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Research Article

The Impact of Road Pricing Policy on The Mode Shift in Jakarta

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ABSTRACT

This journal examines the level of service (LoS) on the Sisingamangaraja to Bundaran HI road segment, comparing conditions before and after the implementation of Electronic Road Pricing (ERP). Jakarta's traffic management policies, such as the 3-in-1 system and the odd-even vehicle restriction, are preliminary steps toward ERP, which is expected to be more effective. Prior to the Covid-19 pandemic, ERP was planned for Sisingamangaraja to Bundaran HI and subsequently for Fatmawati and Panglima Polim road segments, but it was delayed due to increased travel costs for commuters. This study collected data from a survey of 498 commuters over a one-month period, focusing on their likelihood to shift from private vehicles to public transport. The analysis identified cost and travel time as significant variables influencing this shift. Through iterative analysis, a Log-Likelihood value close to zero was achieved, indicating that the willingness to pay (WTP) for ERP is Rp. 41,500 for motorcycle users and Rp. 49,000 for car users. Additionally, ERP implementation was shown to reduce the LoS on the specified road segment, with an observed decrease of 0.64 on the Lebak Buluk-HI route in both directions.

Keywords: Mode Shifting, ERP, WTP, Public Transport, Congestio.

INTRODUCTION

Jakarta's congestion level is now ranked 29th out of 389 cities in the world, resulting in an increase when compared to last year [8]. Road conditions in big cities such as Jakarta need a breakthrough in an effort to traffic management and ERP (Electronic Road Pricing) is tools that considered to be effective solution in the long term. At first the traffic restriction with the 3 in 1 and odd-even scheme was a transitional policy towards a traffic restriction policy that was considered effective, namely ERP. The plan to implement a Road Pricing or ERP in Jakarta aims to solve the problem of increasing congestion [1]. With the Road Pricing, it is hoped that the use of private vehicles will decrease or maybe switch to another segment [2]. Initially, the implementation of the Road Pricing will be carried out in 2020 by starting on the Sisingamangaraja-HI Roundabout road and continuing with the Fatmawati-Panglima Polim road. However, due to the Covid-19 pandemic, the timeline for the implementation of Road Pricing has been postponed. In addition, due to the implementation of Road Pricing, it also has an impact on mode switching for travellers who object to increasing the burden of travel fares [3]. One of the modes of public transportation that has an impact is the MRT because it has the same corridor as the implementation of the Road Pricing at the HI-Sisingamangaraja Roundabout, where the MRT as a mode has various advantages, especially time efficiency which in about 15 minutes can travel from Lebak Bulus to the HI Roundabout or vice versa [4]. From some of the descriptions presented in the background, it can be identified that the problem in the form of congestion that occurs in Jakarta has a new solution in the form of a Road Pricing system but so far it has not been implemented. It is necessary to identify the behavior

of travellers in the choice of mode due to the implementation of Road Pricing in DKI Jakarta on the Sudirman Road Section based on the optimal tariff scenario.

LITERATURE REVIEW

Road Pricing

The implementation of road pricing policies significantly impacts public perception, shaping how people understand and value its benefits. The primary justification for road pricing lies in addressing congestion caused by the increasing number of individuals relying on private vehicles instead of public transportation. This policy has the potential to influence road users' choice of transportation modes [1]. However, public acceptance of road pricing in Jakarta, Indonesia's capital, remains uncertain. This research examines public acceptance through three models: socio-demographic differences (Model 1), perceptions of traffic management strategies (Model 2), and views on revenue allocation from road pricing (Model 3). By employing logistic regression (logit) to analyze the discrete nature of public acceptance as a binary variable, the study finds that Model 1 lacks statistical significance, Model 2 reveals significant perceptions of traffic management, and Model 3 highlights the importance of revenue allocation, particularly for public transportation improvements, road connectivity, and environmental preservation.

The concept of toll roads, widely adopted in several countries, requires careful consideration, particularly regarding tariff determination and the allocation of generated revenues. In European contexts, various factors must be accounted for to gain public approval for changes in transportation policy. Congestion charging schemes have been historically rare, with successful approval in referendums occurring only in Stockholm and Milan [2]. This paper explores voter behavior in road pricing reforms, identifying critical factors such as voter expectations, awareness of policy implications, familiarity with the debate, perceived fairness, environmental concerns, dependency on private vehicles, and the perceived value of trials. Resistance to congestion charging in places like Manchester and Edinburgh often stems from doubts about its effectiveness and insufficient information about congestion rates. Drawing insights from studies on successful congestion charging initiatives, this paper suggests a two-phase strategy to address challenges and ensure the successful implementation of congestion pricing as part of broader transportation reforms.

In Asian countries, community responses to road pricing policies vary significantly, influenced by specific factors affecting public acceptance. Road pricing is being introduced across several nations to mitigate traffic congestion. Research indicates that public attitudes towards road pricing before its implementation are crucial for its success [3]. Surveys conducted in Taichung (Taiwan) and Kyoto (Japan) employed a bivariate probit model to examine respondents' attitudes towards road pricing and their willingness to support it in hypothetical voting scenarios. Findings suggest a complementary relationship between public acceptance of road pricing and their attitudes prior to implementation. Further analysis using seemingly uncorrelated regression models indicates a strong correlation between individuals' willingness to reduce personal car use and their expectations of similar behavior from others following the introduction of road pricing. This evidence underscores the interconnected nature of public and individual responses in shaping the success of such policies.

Mode Shift

Modeling a mode shift, even between just two options like taxis and buses, is highly challenging. This complexity arises from numerous factors that are hard to measure, such as comfort, safety, reliability, and the availability of a vehicle when needed [4]. The factors influencing mode choice can be categorized into two main groups: movement characteristics and transportation mode facility characteristics. Movement characteristics include the purpose of travel, timing, and trip distance, all of which significantly affect mode shift decisions. On the other hand, transportation mode facility characteristics are divided into quantitative factors, such as travel time, cost, availability of space, and parking fees, and qualitative factors, which are harder to quantify, such as comfort, safety, reliability, regularity, and the features of a specific city or zone.

Discrete

The form of the mode shift model in European countries is dominated by the movement distribution model so that the mode shift model must be used after the movement distribution modeling stage has been carried out. This type of model has the advantage of considering the characteristics of road users because the movement has been aggregated in the form of an origin-destination matrix The first model developed considers only one or two

characteristics of the movement, usually the travel time. It can be seen that the S curve is felt to be the most suitable to better reflect the behavior of this movement. Figure shows the proportion of movements that will use the mode as a function of the difference in time or the difference in travel costs between one mode and another.

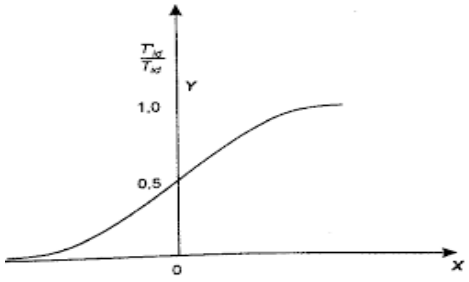


Fig. 1. Mode Shift Curve

Source: Tamin, O. Z. (2000)

The curve is an empirical curve obtained directly from the data and can be used to calculate the proportion of road users who will switch to another faster mode of transportation – called the diversion curve. One of the constraints of the model is that it is only used for the movement matrix which already has an alternative mode to be used. This model has a weak theoretical basis so that its forecasting ability is doubtful. This model also ignores several policy sensitivity variables such as tariffs and parking fees. Also, because it is aggregated, this model cannot be used to model precisely the limits and features of modes available to each individual or household.

Stated

The stated preference method is a technique used to gather respondents' reactions to various hypothetical scenarios. This approach allows researchers to fully control the factors within the proposed situation. Respondents are asked to indicate their preferences when faced with specific situations, reflecting how they would respond in real-life circumstances. Typically, experimental designs are used to create the alternatives presented to respondents. These designs are often orthogonal, meaning the attributes are combined independently, making it easier to isolate and analyze the impact of each attribute [5], [7].

The key feature of the stated preference survey technique is its reliance on respondents' opinions about their reactions to alternative hypothetical scenarios [6]. Each alternative is characterized by a set of attributes, such as travel time, cost, headway, and reliability. Researchers carefully construct these alternatives to estimate the individual influence of each attribute using experimental design techniques. To achieve this, questionnaires must present hypotheses that are comprehensible, logical, and easy for respondents to engage with. Respondents provide their feedback by ranking, rating, or selecting the best option from pairs or groups of statements. These responses are then analyzed to quantify the importance of each attribute.

The strength of the stated preference method lies in the flexibility it offers for designing experiments that explore a wide range of scenarios for research purposes. However, this flexibility must be balanced with the need to ensure that the scenarios are realistic enough to elicit meaningful and accurate responses from participants.

METHODOLOGY

This study was conducted to analyze the modeling of the application of Road Pricing in DKI Jakarta on the impact of the movement of travelers in the choice of modes. The research flow used for this research consists of several stages. At the initial stage, the authors identify problems by looking for problems that are closely or often heard, especially regarding congestion in the capital city of Jakarta, which will be implemented by a new policy, namely Road Pricing. Then, the authors look for journals and resource persons who can provide further information regarding the issues raised. And proceed with making the methodology of the research so that the stages carried out can run well.

The next stage, the authors collect primary data in the form of a survey of public preferences for the application of Road Pricing to determine tariff scenarios. Then, the input model processing is carried out in order to produce existing conditions regarding the road load, especially in the research corridor. Furthermore, the mode shift is obtained from the results of the community preference survey which is processed using binomial logit in order to obtain the sensitivity of the tariff used for a tariff scenario.

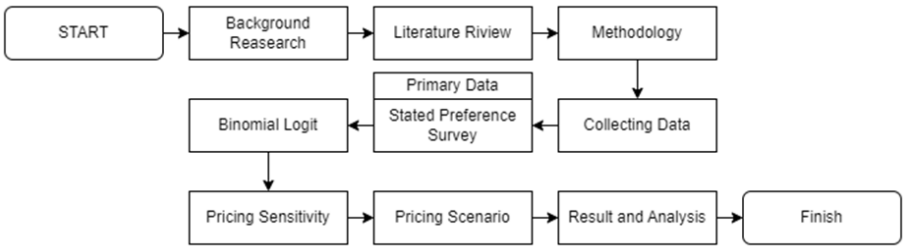


Fig. 2. Flowchart

Source: author's work (2024)

RESULT AND DISCUSSION

Survey

In the analysis of willingness to pay using primary data by collecting the results of respondents directly using human resources (surveyors). Surveyors are assigned to reach out directly via online to respondents who have the potential to meet the criteria. Some of the criteria referred to are residing in the Jabodetabek area, working/activating in the DKI Jakarta area, and traveling with the main mode of private vehicle car/motorcycle. The selection of human resources is carried out based on the location of residence to reach all regions that have targets for each region.

The sample used is based on Jabodetabek Commuter Statistics data with a total movement of 2,099,887 people traveling from Jabodetabek to Jakarta. Where, from the population, a sample calculation using the Slovin formula which has an error of 5% is obtained, a sample of 400 people is obtained. From the number of samples, the target per city or district is determined according to the percentage of people's movement based on the referenced data, and is distributed evenly for the motorcycle and car samples as follows.

Table 1: Distribution of Respondent Samples per City/Regency

City/Regency	Total Sample	Percentage of Commuters	Number of Samples	Motorcycle Samples	Car Samples
South Jakarta	400	7%	29	15	14
East Jakarta		12%	48	24	24
Central Jakarta		4%	18	9	9
West Jakarta		10%	42	21	21
North Jakarta		6%	24	12	12
Bogor Regency		7%	28	14	14
Bogor City		1%	3	2	1
Depok		14%	57	29	28
Tanggerang Regency		3%	13	7	6
Tanggerang City		8%	33	17	16
South Tangerang City		8%	30	15	15
Bekasi Regency		5%	22	11	11
Bekasi City		13%	53	27	26

Source: author's work (2024)

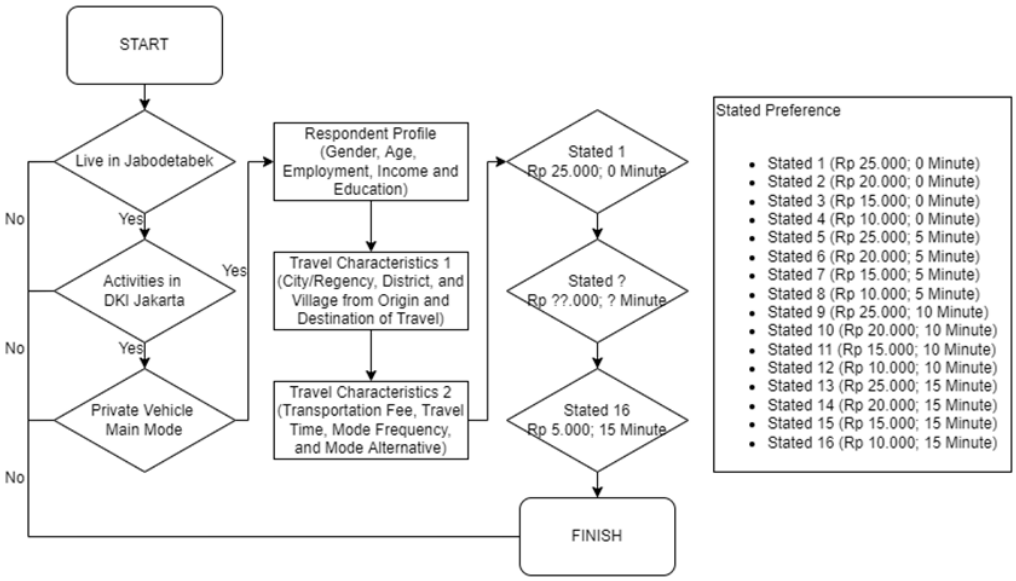


Fig. 3. Questionare Flow

Source: author's work (2024)

This survey aims to determine the tendency of commuters to switch from using private vehicles to public transportation modes for their main commuting trip, by proposing a scenario of increasing private vehicle travel costs in the scenario of implementing the Road Pricing policy. Design This survey is an online survey using the Stated Preference method according to the purpose of the research. The flow of the questionnaire can be seen in the image below. The questionnaire consists of 5 (five) sections, including:

- Opening Section: initial information on implementation;
- Part A: screening questions to validate respondent criteria;
- Part B: questions related to the respondent's profile;
- Part C: questions related to the characteristics of the trip;
- Part D: questions regarding people's preferences;

In its implementation to collect the required respondent data, surveyors distribute questionnaires personally or communally. For Personal, surveyors directly contact the target respondents by directing or helping to fill out the questionnaire and if there are questions, they can be asked directly to the accompanying surveyor. As for communal, a broadcast message is made containing the background, objectives, and criteria of the respondents with the hope that those who read and meet the criteria will fill out the questionnaire while still attaching a contact person if there is confusion in filling out and need assistance.

The data collection process that was carried out for a month obtained a total of 498 respondents who filled out the questionnaire. From these results, it is necessary to clean the data to separate respondents who do not meet the 3 criteria requirements with the results of 443 respondents who meet all the criteria described as follows.

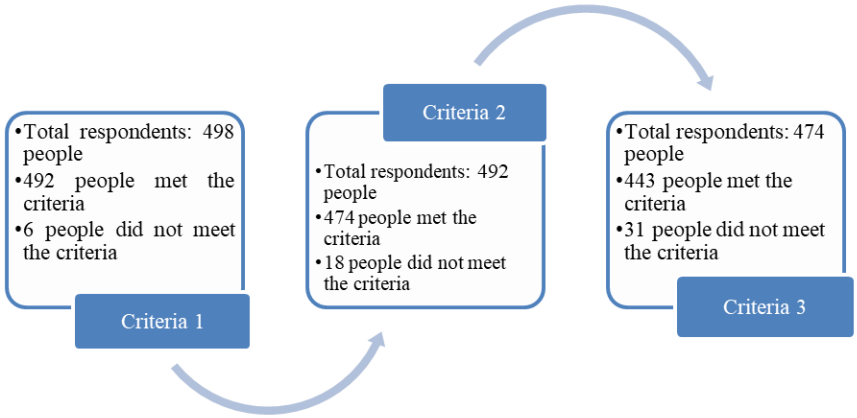
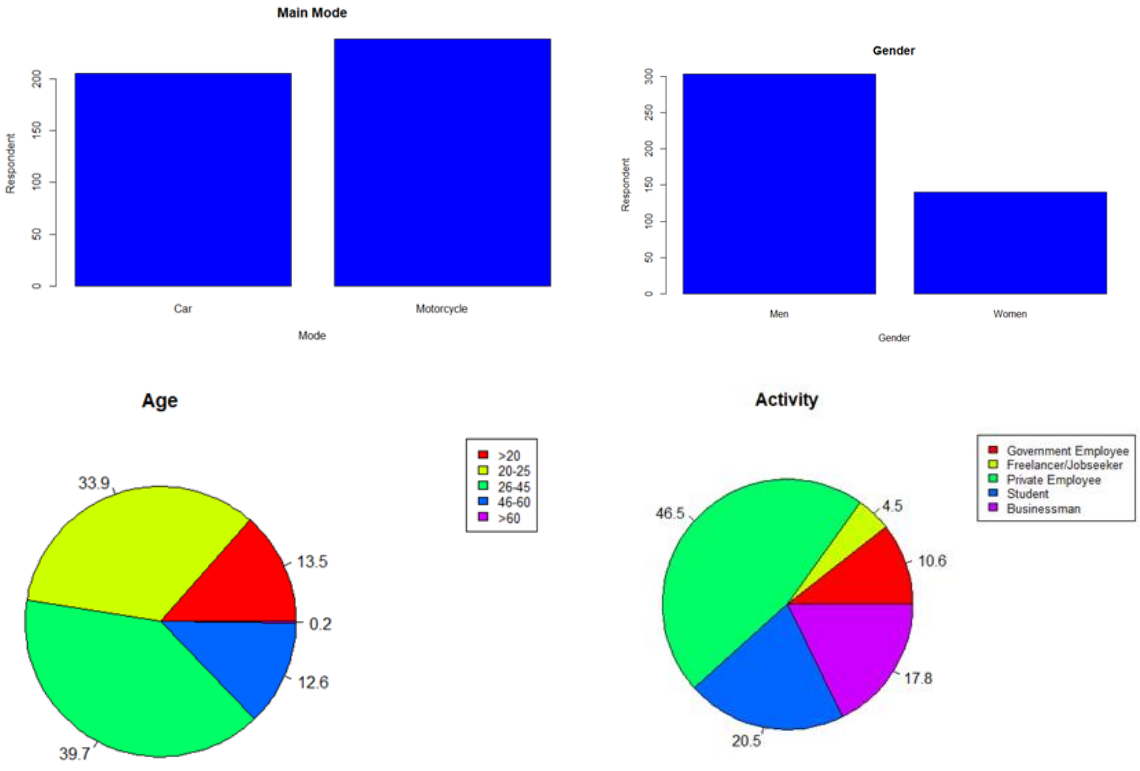


Fig. 4. Data Cleaning Process

Source: author's work (2024)

Data Inference

Respondents who are ready to be processed as many as 443 people have profiles, characteristics, as well as a matrix of origin of travel destinations which can be seen in the figure below.



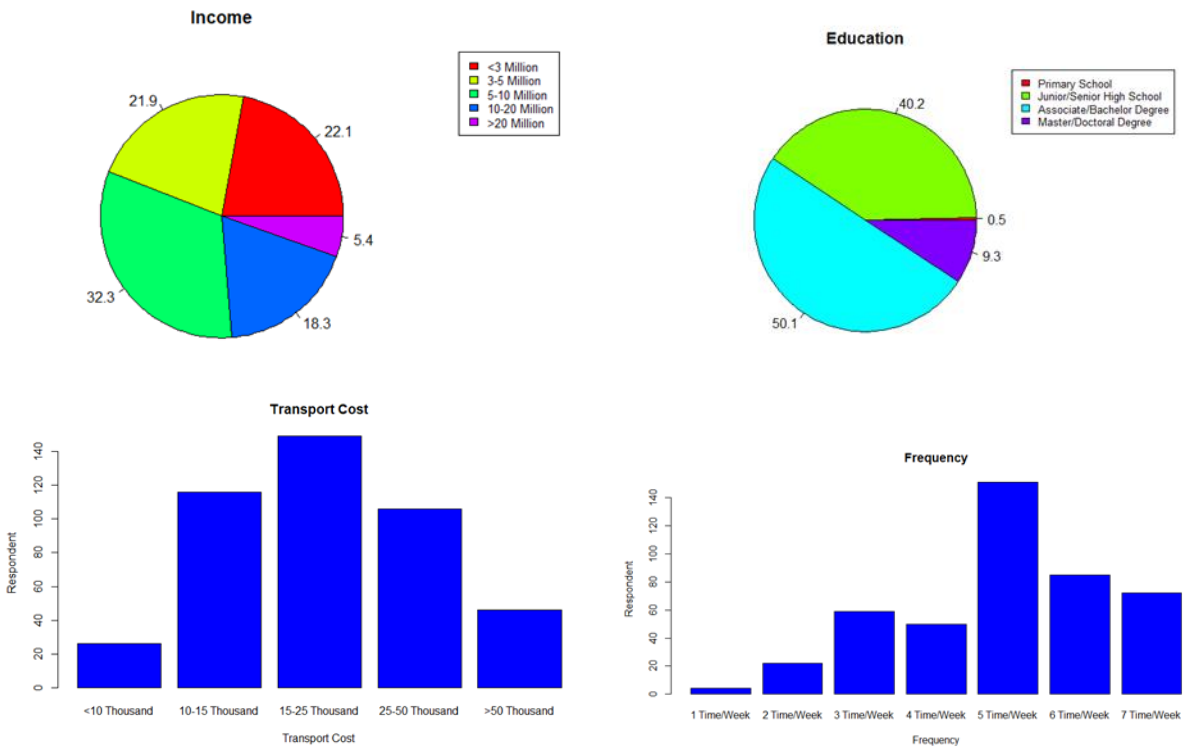


Fig. 1. Travel Characteristics

Source: author's work (2024)

Analysis of Existing Conditions

In the analysis of existing conditions, the research focuses on Sudirman Street for the primary corridor for implementing road pricing. The objective is analyze current traffic volume and distribution origin-destination matrix passing through the corridor. The data was obtained through CUBE application, utilizing road network and origin-destination matrix from secondary data, with reference to the year 2018 as base year of the JUTPI survey. The modelling approach used variables such as Passengers Equivalent Factor and Value of Time from JUTPI study.

The developed model accounts for the relationship between travel time and traffic volume on the road. The travel time is calculated based on traffic volume and speed, with additional penalties applied for toll roads and priced roads. The analysis results shows a total traffic volume on Sudirman Street of 74.644 emp/day with a v/c ratio of 0,9 or equal to Level of Service (LOS) E, indicating traffic conditions are almost saturated.

$$volume\ of\ vehicles\ in\ the\ corridor = \frac{\sum Volume\ link\ x\ link\ length}{total\ link\ length}$$

Value of traffic volume on the existing Sudirman road section is then converted to the v/c ratio. This section divided into 16 links, and is calculated in two directions, namely Lebak Bulus – Bundaran HI and opposite directions.

Table 2: V/C Ratio on the Sudirman road section

No	Direction	Traffic Volume	Ratio V/C	Level of Service (LoS)
1.	Lebak Bulus – Bundaran HI	79953,10	0,96	E
2.	Bundaran HI – Lebak Bulus	69347,72	0,83	D

Source: author's work (2024)

In addition to calculating vehicle volume, it is also necessary to knows the occupancy of public transportation which is limited to MRT mode. Based on the data obtained, an analysis was conducted on the occupancy rate derived from the movement of travelers entering and exiting the MRT station in each direction. The calculation is performed by

determining the number of people entering, adding the previous occupancy, and subtracting the number of people exiting at the station before proceeding to the next station.

Analysis of scenario conditions

In general, the pair of cost and travel time variables are absolute variables that are considered in determining the variables that will be used to generate the amount of willingness-to-pay (WTP) for users of private vehicles (cars or motorbikes) who have activity goals in Jakarta. Other variables can be considered as additional variables if the test of the Log-Likelihood value in the modeling shows results that are close to zero. To get the right pair of variables, a combination pair of costs, travel time and other variables is arranged, which is then assigned to the utility model. Following are the results of the Log-Likelihood values and parameter constants with all variables included in the model.

Table 3: Run Results Utility Function All Parameters

Log-Likehood	-1728.918				
Parameter	Estimate	Standard Error	T-Value	Pr (>t)	Significance
ASC.ERP	3.680E+00	3.996E-01	9.208	<2E-16	***
cons.MAINMODE	6.546E-01	1.111E-01	5.894	3.78E-09	***
cons.GENDER	8.230E-02	1.035E-01	0.795	0.426536	
cons.AGE	-1.530E-01	7.399E-02	-2.067	0.038709	*
cons.OCCUPATION	-3.123E-01	1.490E-01	-2.096	0.036047	*
cons.INCOME	3.954E-01	6.994E-02	5.653	1.58E-08	***
cons.EDUCATION	-7.884E-03	9.141E-02	-0.086	0.931274	
cons.ORIGIN	7.520E-02	1.015E-01	0.741	0.458946	
cons.EXPENDITURE	-2.227E-01	4.935E-02	-4.514	6.38E-06	***
cons.MILEAGE	-5.610E-02	3.880E-02	-1.446	0.148212	
cons.FREQUENCY	-1.232E-01	3.459E-02	-3.562	0.000368	***
cons.ALTERNATIVE	-2.809E-02	4.655E-02	-0.603	0.546227	
cons.COST	-8.666E-05	8.448E-06	-10.259	<2E-16	***
cons.TIME	2.241E-01	1.087E-02	20.618	<2E-16	***

Source: author's work (2024)

Based on the results of the first iteration, several variables have a significance value of less than 0.05 including the Main Mode, Age, Occupation, Income, Transportation Expenditure, Travel Frequency, Cost and Time. As for the others, such as Gender, Last Education, Type of Occupancy, Mileage, and Alternative Modes will be ignored in the next iteration. So that the next combination of variables is obtained, where all variables have a high significance value even less than 0.01 with a log likelihood value of -1700 which is smaller than the previous iteration. From these results will be continued to obtain the equation in the next process.

Table 4: Results of Run Parameters of Certain Variable Utility Functions

Log-Likehood	-1700.631				
Parameter	Estimate	Standard Error	T-Value	Pr (>t)	Significance
ASC.ERP	3.182E+00	2.963E-01	10.741	<2E-16	***
cons.MAINMODE	6.401E-01	1.064E-01	6.016	1.79E-09	***
cons.INCOME	2.251E-01	4.079E-02	5.517	3.44E-08	***
cons.EXPENDITURE	-1.956E-01	4.630E-02	-4.225	2.39E-05	***
cons.FREQUENCY	-1.211E-01	3.243E-02	-3.734	0.000188	***

cons.COST	-8.628E-05	8.478E-06	-10.177	<2E-16	***
cons.TIME	2.236E-01	1.085E-02	20.604	<2E-16	***

Source: author's work (2024)

Then, a utility equation can be generated as a form of binomial logit of travelers who are willing to continue using private vehicles if Road Pricing is applied which is represented in the form of U_JB, where the number of private vehicle users who have a destination Activities in Jakarta are influenced by factors including, Main Mode (Car or Motorcycle), Income, Expenditure, Frequency, Cost, and Time. Thus, for the Road Pricing policy, the following utility model is used:

$$U_{JB} = 3{,}182 + 0{,}640x_1 + 0{,}225x_2 - 0{,}196x_3 - 0{,}121x_4 - 0{,}863x_5 + 0{,}224x_6$$

Where: X1 = Main mode; X2 = Income; X3 = Expenditure; X4 = Frequency; X5 = Cost; X6 =Time

Based on stated preference data obtained from the survey results, it can be determined the size of the sampling number of respondents who accept the Road Pricing policy and continue to use private vehicles with certain offers issued in the set of questions in the questionnaire. This is related to the variable of time savings and additional travel costs incurred by applying Road Pricing to be compared with those who do not receive and will switch to public transportation. These preferences are then plotted into a graph to predict the most choices made by respondents regarding travel time savings and additional travel costs, as shown in the following figure.

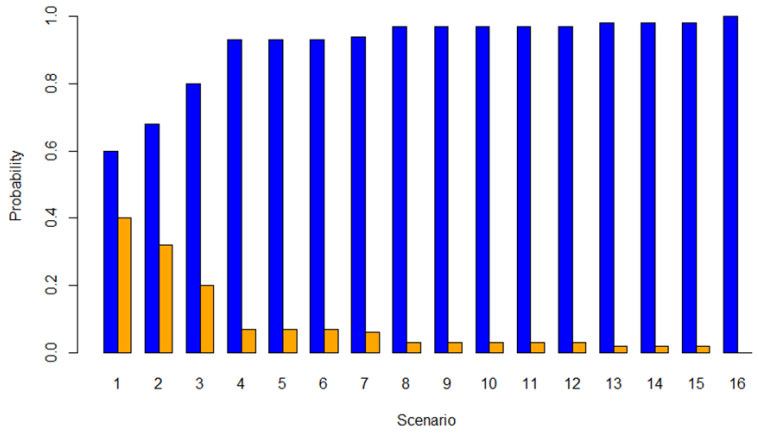


Fig. 6. Preferences for accepting the Road Pricing Policy permanently or not Accepting the Policy by switching to public transportation

Source: author's work (2024)

The image above shows that the tendency of Private Vehicle users who have an activity purpose in Jakarta intersects at point number 1, which corresponds to the 1st set of questions with choices tariff of Rp. 25,000 and without any time savings. The magnitude of this variable is then entered into the utility equation to obtain the probability of travelers who accept the implementation of the Road Pricing policy by continuing to use private vehicles.

Meanwhile, the sensitivity graph is formed based on the obtained function, where the income, expenditure, and frequency factors are determined based on the mode value for each influencing factor. For the income factor, the mode value is obtained in category 3, namely the income of 5-10 million. Furthermore, for the expenditure factor, the mode value for category 3 is obtained, namely the expenditure of 15-25 thousand. And for the frequency factor, the mode value for vehicle class 5 is obtained for 5 times a week. As for the other factors, namely the cost and the main mode factor (between motorcycles and cars) which will be tried to be seen as a variation of the sensitivity graph as a combination that fits the scenario of the questionnaire.

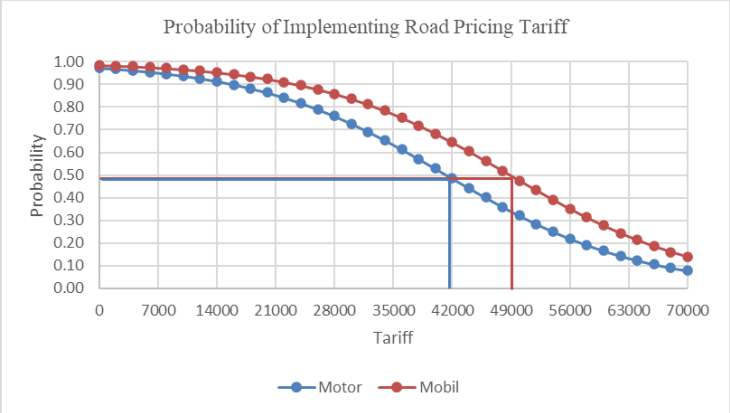


Fig. 7. Probability of each type of private vehicle against the scenario of Application of Road Pricing Policy Tariffs

Source: author's work (2024)

Plotting the probability curve will be described in 2 dimensions with the x-axis representing tariffs and the y-axis representing the probability of acceptance of the policy implementation. The curve depicts the change in probability between travelers who accept the policy and do not accept it until it is finally shown an intersection point at 0.5 probability of accepting the Road Pricing will provide the same benefits as without the policy, which represents the respondent's perception. With this basis, it is found that at 50% probability, the value of the application of Road Pricing that can be accepted by users of the main motor mode with scenarios without time saving is Rp. 41,500, -. Meanwhile, for the scenario of users of the main mode of cars with scenarios without time saving is Rp. 49,000,-

Level of Service ERP

Before the ERP system was implemented, the road section between Bundaran HI and Lebak Bulus consisted of 33 links, and the Level of Service (LoS) degree had already reached a saturation point. The calculation formula for the weight is as follows:

$$Corridor\ volume = \frac{\sum volume\ link\ x\ link\ length}{total\ link\ length}$$

Table 5: The LoS in existing condition

No	Ruas Jalan	LoS
1.	Lebak Bulus - HI	0,96
2.	HI – Lebak Bulus	0,9

Source: author's work (2024)

When the ERP is implemented, as per the previous analysis, there are two scenarios with WTP values of Rp. 41,500 and Rp. 49,000.

Following the implementation of ERP in either Scenario 1 or Scenario 2, there will be a shift in road user mobilization from private vehicles to public transportation. This will impact the LoS on the road section, which could change, along with a reduction in travel time.

If Scenario 1 of ERP is applied, the vehicle volume on the road section will be 21,269.17 vehicles per day. Meanwhile, for Scenario 2 of ERP, the vehicle volume will be 21,865.79 vehicles per day.

Table 6: The LoS each Scenario

No	Ruas Jalan	LoS Existing	LoS Scenario 1	LoS Sceanrio 2
1.	Lebak Bulus - HI	0,96	0,96	0,96
2.	HI – Lebak Bulus	0,9	0,9	0,9

Source: author's work (2024)

Table 7: The LoS in skenario 2

No	Ruas Jalan	LoS
1.	Lebak Bulus - HI	0,96
2.	HI – Lebak Bulus	0,9

Source: author's work (2024)

CONCLUSION

The utility equation is generated as a form of binomial logit from travelers who are willing to continue using private vehicles if Road Pricing is applied which is represented in the form of U_JB, where the number of private vehicle users who have activity goals in Jakarta is influenced by factors including, Main Mode (Cars) or Motor), Income, Expenditure, Frequency, Cost, and Time. With the obtained tariff scenario without any time savings, it is Rp.41,500,- for motorbike users and Rp.49.000,- for car users as a 50% probability of implementing an acceptable Road Pricing.

The Level of Service (LoS) in scenario 1 is 0.33 and 0.29 for the Lebak Bulus-HI direction and its reverse. With the implementation of ERP in scenario 2, the LoS on the same road segment changes to 0.32 and 0.26 for the Lebak Bulus-HI direction and its reverse.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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