunyi – Sumedang is \( (U_{JT} - U_{JR}) = 0.1079 - 0.507726x_1 - 0.8953764x_2 \), while Sumedang – Cileunyi is \( (U_{JT} - U_{JR}) = 0.0790 - 0.301341x_1 - 0.548446x_2 \). Multiple linear regression analysis was used to obtain the forecasting of private vehicle that diverts to the new toll road (Cisumdawu Toll Road). Trip characteristics such as trip origin and destination, types of trips, occupations, salary, and others become a motive for respondents to choose a new trip mode. Results of the new trip mode forecasting that prefer to divert to the toll road in terms of the value of cost and time for Cileunyi – Sumedang are 74.11% and 86.62% respectively, while for Sumedang – Cileunyi are 69.60% and 76.48% respectively. These results are relatively high compare to toll planning document. The impact of this results can be determined such as lower overall fuel consumption, lower pollution and more important is the maintenance cost of national road will be decrease.

Keywords: state preference, multiple linear regression, intercity road, toll road

1. Introduction
Toll road is one of the solutions to extend the road network. When the toll road fully functional, the traffic from the non-toll road will divert to this new toll road. Then, it will make a direct impact on the non-toll road which is the volume of traffic will decrease. When the traffic load on non-toll road decrease, the cost of non-toll road maintenance will also decrease and increase the non-toll road lifetime. This will save cost for road maintenance of the non-toll road and also saving energy for the vehicle to travel on new toll road. The on-construction Cisumdawu Toll Road will be expected to open next year, it is important to find out how many vehicles will choose and what are the characteristic of potential toll road user before the impact calculated.

However, to calculate and analyze the trip characteristics, a specific method was used. This study was using Stated Preference method to be obtained the time and cost saving. There were studies conducted regarding to define the characteristics using Stated Preference method. Surbakti and Bombongan [1] were defined the transportation modes choice between airport train and bus users from Medan to Kuala Namu Airport is influenced by cost, time, headway and service. On the other hand, Handayani et al [2] were identified time and cost savings of inner city toll road in Surabaya. Meanwhile,
Rahman [3] was using Stated Preference method to determined intercity public transport mode choice, focuses on vehicle types Kijang (minibus) and Sedan in Palu, Central Sulawesi. The purpose of this study is to analyze the trip characteristics in the intercity road, particularly at Cileunyi – Sumedang segment and vice versa. Then, determine the multiple linear regression of this road segment, and analyze the toll road user forecasting of a private vehicle in terms of the value of time and cost with Stated Preference method.

2. Research Method
There are several surveys that have been conducted in this study regarding the data collections. The first survey is traffic count. This kind of survey was conducted in order to obtain average daily traffic (ADT). ADT is considered in the determination of the sample amount used in the roadside interview survey. The roadside interview was conducted in order to obtain trip characteristics, such as trip origin, trip destination and type of the trip.

The survey was conducted at the intercity road from Cileunyi to Sumedang. Traffic count survey was conducted 10 hours per day (6.00 – 10.00, 11.00 – 15.00, and 16.00 – 20.00) in three days (Wednesday, Friday, and Saturday) with the assumption of Wednesday and Friday are considered as a weekdays and Saturday considered as a weekend. Meanwhile, a roadside interview survey was conducted in three days (Thursday, Monday, and Sunday) with the assumption of Thursday and Friday are considered as weekdays and Sunday considered as a weekend.

Stated Preference method was used in order to analyze the potential toll road user in study location. Stated preference method is a technique that use individual respondents’ statements about their preference in a set of transport options to estimate utility functions [1]. It will analyze the characteristic of potential toll road user that will be used new toll road (Cisumdawu Toll Road).

After collecting the data, the next step is mode choice modelling. This process is intended to determine the data validity. Then, conducting sensitivity test in order to the understanding value of mode choice probability of current mode and new mode plans.

3. Results and Discussion

3.1. Traffic Count Survey
Traffic count surveys were conducted on three days. The objective of this survey is to calculate the average daily traffic (ADT). ADT was used to determine the observation sample on roadside interview survey. The equation for determining ADT is described below:

\[
ADT = \frac{V_{ph}}{1.5} \times OH
\]

Where,
- ADT = Average Daily Traffic (veh);
- Vph = Peak Hours Volume (veh);
- 1.5 = Time divider when not in survey condition;
- OH = Operational hours (duration of the survey).

Results of traffic count would be divided into Cileunyi – Sumedang and Sumedang – Cileunyi.

3.1.1. Cileunyi – Sumedang. According to the survey, the total volume of peak hour period is 3916 vehicles. Then, calculate ADT using equation (1). Thus, ADT of Cileunyi – Sumedang with 12 hours’ survey duration is 31328 vehicles. In order to determine the sample number, Slovin’s method with 1 percent error margin was used. Furthermore, observation sample needed for the roadside interview survey is 99.68 and rounded to 100 people.
3.1.2. Sumedang – Cileunyi. According to the survey, the total volume of peak hour period is 3715 vehicles. Then, calculate ADT using equation (1). Thus, ADT of Sumedang – Cileunyi with 12 hours’ survey duration is 29720 vehicles. In order to determine the sample number, Slovin’s method with 1 percent error margin was used. Furthermore, observation sample needed for the roadside interview survey is 99.66 and rounded to 100 people.

3.2. Roadside Interview Survey
The roadside interview was conducted in order to analyze the trip characteristics. From previous calculations, the observation sample needed to conduct this survey is 100 participants, both from Cileunyi – Sumedang and Sumedang – Cileunyi. This interview considered several parameters, such as age, education background, occupations, salary, daily trip, trip origin and destination, weekly trip intensity, vehicle fuel cost, parking cost, and maintenance cost. These parameters would be considered in the analysis of toll road user forecasting, regarding the new toll road in that area (Cisumdawu Toll Road).

3.2.1. Occupations. Results of the interview will be shown based on the highest occupations percentage of respondents that tends to convert to new trip mode (Cisumdawu Toll Road).

![Figure 1. Highest Occupations Percentage of Respondents on Each Day of Survey](image)

According to trip characteristics based on occupation above, respondents who have a tight schedule prefer to convert to new trip mode (Cisumdawu Toll Road).

3.2.2. Salary. Results of the interview will be shown based on the highest salary percentage of respondents that tends to convert to new trip mode (Cisumdawu Toll Road).

![Figure 2. Highest Salary Percentage of Respondents on Each Day of Survey](image)

According to trip characteristics based on salary above, respondents who have a higher salary prefer to convert to another trip mode (Cisumdawu Toll Road).

3.2.3. Trip Origin and Destination. Results of the interview will be shown based on the trip origin and destination percentage of respondents that tends to convert to new trip mode (Cisumdawu Toll Road).

![Figure 3. Trip Origin and Destination Percentage of Respondents on Each Day of Survey](image)
According to trip characteristics based on origin and destination above, respondents whose have a long-distance travel prefer to convert to another trip mode (Cisumdawu Toll Road).

3.2.4. Types of Trip. Results of the interview will be shown based on the types of the trip percentage of respondents that tends to convert to new trip mode (Cisumdawu Toll Road).

![Figure 4. Types of Trip Percentage of Respondents on Each Day of Survey](image)

According to trip characteristics based on the type of trip above, respondents who spent more time on a trip due to congestion prefer to convert to new trip mode (Cisumdawu Toll Road).

3.2.5. Weekly Trip Intensity. Results of the interview will be shown based on the intensity of weekly trip percentage of respondents that tends to convert to new trip mode (Cisumdawu Toll Road).

![Figure 5. Weekly Trip Intensity Percentage of Respondents on Each Day of Survey](image)

According to trip characteristics based on weekly trip intensity above, respondents who have several trips in a week prefer to convert to another trip mode (Cisumdawu Toll Road).

3.3. Toll Road User Forecasting

Forecasting of toll road user would consider the value of time and cost of the current intercity road from Cileunyi to Sumedang and vice versa with new trip mode plans (Cisumdawu Toll Road). This forecasting using Stated Preference method. Stated Preference method is a technique that use individual respondents’ statements about their preference in a set of transport options to estimate utility functions [4].

3.3.1. Cileunyi – Sumedang.

| Time       | Cost | Jt/Jr   | X     | ln((1-p)/P) | X1y1 | X1^2   |
|------------|------|---------|-------|-------------|------|--------|
| 15 minutes | 20000| 27.857  | 1.445 | -1.510      | -2.181| 2.088  |
| 30 minutes | 20000| 15.260  | 1.184 | -1.158      | -1.370| 1.401  |
| 45 minutes | 20000| 3.133   | 0.496 | -0.443      | -0.220| 0.246  |
| 60 minutes | 20000| 0.053   | -1.275| 1.690       | -2.155| 1.625  |
| 15 minutes | 25000| 14.442  | 1.160 | -1.158      | -1.343| 1.345  |
| 30 minutes | 25000| 7.010   | 0.846 | -0.807      | -0.682| 0.715  |
| 45 minutes | 25000| 1.835   | 0.264 | -0.140      | -0.037| 0.069  |
| 60 minutes | 25000| 0.055   | -1.259| 1.690       | -2.128| 1.586  |
| 15 minutes | 30000| 3.201   | 0.505 | -0.378      | -0.191| 0.255  |
| 30 minutes | 30000| 2.648   | 0.423 | -0.269      | -0.114| 0.179  |
| 45 minutes | 30000| 0.743   | -0.129| 0.231       | -0.030| 0.017  |
| 60 minutes | 30000| 0.057   | -1.243| 1.690       | -2.101| 1.545  |
| 15 minutes | 40000| 2.091   | 0.320 | -0.185      | -0.059| 0.103  |
Value of Y and R² will be shown on the graphic below:

\[ y = -1.05x + 0.1079 \]
\[ R^2 = 0.9853 \]

**Figure 6. Mode Trip Relationship (Cileunyi – Sumedang)**

The coefficient of determination (R²) is showing the relationship among variables. According to the Figure 8, R² value is 0.9853. It means 98.53% of this mode utility is affected by all attributes, while the other 1.47% is not affected by another attribute which not considered in this mode.

### 3.3.2. Sumedang – Cileunyi

**Table 2. Respondents Choices (Sumedang – Cileunyi)**

| Time   | Cost | $J_0$ | W | X | $\ln((1-p)/P)$ | $Y_1$ | $X_1y_1$ | $X_1^2$ |
|--------|------|-------|---|---|----------------|-------|----------|---------|
| 15 minutes | 20000 | 29.385 | 1.468 | -1.380 | -2.026 | 2.155 |
| 30 minutes | 20000 | 15.360 | 1.186 | -1.195 | -1.418 | 1.408 |
| 45 minutes | 20000 | 2.686 | 0.429 | -0.389 | -0.167 | 0.184 |
| 60 minutes | 20000 | 0.119 | -0.924 | 1.032 | -0.953 | 0.853 |
| 15 minutes | 25000 | 18.825 | 1.275 | -1.235 | -1.574 | 1.625 |
| 30 minutes | 25000 | 5.395 | 0.732 | -0.673 | -0.493 | 0.536 |
| 45 minutes | 25000 | 1.726 | 0.237 | -0.167 | -0.040 | 0.056 |
| 60 minutes | 25000 | 0.214 | -0.670 | 0.865 | -0.580 | 0.449 |
| 15 minutes | 30000 | 13.268 | 1.123 | -1.158 | -1.300 | 1.261 |
| 30 minutes | 30000 | 4.576 | 0.661 | -0.644 | -0.425 | 0.436 |
| 45 minutes | 30000 | 1.387 | 0.142 | -0.052 | -0.007 | 0.020 |
| 60 minutes | 30000 | 0.052 | -1.285 | 1.510 | -1.940 | 1.652 |
| 15 minutes | 40000 | 6.702 | 0.826 | -0.807 | -0.666 | 0.683 |
| 30 minutes | 40000 | 3.025 | 0.481 | -0.399 | -0.192 | 0.231 |
| 45 minutes | 40000 | 0.807 | -0.093 | 0.203 | -0.019 | 0.009 |
| 60 minutes | 40000 | 0.051 | -1.293 | 1.817 | -2.350 | 1.672 |
| 15 minutes | 50000 | 1.560 | 0.193 | -0.185 | -0.036 | 0.037 |
| 30 minutes | 50000 | 0.683 | -0.165 | 0.213 | -0.035 | 0.027 |
| 45 minutes | 50000 | 0.281 | -0.552 | 0.602 | -0.332 | 0.304 |
| 60 minutes | 50000 | 0.005 | -2.322 | 2.299 | -5.338 | 5.393 |

\[ \Sigma \]
\[ 106.107 \]
\[ 1.449 \]
\[ 0.256 \]
\[ -19.893 \]
\[ 18.991 \]

Value of Y and R² will be shown on the graphic below:
Figure 7. Mode Trip Relationship (Sumedang – Cileunyi)

The coefficient of determination ($R^2$) is showing the relationship among variables. According to Figure 9, $R^2$ value is 0.99. It means 99.00% of this mode utility is affected by all attributes, while the other 1.00% is not affected by another attribute which not considered in this mode.

3.4. Multiple Linear Regression (Cost and Time)

In order to obtain utility equation in terms of the value of time and cost, multiple linear regression was applied. The equation is described below:

$$Y = a + bx_1 + bx_2$$  \hspace{1cm} (2)

Where,

$Y$ = Utility (New trip mode and current trip mode);

$a$ = Constants;

$b$ = Model parameter;

$x_1$ = Cost (Travel cost difference);

$x_2$ = Time (Travel time difference).

3.4.1. Cileunyi – Sumedang. Multiple linear regression for Cileunyi – Sumedang could be calculated from equation (2). Thus, the result is described below:

$$Y = 0.1079 + (-1.04998 \times 0.48355899)x_1 + (-1.04998 \times 0.8527572)x_2$$

Therefore, multiple linear regression equations for trip mode Cileunyi – Sumedang is described below:

$$(U_{JT} - U_{JR}) = 0.1079 - 0.507726x_1 - 0.895376x_2$$  \hspace{1cm} (3)

3.4.2. Sumedang – Cileunyi. Multiple linear regression for Sumedang – Cileunyi could be calculated from equation (2). Thus, the result is described below:

$$Y = 0.0790 + (-1.069 \times 0.281783)x_1 + (-1.069 \times 0.512855)x_2$$

Therefore, multiple linear regression equations for trip mode Cileunyi – Sumedang is described below:

$$(U_{JT} - U_{JR}) = 0.0790 - 0.30134k_1 - 0.548446k_2$$  \hspace{1cm} (4)

3.5. Results of New Trip Mode Forecasting Analysis (Cisumdawu Toll Road)

3.5.1. Cileunyi – Sumedang. Results of the respondents answer in terms of the value of time and cost for Cileunyi – Sumedang towards forecasting of conversion from current mode (intercity road) to new trip mode plans (Cisumdawu Toll Road) for private vehicle is showing in the graphic below:
According to the value of cost perspective on Figure 10, 74.11% respondents prefer to convert to new trip mode plans (Cisumdawu Toll Road), while 25.89% still prefer the current intercity road. Furthermore, the dominant total cost that respondents would like to spend is IDR 20.000. Meanwhile, the other options, IDR 40.000 and IDR 50.000 have fewer percentages.

Figure 11 is showing respondents answer for the value of time perspective. According to the figure above, 86.62% respondents prefer to convert to new trip mode plans (Cisumdawu Toll Road), while 13.38% still prefer the current intercity road. Furthermore, 15 minutes travel time have bigger percentages to convert to toll road mode. Meanwhile, 60 minutes travel time have a less percentage due to the time is equal to travel time through intercity road. The expected cost and time of respondents to choose toll road is IDR 20.000 and 15 minutes travel time from Cileunyi to Sumedang (about 30 km).

3.5.2. Sumedang – Cileunyi. Results of the respondents answer in terms of the value of time and cost for Cileunyi – Sumedang towards forecasting of conversion from current mode (intercity road) to new trip mode plans (Cisumdawu Toll Road) for private vehicle is showing in the graphic below:

According to the value of cost perspective on Figure 12, 69.60% respondents prefer to convert to new trip mode plans (Cisumdawu Toll Road), while 30.40% still prefer the current intercity road. Furthermore, the dominant total cost that respondents would like to spend is IDR 20.000. Meanwhile, the other options, IDR 40.000 and IDR 50.000 have fewer percentages.
Figure 13 is showing respondents answer for the value of time perspective. According to the figure above, 76.48% respondents prefer to convert to new trip mode plans (Cisumdawu Toll Road), while 23.52% still prefer the current intercity road. Furthermore, 15 minutes travel time have bigger percentages to convert to toll road mode. Meanwhile, longer travel time has a less percentage due to the time is equal to travel time through intercity road. The expected cost and time of respondents to choose toll road is IDR 20.000 and 15 minutes travel time from Sumedang to Cileunyi (about 30 km).

3.6. Sensitivity Test

Sensitivity test is a tool to the understanding value of mode choice probability of current mode and new mode plans. Rahman [2] described that sensitivity analysis of attribute from one of conversion was done with assuming the conversion is not affect other attributes or the feedback effect was not considered. According to Muhammad [5], correlation coefficient value was used in order to obtain sensitivity test value towards independent variable. The correlation coefficient is one of the statistical analysis that can be used to find a correlation between two variables.

3.6.1. Cileunyi – Sumedang

![Figure 12. Sensitivity Graphic of Cost Attribute between Toll Road and Current Intercity Road](image)

Figure 12. Sensitivity Graphic of Cost Attribute between Toll Road and Current Intercity Road

Figure 14 is showing positive curved line. Therefore, if there is a significant difference in cost attributes, respondents prefer to choose the current mode (intercity road). Meanwhile, if there is no/less difference in cost attributes, respondents would prefer new trip mode (Cisumdawu Toll Road).

![Figure 13. Sensitivity Graphic of Time Attribute between Toll Road and Current Intercity Road](image)

Figure 13. Sensitivity Graphic of Time Attribute between Toll Road and Current Intercity Road

Figure 15 is showing positive curved line. Therefore, if there is a significant difference in time attributes, respondents prefer to choose the current mode (intercity road). Meanwhile, if there is no/less difference in time attributes, respondents would prefer new trip mode (Cisumdawu Toll Road).
3.6.2. Sumedang – Cileunyi

![Cost Difference Graph](image)

**Figure 14.** Sensitivity Graphic of Cost Attribute between Toll Road and Current Intercity Road

Figure 16 is showing positive curved line. Therefore, if there is a significant difference in cost attributes, respondents prefer to choose the current mode (intercity road). Meanwhile, if there is no/less difference in cost attributes, respondents would prefer new trip mode (Cisumdawu Toll Road). The line on Sumedang – Cileunyi is less curved than Cileunyi – Sumedang due to the average cost difference from Sumedang – Cileunyi is lower. Thus, the line is nearly having a straight shape rather than curved.

![Time Difference Graph](image)

**Figure 15.** Sensitivity Graphic of Time Attribute between Toll Road and Current Intercity Road

Figure 17 is showing positive curved line. Therefore, if there is a significant difference in time attributes, respondents prefer to choose the current mode (intercity road). Meanwhile, if there is no/less difference in time attributes, respondents would prefer new trip mode (Cisumdawu Toll Road). The line on Sumedang – Cileunyi is less curved than Cileunyi – Sumedang due to fewer vehicles that travel from Sumedang – Cileunyi.

4. Conclusion

The potential toll road user between Cileunyi and Sumedang is more preferably to total time travelled rather than cost. For instance, on Cileunyi to Sumedang, more than 86% will divert to toll road if the travel time is less than 15 minutes and more than 60% will divert to toll road if the tariff is less than Rp. 20,000.\textcent; The result is relatively high compared to toll road planning documents (30% divert to toll road). Moreover, high diverted traffic to new toll road can reduce overall fuel consumption, pollution and lower maintenance cost of national road.

This time-preferred toll road trip result can be explained with Figure 6 that the highest percentage trip purpose on a weekday is work. Mode choice model of new trip mode plans (Cisumdawu Toll Road) and current intercity road for Cileunyi – Sumedang is $(U_{IT} - U_{JR}) = 0.1079 - 0.507726x_1 - 0.8953764x_2$, while Sumedang – Cileunyi is $(U_{IT} - U_{JR}) = 0.0790 - 0.301341x_1 - 0.548446x_2$.

5. References

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