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Design of Electronic Road Pricing in Jakarta Based on Willingness and Ability to Pay: Addressing Traffic Congestion with Pricing Effectiveness

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ABSTRACT

Congestion in Jakarta is a significant problem that impacts socio-economic aspects. The odd-even policy implemented by the government is considered ineffective because it encourages people to have two vehicles with odd and even license plates so as not to reduce the number of cars on the road significantly. Therefore, the government plans to implement Electronic Road Pricing (ERP), which promotes a more equitable distribution of transportation modes and the reduction of congestion. This research aims to design ERP tariffs that are effective in reducing congestion. This study uses a quantitative approach in data collection, which is then analyzed using a combination of Ability to Pay (ATP), Willingness to Pay (WTP), and Analytical Hierarchy Process (AHP). The results of the study show that the optimal fare is in the range of Rp 18,000 – Rp 22,000 for cars, while for motorcycles, it is in the range of Rp 7,000 – 9,500. The study also showed that the value of ATP > WTP. This imbalance can lead to ineffectiveness, so a pricing strategy must be made so that rates are fairer and more effective for different levels of society. This study highlights the importance of incorporating ATP and WTP analyses in determining fair rate structures. In addition, AHP is important for determining the optimal ERP rate by giving weight to the WTP value factor so that the analysis results are more accurate and objective. With a well-designed tariff, ERP can potentially serve as a viable solution to Jakarta's congestion problem.

1. INTRODUCTION

Traffic volume is one of the leading causes of congestion in big cities related to transportation, land use, and social welfare [1]. People's travel trends can influence congestion, including land use patterns such as population dispersion and expansion of residential areas that adjust the distance between housing and the destination of work and other destinations or community travel patterns, where people tend to travel by motorized vehicles [2]. That is the push demand for increased mobility and accessibility in transportation [3].

The negative impact caused by congestion can affect the economy, society, and the environment. Economically, congestion can cause travel time to increase and increase vehicle fuel consumption, which leads to reduced performance productivity and economic disruption [4]. The environmental impact caused by this congestion is that emissions from the combustion of motor vehicles can increase the greenhouse effect, which increases the earth's temperature. The most severe impact is climate change [5, 6]. Meanwhile, the social effects caused by this congestion are affecting the community's health. Mokbel's [7] revealed that particulate matter (PM), especially $PM_{2.5}$, can pose a cancer risk.

To resolve congestion, the management of cities can solve this problem [8]. Efforts that can be made include improving traffic infrastructure, which can be done by widening roads and building over or underpasses, increasing mass transportation as a manifestation of sustainable transportation that is affordable, efficient, safe, and comfortable, and improving traffic system regulation (traffic management) to support traffic infrastructure and public transportation facilities [9]. One of the efforts that can be made in traffic management to control traffic is called Congestion Charge nowadays, better known as ERP [10].

The ERP system was first implemented in Singapore's central business district, and traffic congestion was successfully solved using a dynamic scheme [10]. After Singapore, several cities in Norway also started to implement it from 1986 to 2001, including Bergen, Oslo, Trondheim, Kristiansand, and Stavanger. The implementation of ERP in London and Stockholm has not only succeeded in overcoming congestion. However, it has also reduced particulate matter by 10-15% and carbon dioxide by 13-16% [11]. Some studies above reveal that congestion is the main problem with implementing ERP, as in Jakarta.

As Indonesia's metropolitan city and economic centre, Jakarta still has a severe congestion problem. Although Jakarta already has good public transportation, the lack of integration of some public transit still makes the public perceive that private transportation is better than public transportation [12]. It is better to use private vehicles than public ones because they are more flexible and offer more accessible travel [13]. BPS [14] states that the number of vehicles in Jakarta in 2022 is 21,856,081 units, of which 21,070,506 units, or 90% of the number of vehicles in Jakarta, are dominated by motorcycles and cars. In 2023, the average number of vehicles in Jakarta is dominated by motorcycles with a total of 89,426 units or 71% of the total average vehicles per day, then cars as many as 33,677 units or 27% of the total average vehicles per day, and buses/trucks as many as 3,057 units or 2% of the total average vehicles per day.

Congestion in Jakarta also affects the economy, society, and environment. World Bank [15] notes that traffic congestion in Jakarta results in an annual economic loss of around USD 5.2 billion, approximately 5.4% of the city's GDP. This loss is primarily due to wasted time in traffic, increased fuel consumption, and delayed goods transportation. Socially, congestion increases inequality and affects the quality of life of Jakarta residents. A study on civil servants in the Greater Jakarta area found that over 51% experienced severe mental health disorders due to prolonged exposure to traffic congestion, with symptoms including anxiety and mood disturbances [16]. Congestion also affects commuters with distress, fatigue, and diminished time for family and socialization, further affecting personal harmony [17]. Environmentally, congestion also decreases air quality in Jakarta. Congestion in Jakarta causes higher emissions of pollutants like carbon monoxide and particulate matter (PM2.5), which harm air conditions and community well-being [18]. Kriswandanu et al. [19] also state that traffic congestion in Jakarta significantly impacts the quality of the environment for residents by contributing to poor air quality.

Implementing ERP to resolve congestion in Jakarta is still a discussion for the regional government, as well as the pros and cons for the public. It is also still not widespread in Indonesian society due to the costs incurred and the low purchasing power of the people. Li and Robuste [20] stated that public acceptance and economic justice issues are the main concerns for implementing ERP. Some critical factors to consider in public acceptance of the implementation of ERP are as follows: 1. Public interest; 2. Use of revenue from ERP implementation; 3. Equality in socio-economic in society; 4. The pricing scheme and its features [21].

Several Asian countries have conducted studies on ERP. With a higher GDP than Indonesia Singapore, the ERP system is a well-established model, effectively managing congestion through dynamic pricing and advanced technology [22]. Seoul's ERP focuses on reducing traffic in central areas, similar to Jakarta's Central Business District approach. Both cities aim to shift commuters to public transport, though Seoul's system is more mature and technologically advanced than Jakarta's [23]. Hong Kong's ERP system emphasizes environmental benefits and urban mobility. Jakarta's ERP could adopt similar strategies to enhance sustainability and public transport integration [24]. While ERP systems in other Asian cities provide valuable insights, Jakarta's unique socio-economic context (e.g., immature public transportation, higher population, and diverse society income) requires a tailored approach. Implementing ERP must balance congestion reduction with social equity and public transport improvements to achieve sustainable urban mobility.

Since Jakarta will implement ERP, the most fundamental thing in balancing congestion reduction with social equity and public transport improvements is the determination of the ERP tariff scheme. Based on this term, WTP and ATP were analyzed to create an effective pricing ERP. These concepts are often used in transportation economics to understand people's behaviour regarding prices and their ability to pay for transportation services [25]. WTP represents the maximum value a person or group is ready to pay for the advantages of a product or service. In contrast, ATP refers to the financial ability of an individual or group to pay for transportation costs. For ERP to gain public acceptance, the pricing structure must align with users' financial capacity (ATP) and perceived benefits (WTP) value, ensuring fairness and minimizing opposition from different socioeconomic segments.

This research was conducted to design an effective ERP that involves the public. This design is based on the public's WTP and ATP to present a solution to traffic congestion by considering the socio-economic circumstances of the public and not burdening the low-income population disproportionately.

2. LITERATURE REVIEW

2.1 Traffic management

Traffic management is the process of planning, controlling, and operating a transportation system to improve mobility and accessibility while minimizing congestion and environmental impact [26]. As a city's population grows and the number of vehicles increases, effective traffic management becomes essential to maintain an efficient transportation system. Minimizing congestion and environmental impact can be done by exploring some key techniques and strategies used in traffic management, which are presented in Table 1 [27].

Table 1. Traffic management strategies and techniques

No.	Strategy	Technique
1.	Capacity management	1. Junction repair; 2. Road management: a) Vehicle type separation (2-wheel and 4-wheel or more); b) On-street parking control; c) Road widening; 3. Traffic area control: a) One-way road; b) Traffic light coordination; c) U-turn or turn restrictions.
2.	Priority management	1. Non-motorized vehicle priority; 2. Bus priority (busway).
3.	Demand management	1. Road closures; 2. Contraflow; 3. Vehicle restrictions: a) Three in One; b) ERP.

2.2 ERP

ERP is a toll road system based on the use and time on the road electronically. This ERP has been applied in several countries to regulate traffic density on certain highways and has had a positive impact. Research results from several cities in countries around the world also show that ERP affects congestion and environmental conditions [28-31], as shown in Table 2.

Table 2. The Effect of ERP implementation on traffic congestion and environmental conditions

Detail	Singapore	London (UK)	Milan (Italy)	Stockholm (Sweden)	Gothenburg (Sweden)
Purpose	Congestion	Congestion	Congestion and air quality	Congestion and air quality	Congestion and air quality
Impact					
Vehicle volume	Decreased by 40 – 45%	Decreased by 18 – 21%	Decreased by 14 – 34%	Decreased by 15 – 20%	Decreased by 9 – 12%
Emission		Decreased by 16%	Decreased by 22%	Decreased by 13%	Decreased by 2.5%
Air pollution		Decreased by 13 – 10%	Decreased by 6 – 40%	Decreased by 8 – 13%	

2.3 WTP and ATP

WTP refers to the highest amount an individual or group is ready to spend on a product or service. WTP analysis can be categorized into two methods, i.e., the Stated Preference (SP) and Revealed Preference (RP) methods. The SP method asks people about their preferences through surveys and choice experiments. The RP method, on the other hand, looks at the actual choices people make in the real market [32].

If used to describe the user's preferences for various attributes, the SP method is called a Discrete Choice Experiment (DCE) [33]. DCE also can be used to assess user preferences for multiple attributes of non-market goods, such as environmental quality or public policy [34]. Public policies often have adjustments or innovations influenced by the public in their implementation. To assess how the public's views on new policy innovations/policies are analyzed through DCE, which can describe public preferences in their attributes, where attributes are adjusted to the goals of policymakers [35].

If used to measure the value or demand for a location or place based on the cost spent by an individual to access the place, it is called the Travel Cost Method (TCM) [36]. It is also mentioned that TCM consists of two elements: one for estimating the value of travel time (VoT) for each individual and the other to consider the variable costs involved (such as fuel, maintenance, tolls, and parking fees) associated with reaching a location. In the TCM method, VoT is essential because it reflects the opportunity cost of time spent travelling [37]. This research shows that VoT directly influences transportation assessments and policymakers. In addition, transport prices, including fuel costs, affect a person's travel pattern [38].

By observing their actual behaviour, the RPM transportation method estimates individuals' value on travel-related attributes, such as time savings or improved service quality. Tveter [37] concluded in his research that the VoT that causes changes in travel costs affects the choice of routes for travellers. VoT is fundamental to transportation economics, reflecting the balance between the time and money travellers are prepared to exchange. Fluctuations in travel costs, influenced by changes in VoT, can cause alterations in preferred routes and transportation modes. This term above suggests that the elasticity of private vehicle use refers to how sensitive travel demand is to variations in travel time or costs. Higher elasticity means travellers are more likely to adjust their travel behaviour when these factors change. The research also revealed that interventions such as free public transport can significantly reduce car usage, demonstrating the elasticity of demand in response to changes in travel costs and the availability of alternatives [39].

ATP value is the difference between household income and living expenses, adjusted proportionally to the household size [40]. Factors that affect the ATP for a transportation service are influenced by the respondent's socio-economic factors, such as revenue level and employment condition. Additionally, the importance of service quality attributes such as safety, convenience, and time reduction significantly affects [41]. The ATP benchmark is the ideal income between income and expenses with what services or goods a person will receive.

Both methods are considered important in determining the price of a good or service, primarily if the pricing is based on the value-based pricing method. Muhammed and Senadheera [42] stated that the affordability of public services is essential for equitable access, especially for low-income groups. It suggests that affordability should be a key consideration in determining the rates of public services, ensuring that services remain accessible and sustainable for all socio-economic groups.

2.4 Combining the SP RP method

In determining the WTP to assess a policy, a particular method can be used according to the characteristics and factors that are considered by the policy. However, for a more comprehensive result, multiple methods can be combined to determine the value, such as combining the SP and RP methods [43]. The combination of SP RP will make the conclusion more comprehensive because SP RP complements each other [44]. Suppose the goal is to make the WTP analysis more accurate. In that case, one may have to pay attention to a few things, i.e., data reliability, implementation result, comprehensiveness, and temporal relevance, because each method has different data characteristics [45].

We need the weight for each method and its criteria to combine the SP RP method. Multiple Criteria Decision Making (MCDM) is used to determine this. MCDM is a method used for data processing to assess and compare alternatives based on various criteria or factors, such as the Analytic Hierarchy Process (AHP) [46]. AHP is particularly effective in merging qualitative and quantitative analysis techniques to address ambiguous, unclear, or complex problems [47]. A key benefit of AHP lies in its ability to incorporate decision-maker's experiences and judgments, highlight their perspectives, compare relevant factors, and systematically evaluate the results of these comparisons, ultimately leading to more convincing decisions [48, 49].

2.5 Review of ERP implementation in several countries

Several countries have implemented ERP systems to address urban congestion and socio-economic disparities. Significant improvements in vehicle speed and unravelling congestion have been shown to address congestion, such as in Madrid, with an increase in average vehicle speed of 10% to 32.5% in different areas of the city [1]. In cities like Stockholm, ERP revenues are reinvested into public transport, which has increased public acceptance and improved social equity [50]. The other socio-economic benefits include reduced travel times, increased productivity, and equitable distribution of transport costs [51]. While specific data on ERP in Indonesia is limited, the potential for congestion reduction is significant, given the high levels of urban traffic congestion in cities like Jakarta. Implementing ERP could mirror the successes seen in other cities by managing traffic flow and reducing vehicle numbers during peak hours.

Meanwhile, ERP has never been implemented in Indonesian cities. However, implementing ERP can be a solution considering the high level of urban traffic congestion in cities such as Jakarta and reflecting on the success of other cities in various countries.

In implementing ERP, determining the appropriate tariff is the most basic thing. Brůhová Foltýnová et al. [52] reveal that implementing ERP systems must consider each city's unique geographical, demographic, and economic conditions. This variability necessitates a tailored approach to rate setting, ensuring that ERP systems are effective and equitable across different urban contexts. The concepts of ATP and WTP can guide the tariffs that consider these various factors [25]. This concept can consider factors such as income, road user preferences, travel costs, and the actual behaviour of road users.

3. METHODOLOGY

3.1 Research area

This research was conducted for one month in October 2024 on four road sections planned to be implemented ERP, referring to the Regulations issued by the Provincial Government No. 5 of 2014, i.e., Jl. Jend Sudirman, Jl. Rasuna Said, Jl. MH Thamrin, and Jl. Gatot Subroto. The road section is the economic centre with the most traffic in Jakarta (> 150,000 vehicles/day) [53]. It has also been integrated with mass transportation services (BRT and MRT). A map of the study area is shown in Figure 1.

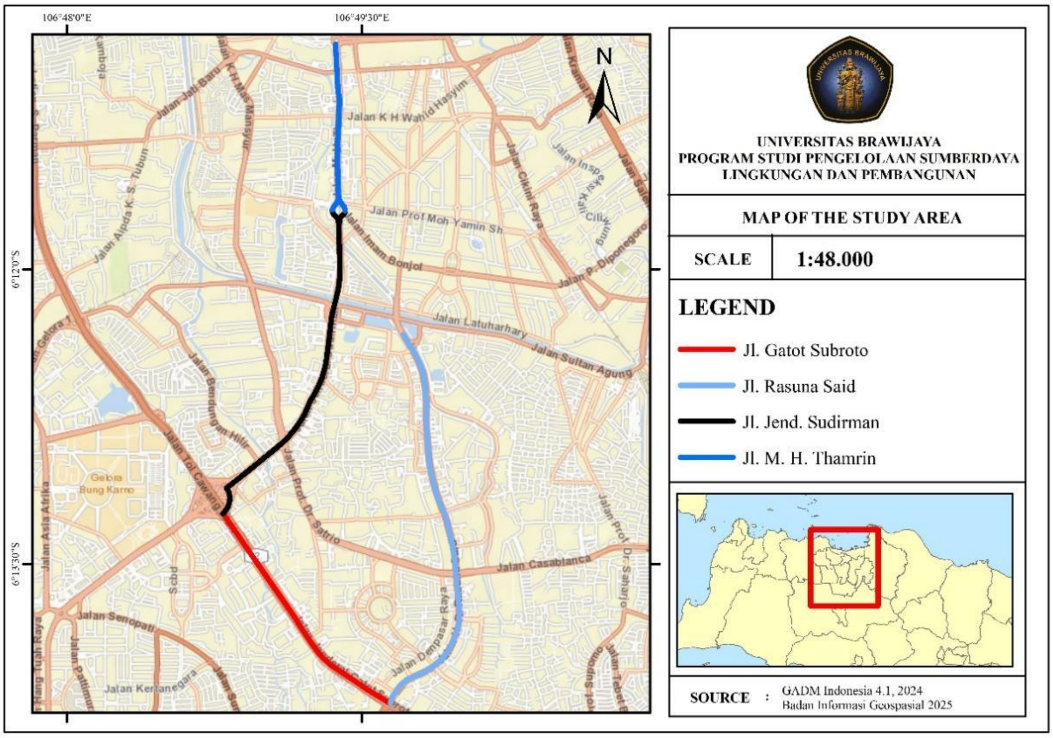

Figure 1. Map of the study area

3.2 Survey method and sample determination

In this research, the researcher used a survey method by distributing questionnaires to road users on the four road sections. The number of samples was taken according to the Cochran method, using stratified random sampling to conduct sample selection.

The Cochran method is suitable for calculating the number of samples whose populations are large or whose exact number is not known for certain, thus enabling the determination of the minimum sample size necessary to achieve results that accurately represent the target population with the specified degree of precision and confidence [54]. Compared to the Slovin method, Cochran is more suitable for sample sizes whose exact numbers are unknown by considering the margin of error, confidence levels, and estimated proportions of the desired population [55]. The formula for the calculation of the Cochran method shown in Eq. (1).

$$n_o = \frac{z^2 \times p \times (1\text{-}p)}{E^2} \tag{1}$$

Let z represent the z-value (1.96 for a 95% confidence level); p denotes the expected population proportion (0.5 if unspecified); and E signifies the margin of error.

Applying the Cochran method to determine the total sample size, utilizing a 95% confidence level, a 5% margin of error, and an estimated population percentage of 0.5 yielded a minimum of 385 respondents. In this study, researchers surveyed 400 respondents.

The respondents were selected using the stratified random sampling technique. This technique can ensure the representation of the main subgroup of interest, in contrast to the simple random or cluster sampling method [56]. By stratifying based on relevant characteristics, the researchers can ensure these groups are adequately represented in the sample. Respondents' inclusion criteria include:

1. Cars and motorcycles user;
2. Age range 18-65 years;
3. Riders who have a consistent frequency, intensity, and pattern of travel in Jakarta;
4. Have a fixed income;
5. Not as an online motorcycle/taxi driver.

While the stratified random sampling approach was carefully designed to ensure representative sampling, there are potential limitations. The sampling method may introduce inherent biases despite its systematic approach. For instance, the inclusion criteria (age range 18-65 years, fixed income, and consistent travel patterns) could potentially exclude important demographic segments, such as gig economy workers or those with less stable incomes. Additionally, the sampling frame might inadvertently over-represent certain socio-economic groups that are more likely to be available and willing to participate in the survey. The main focus is to ensure that the sample comprises regular road users with a consistent frequency, intensity, and pattern and to avoid oversampling from unwanted groups.

3.3 Design of the questionnaire

The research questionnaire is designed to consist of several questions, such as the socio-demographic characteristics, travel characteristics, income per month, expenditure per month, expenditure for transportation per month, ownership of motor vehicles, and frequency and time required to pass through roads to apply ERP. The next step is to determine the WTP and ATP for the ERP service from the data.

3.4 Data analysis

3.4.1 ATP

In this research, ATP value is obtained based on input data in the form of income, total expenses, transportation costs, number of frequencies, and distance travelled. The distance used in the ATP analysis is the distance travelled through the route the ERP plans to implement. ATP is calculated by considering income, expenses, transportation costs (non-fixed and fixed), and the frequency and distance travelled by respondents. The amount of ATP is the number of transportation costs totalled by the margin of income and expenses minus investment costs divided by the frequency of monthly trips as formulated in Eq. (2):

$$ATP = \frac{[(Inc\text{-}Exp\text{-}Inv]}{FoM} \tag{2}$$

where, *Inc* is income, *Exp* is Expense, *Inv* is investment cost, and *FoM* is the frequency of monthly trips.

3.4.2 WTP

The value of WTP is acquired by conducting an analysis using a combination of Stated Preference – Reveal Preference methods [44], i.e., DCE, TCM, and RPM. DCE allows for the estimation of individual preferences for different attributes of the ERP system [33]. TCM provides insights into the monetary value individuals place on travel time and costs [36]. RPM reveals actual behaviour based on observed choices [37]. These methods were chosen over others due to their ability to combine stated and revealed preferences, offering a comprehensive understanding of how users value ERP implementation [44]. The estimation of WTP value using method, i.e.:

1. The formula calculates DCE using three attributes: time savings, reliability, and comfort. To get the WTP DCE value, use the formula in Eq. (3), with attribute weight based on the primary survey result [57].

$$WTP_{DCE} = \sum(attval \times attwght) \tag{3}$$

where, *attval* is attribute value, and *attwght* is attribute weight.

The attribute value is calculated using Eqs. (4)-(6).

$$Time\ Saving = (PTT\text{-}ETT) \times VoT/min \tag{4}$$

$$Reliability = (PTT\text{-}ETT) \times VoT/min \times Coeff.Rbl \tag{5}$$

$$Comfort = (PTT\text{-}ETT) \times VoT/min \times Coeff.Cmft \tag{6}$$

where, *PTT* is the present travel time, *ETT* is the expected travel time, *and Coeff.Rbl* is coefficient of reliability, and *Coeff.Cmft* is coefficient of comfort

With *VoT/min* calculated with Eq. (7):

$$VoT/Min = \left(\frac{Monthly\ Revenue}{WorkHr \times WorkDy \times 60}\right) \tag{7}$$

where, *WorkHr* is working hours and *WorkDy* is working days.

2. TCM involves several components (e.g., fuel, time, and maintenance costs). It is obtained using the formula Eqs. (8)-(10).

$$Fuel\ Cost = Fuel/Km \times PoF/L \times LoR \tag{8}$$

$$Time\ Cost = VoT/Min \times TimeRdc \tag{9}$$

$$Maint.\ Cost = Cost/km \times LoR \tag{10}$$

where, *PoF/L* is the price of the fuel per liter, *LoR* is the length of the road, and *TimeRdc* is the time reduction.

3. Revealed Preference Method (RPM), studying the actions of consumers of products and services in order to tease out the values underpinning them. TCM, for instance, assumes that the cost paid to accomplish a goal indicates the value that consumers are rewarded for this goal pursuit [58]. The analysis of WTP is associated with the coefficient of elasticity, which calibrates calculations by altering demand sensitivity to price variations [59]. RPM analysis with the elasticity of the vehicle, with the formula as Eq. (11), where car coefficient elasticity is -0.3 and motorcycle coefficient elasticity -0.5 [59].

$$WTP_{RPM} = TCM \times (1\text{-}Coeff.\ Elasticity) \tag{11}$$

3.4.3 AHP for combined SP RP method

The AHP was integrated to prioritize and weigh the factors affecting user decisions. AHP's systematic approach enables the aggregation of multi-criteria decision-making, ensuring that the trade-offs between different factors (e.g., cost, time, convenience) are considered in the modelling process, enhancing the robustness of the analysis [48]. From the definition above, AHP can give weight to each WTP method (DCE, TCM, RPM) by assessing relevant factors based on preferences and priorities. The analysis results become more accurate and objectively acceptable by weighting each method according to its relevance factors.

The process of the AHP follows [60]:

Step 1: Defining the AHP framework

The SP RP method combination calculations are organized around three approaches (DCE, TCM, and RPM), each with related criteria structured in levels representing the elements' hierarchical connections. A more intricate structural model with multi-tiered analysis is developed to address this complexity. Given the in-depth nature of the study, the model can have multiple levels; however, the top level consists of a single element, which is the desired goal or outcome (value of combined WTP). The intermediate level delineates the steps necessary to attain this objective (the three WTP methods), which can be categorized into multiple sub-levels. The lowest level outlines the actions and decisions required to achieve the goal, including criteria such as data reliability (DR), implementation cost (IC), comprehensiveness (C), and temporal relevance (TR). Once the hierarchical structure is established, the relationships among the factors at each level become clear. This hierarchy is illustrated in Figure 2.

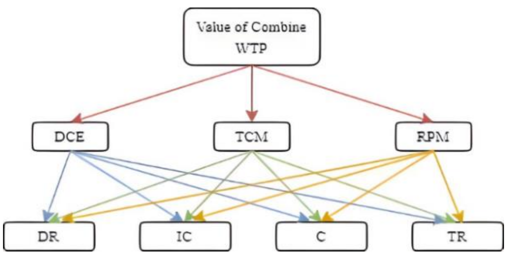

Figure 2. AHP framework for combine SP RP method

The significance of each factor is assessed using a scale of 1-9 [61], with Table 3 providing the meanings for each value on the 1-9 scale.

Step 2: Building a pairwise comparison matrix

Once the criteria are determined, the next step is to compare each criterion in pairs using a predetermined assessment scale. A paired comparison matrix $A=[a_{ij}]$ will be formed, where each element a_{ij} shows a comparison between the criteria *i and j*.

A pairwise comparison matrix can be described as Eq. (12):

$$A = \begin{bmatrix} 1 & m_{12} & \cdots & m_{1n} \\ m_{21} & 1 & & \vdots \\ \vdots & & 1 & \\ m_{n1} & \cdots & & 1 \end{bmatrix} = (A_{ij})_{n \times n} \tag{12}$$

Table 3. Importance scale for prioritization

Importance's Scale	Definition
1	Equal significance
3	Moderate significance
5	Strong significance
7	Very strong significance
9	Extreme significance
2, 4, 6, 8	Between values

Once the pairwise comparison matrix is arranged, the next step is to normalize the matrix. Normalization is conducted by dividing each element of *aij* by the number of columns, thus producing a normalization matrix n_{ij}, where each element n_{ij} is calculated with the formula as Eq. (13):

$$n_{ij} = \frac{a_{ij}}{C_j} \tag{13}$$

where, C_j is the number of columns j in the pairwise comparison matrix.

Then, the criterion's weight will be calculated by taking the average of the normalized value on each line. Weight criteria w_i for criteria i calculated with the formula as Eq. (14):

$$w_i = \frac{1}{m}\sum_{j=1}^{m} n_{ij} \tag{14}$$

Step 3: Consistency test

After the weight calculation steps are done, testing the consistency in the paired comparison matrix is important. The consistency test aims to ensure that the comparisons made between the elements in the matrix are consistent and not contradictory and that the results are valid. The first step is to calculate the consistency index (CI). CI is used to measure whether the pairing ratio in the matrix is consistent. CI is calculated using the following formula as Eq. (15):

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{15}$$

where, $\lambda_{\max}$ represents the maximal eigenvalue of the paired comparison matrix and n is the sum of the criteria or alternatives in the comparison matrix.

Upon establishing the CI value, the subsequent step is to compute the consistency ratio (CR) to evaluate the consistency of the entire comparison matrix. CR is found by dividing the CI by the random consistency index (RI) based on the matrix's size (number of criteria or alternatives), as shown in the formula in Eq. (16).

If the CR value is less than 0.1, then it is consistent.

$$CR = \frac{CI}{RI} \tag{16}$$

Step 4: Evaluate the final decision

To get the final weights in each method, multiply each method's weight for each criterion by the criterion's importance.

4. RESULT

4.1 Socio-demographic characteristics of respondents

The survey results showed information related to the characteristics of respondents who passed through four roads that ERP would implement. Characteristics include data such as gender, age, educational background, and occupation. Figure 3 illustrates the composition of the profiles.

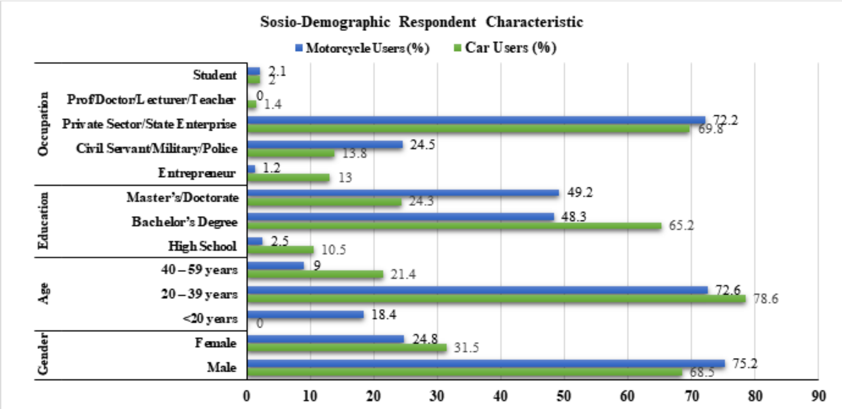

Figure 3. Socio-demographics characteristic respondent

Meanwhile, Figure 4 shows the characteristics of the respondents' number of weekly trips and vehicle ownership compared to their daily vehicle use.

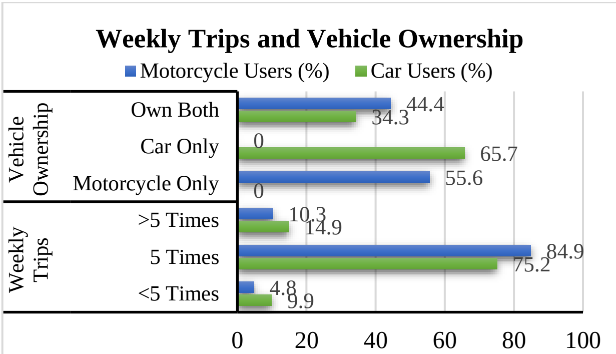

Figure 4. Characteristics of weekly trips and ownership of respondents' vehicles

The data survey showed that 274 respondents are car users and 126 are motorcycle users. Car users are dominated by males (68.5%) with a productive age of 20-39 years, as much as 78.6%, and 40-59 years old, as much as 21.4%, while motorcycle users it is also dominated by males (75.2%) with a productive age of 20-39 years as much as 72.6%. In the educational background, car users are dominated by bachelor's degrees (65.2%). However, for motorcycle users, there is almost a balance between bachelor's and master's/doctoral degrees, as much as 48.3% and 49.2%. Regarding job characteristics for car and motorcycle users, both are dominated by respondents who work in the private sector/state enterprise (69.8% for car users and 72.2% for motorcycle users).

The survey data also showed that respondents mostly travel five times a week; most who use cars only own cars (65.7%), and most motorcycle users only own motorcycles (55.6%).

After studying the demographic distribution, the number of trips over one week, and vehicle ownership, we analyzed the travel characteristics of respondents in more detail based on time, distance, and travel costs on the four roads planned for ERP implementation, as shown in Table 4.

Table 4. Characteristics of respondents' travels by time, distance, and cost in one trip

1. Jl. Jend. Sudirman

Characteristics	Car Users (%) [1]	Motorcycle Users (%) [2]
Travel Time		
< 30 min	39.58	52.27
30 - 60 min	50.00	40.91
61 - 90 min	8.33	4.55
91 - 120 min	2.08	2.27
> 120 min	1.04	0.00
Travel Distance		
< 5 km	19.79	20.45
5 - 10 km	35.42	40.91
11 - 15 km	35.42	29.55
16 - 20 km	25.00	18.18
> 20 km	10.42	6.82
Travel Cost		
< IDR10,000	5.21	40.91
IDR10,000 up to IDR25,000	35.42	45.45
IDR26,000 up to IDR40,000	30.21	9.09
IDR41,000 up to IDR55,000	19.79	4.55
> IDR55,000	14.58	0

Note: [1] n = 96 respondents, [2] n = 44 respondents

2. Jl. Rasuna Said

Characteristics	Car Users (%) [1]	Motorcycle Users (%) [2]
Travel Time		
< 30 min	40.00	52.00
30 - 60 min	50.91	40.00
61 - 90 min	7.27	4.00

91 - 120 min	1.82	4.00
> 120 min	1.82	0.00
Travel Distance		
< 5 km	20.00	20.00
5 - 10 km	34.55	40.00
11 - 15 km	34.55	32.00
16 - 20 km	25.45	16.00
> 20 km	10.91	8.00
Travel Cost		
< IDR10,000	5.45	40.00
IDR10,000 up to IDR25,000	34.55	48.00
IDR26,000 up to IDR40,000	30.91	8.00
IDR41,000 up to IDR55,000	20.00	4.00
> IDR55,000	14.55	0

Note: 1) n = 55 respondents, 2) n = 25 respondents

3. Jl. Gatot Subroto

Characteristics	Car Users (%) 1)	Motorcycle Users (%) 2)
Travel Time		
< 30 min	39.71	53.13
30 - 60 min	50.00	40.63
61 - 90 min	7.35	6.25
91 - 120 min	1.47	0.00
> 120 min	1.47	0.00
Travel Distance		
<5 km	20.59	18.75
5 - 10 km	35.29	40.63
11 - 15 km	35.29	31.25
16 - 20 km	25.00	18.75
> 20 km	10.29	6.25
Travel Cost		
< IDR10,000	4.41	40.63
IDR10,000 up to IDR25,000	35.29	46.88
IDR26,000 up to IDR40,000	29.41	9.38
IDR41,000 up to IDR55,000	20.59	3.13
> IDR55,000	14.71	0

Note: 1) n = 68 respondents, 2) n = 32 respondents

4. Jl. MH. Thamrin

Characteristics	Car Users (%) 1)	Motorcycle Users (%) 2)
Travel Time		
< 30 min	40.00	52.00
30 - 60 min	50.91	40.00
61 - 90 min	7.27	4.00
91 - 120 min	1.82	4.00
>120 min	1.82	0.00
Travel Distance		
<5 km	20.00	20.00
5 - 10 km	34.55	40.00
11 - 15 km	34.55	32.00
16 - 20 km	25.45	16.00
>20 km	10.91	8.00
Travel Cost		
<IDR10,000	5.45	40.00
IDR10,000 up to IDR25,000	34.55	48.00
IDR26,000 up to IDR40,000	30.91	8.00
IDR41,000 up to IDR55,000	20.00	4.00
> IDR55,000	14.55	0

Note: 1) n = 55 respondents, 2) n = 25 respondents
Source: Primary survey results, 2024

Based on the travel characteristic presented in Table 5, The survey data shows that respondents who on their way pass through the four roads that ERP will implement, most of them spend up to 60 minutes on a trip with a kilometre of up to 15-20 km, depending on the vehicle used. Usually, motorcycles can cover longer distances than cars. If calculated, most car user respondents spend 60 minutes on a trip with a distance of 15 km, the average speed is only 15 km/h, and for motorcycle users with 60 minutes to reach a distance of 20km, the average speed is around 20 km/h.

The data also shows that more than 50% of car user respondents' travel costs range from IDR10,000 to IDR40,000, and motorcycle user respondents' travel costs range from IDR10,000 to IDR25,000 for a one-way trip. If calculated, car user respondents' travel cost per km reaches IDR 2,700 per km. For motorcycle user respondents, it reaches IDR 1,250 per km.

Meanwhile, Table 5 shows the travel time data needed to pass through 4 roads that will be implemented in ERP.

From the table below, passing through 4 roads that ERP will implement takes an average of more than 30 min for car users and 15-30 min for motorcycle users.

Table 5. Travel time needed to pass through roads ERP roads

Vehicle Type	Travel Time	Percentage (%)
Jl. Jend Sudirman		
Car User	< 15 min	5.21
	15 - 30 min	35.42
	> 30 min	59.38
Motorcycle User	< 15 min	20.45
	15 - 30 min	54.55
	> 30 min	25.00
Jl. Rasuna Said		
Car User	< 15 min	7.27
	15 - 30 min	32.73
	> 30 min	60.00
Motorcycle User	< 15 min	24.00
	15 - 30 min	52.00
	> 30 min	24.00
Jl. Gatot Subroto		
Car User	< 15 min	4.41
	15 - 30 min	30.88
	> 30 min	64.71
Motorcycle User	< 15 min	18.75
	15 - 30 min	53.13
	> 30 min	28.13
Jl. MH. Thamrin		
Car User	< 15 min	5.45
	15 - 30 min	34.55
	> 30 min	60.00
Motorcycle User	< 15 min	24.00
	15 - 30 min	52.00
	> 30 min	24.00

Source: Primary survey results, 2024

The speed to pass through the four road sections can be calculated by dividing the length of the road by the average travel time. Data from the DKI Jakarta Transportation Agency shows the road lengths for Jl. Jend Sudirman are 3.6 km, Jl. Rasuna Said is 2.5 km, Jl. Gatot Subroto are 5.5 km, and Jl. MH. Thamrin 2.5 km. With a travel time of more than 30 minutes, the speed of car users ranges from 6km/h to pass Jl. Jend Sudirman, 4 km/h to pass Jl. Rasuna Said, 9 km/h to pass Jl. Gatot Subroto and 4 km/h to pass Jl. MH. Thamrin. Meanwhile, for motorcycle users, the speed to pass through the four roads ranges from 9.5 km/h to pass Jl. Jend Sudirman, 7 km/h to pass JL. Rasuna Said, 15km/h to pass Jl. Gatot Subroto and 7 km/h to pass Jl. MH Thamrin. This speed is still far from the target vehicle speed in Jakarta, as stated in the Jakarta Spatial and Regional Plans, which is 35 km/h. The reason for this is the number of vehicles that have grown rapidly over two decades that have not been followed by transportation management [62]. It is exacerbated by the growing population pushing for high mobility and the production of private vehicles experiencing a surge worldwide [63]. Rapid economic development has added to the movement of people to big cities to seek access to education, jobs, and housing. This process also causes various impacts, including traffic congestion [64]. Because this is inevitable, traffic congestion and emissions in developing countries will continue to increase. Interventions can be made to address this problem through infrastructure improvements (e.g., lane additions, geometric design improvements, etc.) or traffic management systems [65].

4.2 ATP

Before determining the ATP value, respondents' income and expenses were analyzed. This analysis was made on respondents who passed through 4 roads that will be implemented ERP for car and motorcycle users.

The results of the analysis show that the characteristics of car users' income on four roads show that all of them are dominated by respondents with an income range of IDR6,000,000 - IDR8,999,999 and an expenditure range of IDR2,000,000 - IDR3,999,999, except in JL. MH Thamrin was dominated by respondents with expenses ranging from IDR4,000,000 - IDR5,999,999.

Meanwhile, respondents who use motorcycles on four roads are dominated by respondents with an income range of IDR3,000,000 - IDR5,999,999 and expenditure in the range of < IDR2,000,000.

Table 6 shows respondents' income and expenditure on four roads that ERP will implement for car and motorcycle users.

Furthermore, an ATP analysis was conducted on respondents who used cars and motorcycles on four roads, which will be implemented in ERP. The study's results showed an average ATP value of Rp 114,000/day. For motorcycle users, the average ATP value is IDR 89,800/day, while for car users, the average ATP value is IDR 136,500. This result shows that a high car ATP value is based on the average income of car users being more significant than that of motorcycle users or generally influenced by the financial ability of a person who travels. Financial resources are key factors affecting a person's ATP in general. Other potential factors include employment status, income level, financial obligations, and economic conditions [66]. The ATP approach considers various factors that affect a household's capacity to pay for services or goods received. These factors include primary and normative spending on food, housing, and utilities [67]. The ATP analysis on the four paths that ERP will implement is shown in Table 7.

4.3 WTP

Based on the results of WTP analysis, using three methods (DCM, TCM, RPM) showed varying values. The lowest WTP value was obtained in the RPM method with a tariff range of IDR 14,000 – IDR 16,000 for cars and IDR 7,000 – IDR 9,000 for motorcycles, while the highest value was obtained in the TCM method with a tariff range of IDR 27,000 – IDR 32,000 for cars and IDR 10,000 – IDR 12,000 for motorcycles. It indicates the complexity of assessing road user preferences. The variation is due to differences in methodological approaches and the specific factors considered in each method.

Table 6. Respondent's income and expenditure

Characteristic	Car Users (%)	Motorcycle Users (%)
Jl. Jend Sudirman		
Income		
IDR3,000,000 – 5,999,999	25.00	45.45
IDR6,000,000 – 8,999,999	41.67	27.27
IDR9,000,000 – 11,999,999	20.83	22.73
IDR12,000,000 – 14,999,999	6.25	4.55
IDR15,000,000 – 17,999,999	6.25	0.00
≥ IDR18,000,000	0.00	0.00
Expense		
< IDR2,000,000	0	54.55
IDR2,000,000 – 3,999,999	41.67	27.27
IDR4,000,000 – 5,999,999	20.83	9.09
IDR6,000,000 – 7,999,999	15.63	9.09
IDR8,000,000 – 9,999,999	10.42	0.00
≥ IDR10,000,000	11.46	0.00
Jl. Rasuna Said		
Income		
IDR3,000,000 – 5,999,999	16.36	40.00
IDR6,000,000 – 8,999,999	45.45	32.00
IDR9,000,000 – 11,999,999	21.82	16.00
IDR12,000,000 – 14,999,999	7.27	12.00
IDR15,000,000 – 17,999,999	9.09	0.00
≥ IDR18,000,000	0.00	0.00
Expense		
< IDR2,000,000	0	60.00
IDR2,000,000 – 3,999,999	50.91	12.00
IDR4,000,000 – 5,999,999	21.82	28.00
IDR6,000,000 – 7,999,999	16.36	0.00
IDR8,000,000 – 9,999,999	10.91	0.00
≥ IDR10,000,000	0.00	0.00
Jl. Gatot Subroto		
Income		
IDR3,000,000 – 5,999,999	10.29	43.75
IDR6,000,000 – 8,999,999	39.71	31.25
IDR9,000,000 – 11,999,999	20.59	9.38
IDR12,000,000 – 14,999,999	17.65	15.63
IDR15,000,000 – 17,999,999	11.76	0.00
≥ IDR18,000,000	0.00	0.00
Expense		
< IDR2,000,000	7.35	46.88
IDR2,000,000 – 3,999,999	29.41	40.63
IDR4,000,000 – 5,999,999	22.06	12.50
IDR6,000,000 – 7,999,999	17.65	0.00
IDR8,000,000 – 9,999,999	23.53	0.00
≥ IDR10,000,000	0.00	0.00
Jl. MH. Thamrin		
Income		
IDR3,000,000 – 5,999,999	18.18	32.00
IDR6,000,000 – 8,999,999	36.36	32.00
IDR9,000,000 – 11,999,999	30.91	36.00
IDR12,000,000 – 14,999,999	14.55	0.00
IDR15,000,000 – 17,999,999	0.00	0.00
≥ IDR18,000,000	0.00	0.00
Expense		
< IDR2,000,000	9.09	52.00
IDR2,000,000 – 3,999,999	18.18	32.00
IDR4,000,000 – 5,999,999	25.45	16.00
IDR6,000,000 – 7,999,999	21.82	0.00
IDR8,000,000 – 9,999,999	25.45	0.00
≥ IDR10,000,000	0.00	0.00

Table 7. ATP value on four roads that will be implemented ERP

Section Road	Car			Motorcycle		
	Average Income (IDR)	Average Expense (IDR)	ATP (IDR)	Average Income (IDR)	Average Expense (IDR)	ATP (IDR)
Jl. Jend. Sudirman	7,000,000	3,000,000	140,000	4,500,000	1,800,000	90,000
Jl. Rasuna Said	7,200,000	3,200,000	140,000	4,300,000	1,700,000	91,000
Jl. Gatot Subroto	6,800,000	3,000,000	133,000	4,200,000	1,600,000	91,000
Jl. MH. Thamrin	7,100,000	3,300,000	133,000	4,400,000	1,900,000	87,500

Note: 1. Investment cost/investment rate of 30% based on the average primary survey data to respondents; 2. Respondents' trip 5 times per week/20 times per month based on primary survey data to respondents

4.3.1 DCE

The first step in determining the DCE value is to calculate the fundamental value of the attribute, i.e., VoT/min. Then, the present travel time obtained from the average travel time of respondents to cross the road will be calculated, and the target time will be determined. Expected time is obtained by dividing the predicted vehicle speed by the length of the road. Vehicle speed using Level of Service (LoS) C, stable traffic flow with an average speed of 35 km/hr [68]. The results of the calculation of the fundamental value of the attribute are shown in Table 8.

Table 8. Results of the fundamental value of the WTP DCE attribute

Component	Car	Motorcycle
Jl. Jend Sudirman		
VoT/Min	IDR729	IDR469
Present travel time	35.08 min	25.05 min
Expected travel time	6.17 min	6.17 min
Jl. Rasuna Said		
VoT/Hr	IDR750	IDR448
Present travel time	34.91 min	24.30 min
Expected travel time	4.29 min	4.29 min
Jl. Gatot Subroto		
VoT/Hr	IDR708	IDR438
Present travel time	35.20 min	25.12 min
Expected travel time	9.43 min	9.43 min
Jl. MH. Thamrin		
VoT/Hr	IDR740	IDR458
Present travel time	34.81 min	23.87 min
Expected travel time	4.29 min	4.29 min

Table 9. Results of WTP DCE

Attribute	Weight*) (%)	Car (IDR)	Motorcycle (IDR)
Jl. Jend Sudirman			
Time-saving	50	10,540	4,425
Reliability	40	5,902	2,478
Comfort	10	1,265	425
Total WTP DCE	**100**	**17,455**	**7.328**
Jl. Rasuna Said			
Time-saving	50	11,484	4,482
Reliability	40	6,431	2,510
Comfort	10	1,378	538
Total WTP DCE	**100**	**19,293**	**7,530**
Jl. Gatot Subroto			
Time-saving	50	9,085	3,417
Reliability	40	5,088	1.914
Comfort	10	1,090	410
Total WTP DCE	**100**	**15,263**	**5,741**
Jl. MH. Thamrin			
Time-saving	50	11,387	4,758
Reliability	40	6,377	2,665
Comfort	10	1,366	571
Total WTP DCE	**100**	**19,131**	**7,944**

Note : *) based on a survey of respondents

Finally, the WTP value is determined using time-saving, reliability (consistency of travel time), and travel comfort. The weights of these three attributes were obtained from a survey of respondents. The results of the WTP DCE are shown in Table 9.

From the results of DCE, time-saving is very valuable for the people of Jakarta. It has the highest weight (50%) compared to reliability (40%) and comfort (10%). It is reinforced that people of Jakarta prefer to drive by private vehicles (cars/motorcycles) rather than public transportation, even though public transportation fares are very affordable. It is due to the socio-demographic conditions of the people of Jakarta, most of whom are workers with high-intensity working time pressure. Coupled with the distribution of public housing, which is mainly domiciled in the buffer cities around Jakarta (Bekasi, Depok, Tangerang), there are even those who live in Bogor. Time-saving is a critical component in setting road charging tariffs. Higher weight in time-saving suggests that travellers are willing to pay more to save time, which can justify higher tariffs [48]. This is particularly relevant in urban areas where congestion leads to significant time losses according to conditions in Jakarta.

The DCE value ranges from IDR 15,000 – IDR 19,000 for cars and IDR 5,700 – IDR 8,000 for motorcycles. From this value, it is possible to see how each attribute affects the consumer's decision and how much they are willing to pay more for improvements to each attribute. This value shows that the average person is willing to pay to go the ERP route, hoping for time savings, travel time consistency, and convenience, but some people will avoid it.

4.3.2 TCM

The results of the WTP TCM are shown in Table 10.

Following DCE, TCM also shows that time is very valuable for the people of Jakarta. Time costs have the highest value compared with fuel and maintenance costs because time savings can directly benefit road users in Jakarta. Besides that, according to research, fuel prices directly impact traffic flows, as evidenced by studies in New South Wales, where higher gasoline prices were found to reduce traffic flows, particularly during off-peak periods. This condition suggests that fuel costs are a significant consideration in road charging, as they influence the decision to use private vehicles versus public transport [38]. However, maintenance cost is less explicitly discussed when determining road charging rates. However, vehicle maintenance is implicitly a component of the overall cost of the car. These costs can affect the decision to use alternative modes of transportation when road charging is implemented [69].

Suppose the ERP tariff uses the TCM approach. In that case, some people are willing to spend an additional cost of around IDR 27,000 – IDR 32,000 for car users and IDR 10,000 – IDR 12,000 for motorcycle users to get time savings in passing through the roads. TCM can estimate how much travel costs are incurred by the people of Jakarta, so that the government can consider it when determining ERP rates to reduce vehicle density.

Table 10. Results of WTP TCM

Component	Car (IDR)	Motorcycle (IDR)
Jl. Jend Sudirman		
Fuel cost *)	5,184	1,440
Time cost	21,079	8,449
Maintenance cost *)	1,800	720
Total WTP TCM	**28,063**	**11,009**
Jl. Rasuna Said		
Fuel cost *)	3,600	1,000
Time cost	22,968	8,965
Maintenance cost *)	1,250	500
Total WTP TCM	**27,818**	**10,645**
Jl. Gatot Subroto		
Fuel cost *)	7,920	2,200
Time cost	18,170	6,834
Maintenance cost *)	2,750	1,100
Total WTP TCM	**28,840**	**10,134**
Jl. MH. Thamrin		
Fuel cost *)	7,920	2,200
Time cost	22,775	9,517
Maintenance cost *)	1,250	500
Total WTP TCM	**31,945**	**12,217**

Note : *) cost/km based on a survey of respondents

4.3.3 RPM

The WTP RPM's results are shown in Table 11.

Table 11. Results of WTP RPM

Road	Car (IDR)	Motorcycle (IDR)
Jl. Jend Sudirman	14,032	7,707
Jl. Rasuna Said	13,909	7,325
Jl. Gatot Subroto	14,420	7,094
Jl. MH. Thamrin	15,972	8,552

In implementing ERP in Jakarta, VoT is a crucial factor; with the addition of travel costs for travellers, there might be a shift in the use of transportation modes. So, in the count of WTP RPM, besides using the VoT factor, the elasticity of the vehicle is also used as a calculation factor. Brůhová Foltýnová et al. [52] states factors that influence road charging tariffs in urban areas, including vehicle elasticity, which refers to how sensitive the demand for road use is to changes in pricing. Key factors include the type of vehicles and the socio-economic characteristics of users. Compared to Jakarta's condition, which has vehicles dominated by private vehicles and the socio-economic conditions of the community value time very much, this can affect the implementation of ERP.

The RPM results, with travel costs as the basis by considering the elasticity of cars and motorcycles, are IDR 14,000 – IDR 16,000 for car users and IDR 7,000 – IDR 8,500.

4.3.4 Con-joint of three methods

In this study, to combine DCE, TCM, and RPM using AHP, the most important thing is a framework to estimate the weight of each method. Weights are obtained by analyzing each method based on established criteria (DR, IC, C, TR). Then, the weight of each method is calculated with several steps. Eq. (17) shows a pairwise matrix for criteria.

A pairwise matrix for each method by criterion's importance is shown in Eqs. (18)-(21).

$$\begin{array}{c} \\ DR \\ IC \\ C \\ TR \end{array}\begin{array}{c} \begin{array}{cccc} DR & IC & C & TR \end{array} \\ \begin{bmatrix} 1 & 3 & 2 & 4 \\ 0.25 & 1 & 0.5 & 2 \\ 0.25 & 2 & 1 & 3 \\ 0.25 & 0.5 & 0.7 & 1 \end{bmatrix} \end{array} \quad (17)$$

$$DR = \begin{array}{c} DCE \\ TCM \\ RPM \end{array}\begin{array}{c} \begin{array}{ccc} DCE & TCM & RPM \end{array} \\ \begin{bmatrix} 1 & 0.7 & 2 \\ 2 & 1 & 0.5 \\ 0.5 & 0.7 & 1 \end{bmatrix} \end{array} \quad (18)$$

$$IC = \begin{array}{c} DCM \\ TCM \\ RPM \end{array}\begin{array}{c} \begin{array}{ccc} DCE & TCM & RPM \end{array} \\ \begin{bmatrix} 1 & 2 & 3 \\ 0.7 & 1 & 0.5 \\ 0.5 & 0.7 & 1 \end{bmatrix} \end{array} \quad (19)$$

$$C = \begin{array}{c} DCE \\ TCM \\ RPM \end{array}\begin{array}{c} \begin{array}{ccc} DCE & TCM & RPM \end{array} \\ \begin{bmatrix} 1 & 3 & 2 \\ 0.3 & 1 & 0.5 \\ 0.7 & 2 & 1 \end{bmatrix} \end{array} \quad (20)$$

$$TR = \begin{array}{c} DCE \\ TCM \\ RPM \end{array}\begin{array}{c} \begin{array}{ccc} DCE & TCM & RPM \end{array} \\ \begin{bmatrix} 1 & 2 & 3 \\ 0.2 & 1 & 0.7 \\ 0.5 & 2 & 1 \end{bmatrix} \end{array} \quad (21)$$

Then, normalize the matrix and calculate the vector priority. Eq. (22) shows the normalization matrix and vector priority for the criteria.

$$\begin{array}{c} DR \\ IC \\ C \\ TR \end{array}\begin{bmatrix} 0.5 & 0.462 & 0.476 & 0.4 \\ 0.125 & 0.154 & 0.119 & 0.3 \\ 0.250 & 0.308 & 0.238 & 0.3 \\ 0.125 & 0.077 & 0.167 & 0.1 \end{bmatrix}\begin{bmatrix} 0.459 \\ 0.149 \\ 0.274 \\ 0.117 \end{bmatrix} \quad (22)$$

Then, Eqs. (23)-(26) shows the normalization matrix and vector priority for each method for each criterion.

$$DR = \begin{array}{c} DCE \\ TCM \\ RPM \end{array}\begin{bmatrix} 0.286 & 0.292 & 0.571 \\ 0.571 & 0.417 & 0.143 \\ 0.143 & 0.292 & 0.286 \end{bmatrix}\begin{bmatrix} 0.383 \\ 0.377 \\ 0.240 \end{bmatrix} \quad (23)$$

$$IC = \begin{array}{c} DCE \\ TCM \\ RPM \end{array}\begin{bmatrix} 0.455 & 0.541 & 0.667 \\ 0.318 & 0.270 & 0.111 \\ 0.227 & 0.189 & 0.222 \end{bmatrix}\begin{bmatrix} 0.554 \\ 0.233 \\ 0.213 \end{bmatrix} \quad (24)$$

$$C = \begin{array}{c} DCE \\ TCM \\ RPM \end{array}\begin{bmatrix} 0.5 & 0.5 & 0.571 \\ 0.15 & 0.167 & 0.143 \\ 0.35 & 0.333 & 0.286 \end{bmatrix}\begin{bmatrix} 0.524 \\ 0.153 \\ 0.323 \end{bmatrix} \quad (25)$$

$$
TR = \begin{array}{c} DCE \\ TCM \\ RPM \end{array} \begin{bmatrix} 0.588 & 0.400 & 0.683 \\ 0.118 & 0.200 & 0.149 \\ 0.294 & 0.400 & 0.213 \end{bmatrix} \begin{bmatrix} 0.542 \\ 0.156 \\ 0.302 \end{bmatrix} \qquad (26)
$$

The final step is a consistency test for each matrix. If the CR value is less than 0.1, then it is consistent. Table 12 shows the result of the consistency test.

Table 12. Consistency test

Matrix	Consistency Ratio (CR)
Criteria	0.084
Reliability	0.055
Implication Cost	0.052
Relativeness	0.079
Temporal Relevance	0.066

To get the final weights in each method, multiply each method's weight for each criterion by the criterion's importance:

For DCE:

(0.383×0.459)+(0.554×0.149)+(0.524×0.274)+(0.542×0.117) = 0.4653

For TCM:

(0.377×0.459)+(0.233×0.149)+(0.153×0.274)+(0.156×0.117) = 0.2679

For RPM:

(0.240×0.459)+(0.213×0.149)+(0.323×0.274)+(0.302×0.117) = 0.2657

The results of the combined estimation of WTP values using the SP RP method are for car users, as seen in Figure 5. The results of the combined estimation of WTP for motorcycles are in Figure 6.

From the results of the WTP estimation with the combination of the SP RP method, the WTP value for cars is in the range of IDR 18,000 – IDR 22,000, while for motorcycles, it is in the range of IDR 7,000 – 9,500. These results are calculated comprehensively, and various factors from each method are considered with a certain weight. Factors that affect the calculation include user preferences with the attributes that affect them, user travel costs, and user behaviour that considers the characteristics and sociodemographics of the people of Jakarta.

Zhou et al. [70] revealed that combining the SP RP method in WTP calculation can provide high accuracy and comprehensive analysis. Enhanced accuracy because SP data can capture preferences for non-market goods or hypothetical scenarios, while RP data provides validation through actual consumer behaviour. Also, combining SP RP allows for a more holistic view of consumer preferences, incorporating hypothetical and real-world elements.

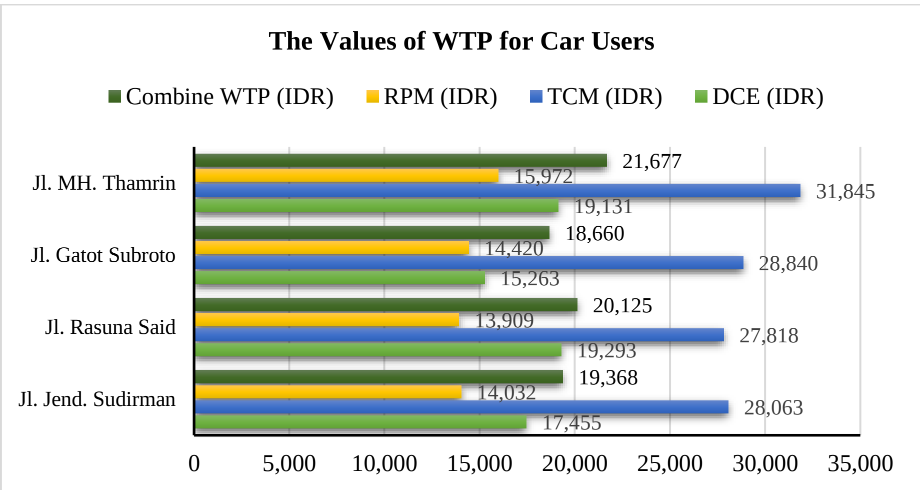

Figure 5. The results of the combined estimation of WTP values for car users

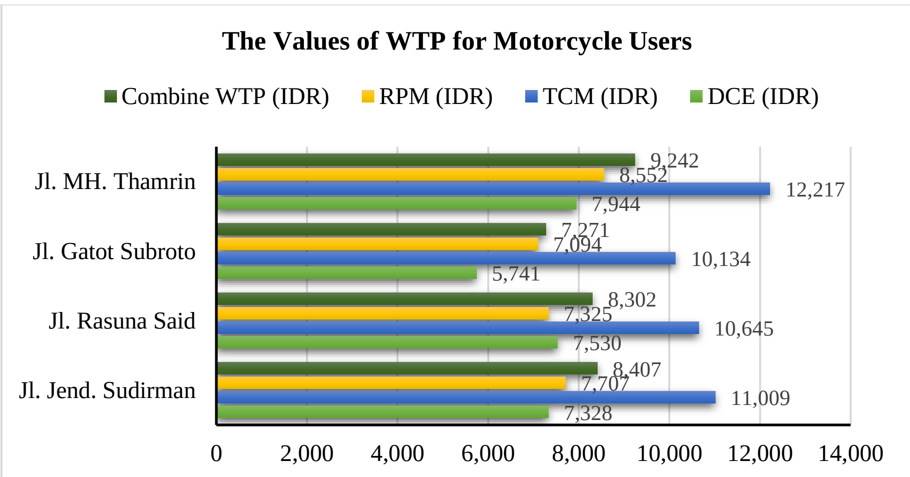

Figure 6. The results of the combined estimation of WTP values for motorcycle users

4.3.4 The sensitivity test

A sensitivity test in WTP enhances research accuracy by assessing how changes in model specifications or assumptions affect estimated scope elasticities [34]. The sensitivity test was conducted on a 10%, 15%, and 20% tariff change with an alteration elasticity coefficient of -0.2, -0.4, -0.6, and -0.8. The results of the sensitivity test are shown in Figure 7.

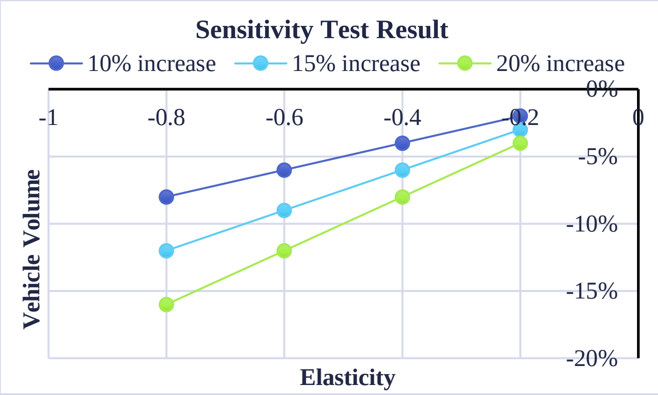

Figure 7. The result of the sensitivity test

Sensitivity analysis reveals how economic prices interact with transportation behaviour. When examining the demand response, we observe a very consistent pattern. For every one percent increase in fares, vehicle volume decreases by about 0.3 percent, a relationship that demonstrates the economic principles underlying transportation choices. This linear elasticity suggests that users are not passive recipients of fare changes but active decision-makers who carefully consider the financial implications of their transportation decisions.

The data shows that fare modification is a powerful tool to influence behaviour. By understanding the exact elasticity of demand, policymakers can devise sophisticated strategies that simultaneously achieve multiple objectives. Carefully calibrated fare increases have the potential to reduce traffic congestion, generate additional revenue, and encourage more sustainable transportation alternatives- all while maintaining a predictable and manageable impact on user behaviour. Based on the results of this sensitivity test can be used as a basis for the implementation of a dynamic pricing scheme. The tariff can be increased dynamically if the congestion has reached a critical point.

The economic implications are not limited to direct behavioural responses. Consistent elasticities suggest a rational economic decision-making process among vehicle users. Individuals make transportation choices through careful calculation, considering the incremental costs to their mobility needs, where a fare increase may trigger a change in transportation behaviour.

Critically, by understanding the exact elasticity of demand, urban planners and policymakers can design more comprehensive policies. They can anticipate how certain fare adjustments affect overall transportation patterns, potentially reducing negative economic impacts while achieving broader urban mobility goals.

4.3.5 ATP and WTP comparison

Several conditions may occur [71], i.e.:

1) ATP > WTP

It demonstrates that the ability exceeds the desire to pay for services. It occurs when most people have high revenue, but the perceived utility of the service is relatively low. In this case, the user is referred to as a chosen rider or someone with the freedom to choose.

2) ATP < WTP

It indicates that the user's desire to pay for the service outweighs their ability. Users with lower incomes may still strongly prefer the service, with their willingness to pay being more driven by the utility they derive from it. In such cases, the user is referred to as a captive rider.

3) ATP = WTP

It indicates that the people's ability and willingness to pay for the services are equal. In this scenario, there is an equilibrium between the benefit the user gains and the expense they bear to pay for the service.

There are sometimes discrepancies between ATP and WTP when determining tariffs. The study found that the average value of ATP is higher than the WTP (ATP > WTP). It shows that the ability to pay Jakarta society is high. However, their willingness is low, and not by their ability.

5. DISCUSSION

One of the interesting findings in this study is the significant difference between WTP and ATP. In general, the results of all WTP methods, even their combinations, show that the people of Jakarta have relatively low rates of WTP compared to their ability to pay ATP. Even with high payment ability, Jakarta people are reluctant to pay ERP. The notable disparity between WTP and ATP in Jakarta's context can be discussed by the prospect theory formulated by Kahneman and Tversky [72]. In theory, decisions are not always rational in an economic sense. Several psychological factors may contribute to Jakarta citizens' reluctance to pay ERP despite their high payment ability. One factor could be loss aversion, where the pain of losing money (paying ERP) is perceived as greater than the pleasure of gaining benefits (reduced traffic congestion) [73]. Framing effects also play a role. Suppose the ERP is framed as a loss (a tax or a fee) rather than a gain (an investment in better traffic management). In that case, it may lead to a lower willingness to pay [74]. Based on this theory, policymakers may need to consider these behavioural aspects when designing and communicating about the ERP system to increase public acceptance and willingness to pay [75].

The discrepancy between ATP and WTP has important implications for policy design, particularly concerning equity and public acceptance [76]. In equity, people have the financial means to pay when ATP exceeds WTP. However, they are unwilling to do so because the perceived benefits (such as time savings or reduced congestion) may not justify the cost [77]. Moreover, this discrepancy can create inequities. For instance, high-income individuals (with higher ATP) might not feel the need to pay. Lower-income individuals (who may have a lower ATP but a higher WTP due to stronger reliance on the service) could be disproportionately affected by high tariffs. This could lead to a regressive pricing structure that burdens those with lower incomes despite having a higher inclination to pay for service improvements. In public acceptance, the discrepancy between ATP and WTP can affect this acceptance. For instance, if policies are not adjusted to align the pricing with actual usage behaviour (WTP), people may view the policy as unfair, leading to decreased support and engagement [42]. Ensuring that public transport options are enhanced and affordable alternatives are available is crucial to alleviate concerns from low-income groups, improving overall public acceptance.

Suppose ERP is implemented later with a fixed-cost scheme. In that case, it is necessary to assess its implementation because there is a discrepancy between ATP and WTP. If inefficiencies are found, implementing a dynamic fare system can address these differences by adjusting costs based on times, travel routes, or congestion levels. Jia et al. [78] revealed that implementing ERP with the characteristics of road users dominated by private vehicles with an average travel pattern of five times per week and implementing a dynamic fare system is effective in overcoming congestion. However, in its implementation, individual traveller information (e.g., demographics, income, expenses, travel costs) should be considered to improve the effectiveness of the ERP scheme. Anjomani [79] also argues that the effectiveness of the pricing scheme is determined by evaluating the demographic factors in addition to the available transportation system and environmental factors. ERP dynamic schemes offer promising solutions for urban traffic management, but challenges remain in their implementation. These include the need for robust data collection and analysis systems, public acceptance, and integration of such schemes with broader urban planning and environmental goals.

As a pioneer in ERP, Singapore's system is very sophisticated, using real-time data to adjust pricing dynamically based on traffic conditions [1]. London and Stockholm also effectively implement ERP, which can reduce congestion and emissions. The effectiveness of ERP depends on the availability of supporting infrastructure, such as efficient public transport systems and modern ticketing technologies [80]. Suppose a dynamic pricing scheme would be implemented in Jakarta. In that case, careful planning and adaptation to local conditions in Jakarta is needed. Jakarta's unique challenges, such as high population density, traffic congestion, immature public transport, and various income societies, may require tailored solutions rather than direct comparisons with other countries' systems. Leveraging computing technologies and models that can help ERP effectiveness is also very important. In addition, considering that Jakarta has just started ERP, data implementation in Jakarta is very limited. Most data collected is limited to interviews with potential user respondents, which should also get attention.

Although this study contributes useful insights into ERP implementation in Jakarta, various methodological limitations should be carefully considered. Firstly, the research applies to only a sample of 400 respondents, which can’t reflect all segments of Jakarta's diverse population, even with sound sampling methodologies. Although scientifically valid, the stratified random sampling might induce selection biases that could affect the findings.

Additionally, the study is limited to several road sections in Jakarta's central business district. Though important to the city's transportation infrastructure, these roads may not capture the full breadth of the urban transportation ecosystem. The specificities of these roads, including their economic relevance, integration with mass transit systems, and particular traffic patterns, may not be fully generalizable to the rest of Jakarta or other Indonesian cities.

Finally, more subtle ATP and WTP realizations include methodological insights in the pricing mechanism design. Even though the metrics are actionable, the alarming gap between these two measures indicates that user behaviour can’t be predicted by economic models alone. There are important psychological dynamics, framing effects, and individual perceptions that cannot be perfectly quantified.

These concerns should not detract from the study's importance. However, they reflect the complicated nature of urban transportation research. Their unique contributions emphasize the importance of continued, multi-method research approaches to reflect the nuanced realities of urban mobility in rapidly developing cities such as Jakarta.

6. CONCLUSION

These findings, particularly the gap between ATP and WTP, contribute valuable knowledge that can be applied to other regions in Jakarta or similar congested cities. In highly populated and congested urban contexts like Jakarta, the critical gap between the ATP and WTP is usually one of the most obvious challenges in actualizing congestion charging schemes. These findings suggest that even if individuals have the financial ability to pay, their reluctance is attributed to psychological factors such as loss aversion and framing effects. Consequently, such challenges may also be replicated in cities with similar demographic and socio-economic characteristics, rendering the behavioural insights of this study extensible to wider urban environments where road pricing schemes are proposed. When making inferences about other areas, these findings must be qualified by local considerations, such as income inequality and public transportation availability.

Future studies should investigate the effects of ERP on traffic behaviour and public behaviour in the long run. Determining how dynamic pricing schemes impact congestion levels in the longer term and whether they meaningfully encourage behaviour changes, like switching to public transportation or changing travel hours, would be necessary to overcome this issue. In addition, further studies should be conducted on public acceptance of dynamic ERP systems and factors which cause people's opinion of fairness to change and designs of ERP systems that can enhance parity.

Integrating ERP with wider urban planning goals is an important area for future research. We must consider demographic details and travel conditions to develop a dynamic pricing system. Future studies could focus on developing models that better predict user behaviour regarding income levels, travel habits, and socio-economic factors, thus creating a framework for a more targeted and fair pricing structure. Moreover, studies should investigate the effect of ERP on environmental targets, such as emissions reduction, and how systems can be designed to meet traffic control and sustainability targets.

Finally, given that ERP implementation is still very early in Jakarta, detailed post-implementation evaluations are necessary to establish how well the system works. These studies need to focus on evaluating the effectiveness of mechanisms for data gathering, the infrastructural support needed for the dynamic pricing scheme, and public response to them. This research would be a necessary step before making enhancements to ERP in Jakarta and other cities facing similar urban problems.

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