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The Electronic Road Pricing System Planning: A Scenario of Curbing Congestion Issues on an Arterial Road in Makassar City, Indonesia

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Abstract

This study aims to analyze the traffic performance on arterial roads in Makassar City in the present and future with the implementation of Electronic Road Pricing, as well as how many tariffs can be applied when Electronic Road Pricing (ERP) is used. The data were collected from traffic surveys and questionnaires distributed to users of four-wheeled and two-wheeled vehicles. From the data, the existing traffic conditions on the road were analyzed, and the probability of moving road users was calculated during the implementation of ERP. Furthermore, the Willingness To Pay method determines the rates that can be applied. The research results show that when ERP is implemented on the Andi Pangeran Pettarani Road, there will be a 40% reduction in traffic flow due to the route changes and a 42% reduction in traffic flow due to the modal shifts. This affects improving traffic performance in the future, where the existing condition of this road segment which was initially at LoS D and E, can be increased to LoS B and C. The tariff that can be applied to the ERP system is Rp 8,838 for four-wheeled vehicles or more and Rp 4,343 for two-wheeled vehicles

1. INTRODUCTION

Makassar City is one of the metropolitan cities in Indonesia, which is also the capital of South Sulawesi Province. The rapid growth of government, trade, and industrial sectors in several cities caused the population to increase. Based on data from the Central Statistics Agency of South Sulawesi, it is predicted that the population number in Makassar city will be 1,571,814 in 2022 (Central Bureau of Statistics for South Sulawesi Province, 2022). The significant population growth of Makassar City causes the high ownership of private vehicles. Cities in developing countries with inadequate public transportation force their residents to use personal vehicles; therefore, the number of private vehicle owners is high (Hasim et al., 2019). The increase in the number of vehicles causes an increase in traffic flow, and this will affect the ability of the road to accommodate the flow of vehicles, resulting in a decrease in road performance (Anton, 2020). This is one of the causes of traffic congestion problems that are getting worse from year to year.

One of the traffic-heavy roads and part of Makassar's primary arterial road network is Jalan Andi Pangeran Pettarani (Makassar Regional Development Planning Agency, 2015). Andi Pangeran Pettarani Street is one of the main streets in Makassar city that links several streets to commercial districts, schools, universities, government offices, and social facilities. Based on a preliminary survey and information obtained from the Land Transportation Management Center of the Ministry of Transportation of Makassar City, the level of service of the A.P. Pettarani road segment is at level D during peak hours of congestion. The effective capacity of the A, P. Pettarani road section is lower than the design capacity due to roadside friction and the high growth rate of vehicles (Hasanuddin, 2018). Lolo et al. (2019) found that street vendors are spreading across several points on A.P. Pettarani street that occupies sidewalks and roadsides to form business facilities as their alternative creation on the conventional job and also a means of support for the urban poor (Anies & Kasim, 2022). This kind of roadside friction can influence road traffic performance and its level of service. In addition, Suruji (2018) also found that the congestion polemic that occurred in Makassar was caused by factors such as stubborn drivers, vehicles that parked on the shoulders and body of the road and seizing the rights of other

drivers. For this reason, a solution is needed to reduce the number of private vehicles user so that heavy traffic can be avoided. One solution that can be pursued is the application of Congestion Pricing. Congestion pricing is an additional fee or levy imposed on motorists when passing certain roads due to the driver's time of existence which causes congestion for other road users (Mohring, 1996). For decades, the standard method for reducing congestion was by forecasting traffic increase and then constructing enough road capacity to accommodate it. In the UK, this approach was abandoned in the 1990s due to evidence that new capacity soon fills up with additional traffic (Cervero, 2003). Other approaches to curb congestion have been tested around the world, including land-use planning, odd-even license plate limits on car use, and more, but these are expensive to implement and also blunt instruments for dealing with congestion because road-building makes driving more attractive and will encourage more driving (Lindsey, 2012).

In Indonesia, the basis for applying traffic control levies has been stated in several policies, such as in Government Regulation no. 97 of 2012 and Law no. 22 of 2009. Congestion pricing is the most effective way to overcome congestion (Agarwal et al., 2015). Electronic Road Pricing (ERP) is another name for congestion pricing. In the ERP system, every vehicle that passes through the road during peak hours requires electronic retribution to cross the street. Road pricing is described as the first best approach to Travel Demand Management (Saleh & Sammer, 2009). Travel demand management (TDM) is an effort to influence the travel behavior of road users in determining the choice of mode, length of trip, frequency of trips, and routes (Ison & Rye, 2008). TDM encourages road users to reduce relatively unnecessary trips, especially private vehicles and promotes using more effective modes of transportation, and one of them is the ERP approach. ERP systems have been implemented to cope with traffic in metropolitan cities and effectively reduce the number of vehicles entering a specific zone (Rizal et al., 2018). The congestion pricing concept has been widely applied to downtown roads in developed countries, such as Singapore, London, Stockholm, Milan, and Gothenburg (Lehe, 2019). In Indonesia, the ERP system has not been implemented at all in any city. ERP system has been planned to be implemented in Jakarta, state the capital of Indonesia, for the first time, and the Jabodetabek Transportation Management Agency (BPTJ) initially targeted this system to be implemented in 2020 (Anwar, 2020; Yuniartha, 2020). However, based on information from the Jakarta Transportation Agency's Electronic Paid Road System Management Unit, the ERP implementation has been postponed and will begin in 2023 (Simorangkir et al., 2021). ERP received a positive response from road users in Jakarta and can be immediately implemented to measure its effectiveness (Rifai et al., 2021). The positive response obtained for the ERP implementation plan in Jakarta and the effectiveness of the ERP system in overcoming traffic problems in metropolitan cities prompted a study to see the possibility of implementing ERP in Makassar City. ERP is expected to be a solution to overcome congestion polemics at several congestion-prone points in Makassar City. This study was conducted to know how if ERP was implemented in one segment of Makassar City. How it affects road traffic performance, and how much the rates can be applied if the policy is implemented. The ERP system implementation policy will be later expected to result in a win-win solution. Not only for service users who paid but also for the wider community and those who are willing to switch to public transportation. The road facilities are easier for those who can afford to pay to utilize. Meanwhile, those who wish to avoid using other own vehicles can take use of reliable, comfortable, punctual, and reasonably priced public transportation.

2. METHODS

Electronic Road Pricing was first introduced in Singapore in 1975, using a manually-paid scheme (Ng & Samuel, 1999, as cited in Rizal et al., 2018). Since then, the road pricing scheme has undergone many changes. Over the past 30 years, it has changed from being a manual scheme based on paper permits that were only relevant during the morning peak period to an electronic system that is now in use nearly all day (Chin, 2005). Establishing ERP is thought to be a successful strategy for implementing traffic limitation schemes, which have been done so in several major cities, including Singapore, Stockholm, and London (Selmoune et al., 2020). The application of costs for congestion drove a 53% reduction of fully chargeable traffic in 2007 at the cost of congestion of £ 8 in London and a 79.8% reduction in 2011 with a congestion fee of € 2 in Milan (Croci,

2016). Furthermore, positive impacts have also been in reducing emissions and road accidents in the area. In addition to having a good impact, ERP also has a negative one, such as in Singapore, retail real estate prices in the cordoned area could decrease by 19% as a result of the ERP toll charge increase of S$1 per car (Agarwal et al., 2015). According to Menon & Guttikunda (2010), the ERP system could be successful in big cities if they provide a widely accessible public transportation system that can facilitate the transition to car-free transportation. ERP implementation in a city can be done when the condition of all road sections is by urban road design standards, and driver behavior follows the rules the driver follows the rules (Bandung City Department & of Transportation, 2016). Therefore, the implementation of ERP can be carried out in cities in Asia if these considerations have been fulfilled.

This research was conducted in one of the primary arterial road networks in Makassar, Jalan Andi Pangeran Pettarani, Makassar City, South Sulawesi Province. The boundary of the road to be studied is the road from the intersection of Boulevard street to the junction of Jalan Raya Pendidikan Makassar City. Based on a preliminary survey and information obtained from the Land Transportation Management Center of the Ministry of Transportation of Makassar City, the level of service of this road section is at level D during peak hours of congestion. This road section was chosen as the research location because, apart from the unstable traffic conditions at certain hours, there are alternative roads that can be considered for vehicle users to pass when the ERP is implemented.



Figure 1. Map and Traffic Condition of The Research Location.

This research was conducted in several stages. The first stage was through a preliminary study. The initial research began by conducting a site survey and checking the peak hour of the location under study. Furthermore, primary data was collected to obtain traffic flow and questionnaire data. Traffic data was obtained through surveys carried out for three days, on Monday, Wednesday, and Saturday, during peak hours, and questionnaire data were obtained by distributing questionnaires to respondents. Questionnaire distribution will be carried out after the traffic survey is completed due to the determination that the number of samples to be calculated is based on the number of vehicles passing A.P. Pettarani street. From the 3-day traffic survey, the highest number of vehicles was obtained in the survey conducted on Monday afternoon with a total of 8,421 veh/hour. This data was used as the basis for calculating the sample. Thus, the sample was determined to be 382 respondents. The data collected from the questionnaire included socio-demographic data and several questions related to the use of A.P. Pettarani street, response to the implementation of electronic road pricing in the future, and perceptions of modal and route shifts. Socio-demographic data, perception regarding the distribution of road pricing revenue, and other traffic management measures were also used by Rentziou et al.

(2011) as independent variables in their models. The secondary data consists of the layout of A.P. Pettarani street and the latest Makassar City GDP data. Data analysis was done after the information had been gathered. Several stages of analysis were carried out in this study. The first was to analyze the traffic performance of existing and future conditions. This analysis used the 1997 IHCM standard for counting the traffic performance of an existing condition. For traffic performance forecasting in the next five years, the analysis was calculated based on population growth data obtained through GRDP. Furthermore, an analysis of traffic conditions with the implementation of the ERP system was carried out. This analysis was conducted based on the results of the respondent's data calculated using binary logistic regression analysis. In a study conducted by Wang et al. (2017), the logit model was used to examine the influence of several socio-psychological characteristics on the likelihood that the policies relating to the electric vehicle would be adopted. Binary Logistics is an analytical method to analyze the discrete nature of receipts whose questions only have yes or no answers (Sunitiyoso et al., 2020). The result of this analysis would show the possibility of users switching routes and modes by users when ERP is implemented. After implementing the ERP system, a re-check of traffic performance on the road is carried out at A.P. Pettarani street to find out if the ERP system makes the Level of Service (LOS) better or not. Furthermore, the final analysis determines how much tariffs can be applied to four-wheeled and two-wheeled vehicles when the ERP is implemented based on the Willingness to Pay value. This analysis is calculated based on respondent data who chose the nominal listed in the distributed questionnaire.

3. RESULT AND DISCUSSION

Traffic performance analysis was carried out based on the Indonesia Highway Capacity Manual (Indonesian Directorate General of Highways of Indonesia, 1997). From the results of data analysis, the average volume of vehicles at peak hours in the morning is 3190 pcu/hour, and peak hours in the afternoon is 4060 pcu/hour. Analysis of traffic performance in 2022 on Andi Pangeran Pettarani is measured based on the parameter in the form of Volume Capacity Ratio (VCR). The calculation results of the degree of saturation can be seen in Table 1.

Table 1 shows that the level of service (LOS) for the existing condition on weekdays is at levels D in the morning and E in the afternoon. Meanwhile, on weekends, the service level is still at level C in the morning, but the service condition worsens at levels D to E in the afternoon. Traffic performance is adjusted to the level of service category that has been regulated, where level C is the level of service level for VCR 0.45 to 0.70, level D for VCR 0.70 to 0.85, and level E for VCR 0.85 to 1.00 (Ministry of Transportation of Indonesia, 2006). Existing condition data shows that on weekdays, the traffic flow conditions in the morning on this road are approaching unstable, and drivers begin to experience short-duration traffic jams in the afternoon. Meanwhile, on weekends, the flow conditions are still stable in the morning, although a higher traffic volume will control the speed and movement of vehicles. Leading to the afternoon, the traffic flow conditions are approaching unstable, and drivers also start to feel short-duration traffic jams.

Table 1. Analysis of Volume Capacity Ratio of Andi Pangeran Pettarani street

Day	Time	Sg	Vehicle Vol. PCU/Hour				Vol. PCU/hour	Capacity PCU/Hour	VCR
			LV	HV	MC	UM			
Week day	Morning	1	2102	36	5170	38	3510	4562	0,77
		2	2267	26	5267	22	3710	4752	0,78
	Afternoon	1	2789	52	5405	33	4224	4562	0,93
		2	2560	35	5661	26	4107	4752	0,86
Week end	Morning	1	1367	55	3280	22	2258	4562	0,49
		2	1546	28	4088	22	2606	4752	0,55
	Afternoon	1	2575	50	5441	41	4005	4562	0,88
		2	2479	46	5157	39	3833	4752	0,81

From the traffic data, the existing conditions were analyzed for traffic conditions in 5 years. The traffic volume prediction in the next five years is influenced by the GRDP of Makassar, so traffic predictions are analyzed using this data. Where to obtain a forecast of future traffic volume is used the formula:

$$P_n - P_o\,(1+r)^n \qquad (1)$$

Traffic performance for the next five years (2023-2027) can be seen in Table 2. Based on the existing condition data, the traffic volume on the A.P. Pettarani road is predicted to increase every year and reach the traffic saturation point because it reaches VCR > 1. It means the Level of Service is at level F, long and very high traffic density and low volume and congestion occur for quite a long duration (Ministry of Transportation of Indonesia, 2006). This condition makes traffic on A.P. Pettarani to be hampered. Therefore, ERP implementation is expected to reduce traffic volume in the future.

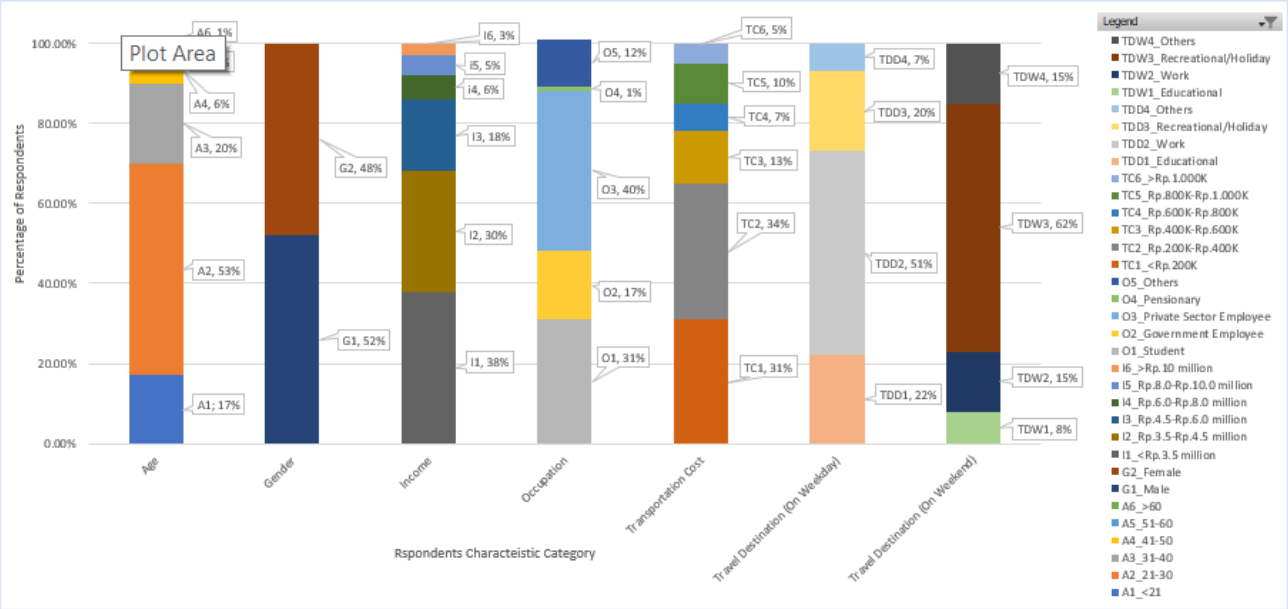
Table 2 Traffic Performance predictions for five years

Day	**Time**	**Sg**	**VCR**				
			2023	**2024**	**2025**	**2026**	**2027**
Weekday	Morning	1	0.81	0.86	0.91	0.96	1.02
		2	0.83	0.87	0.92	0.98	1.03
	Afternoon	1	0.98	1.03	1.09	1.16	1.22
		2	0.91	0.97	1.02	1.08	1.14
Weekend	Morning	1	0.52	0.55	0.58	0.62	0.65
		2	0.58	0.61	0.65	0.69	0.72
	Afternoon	1	0.93	0.98	1.04	1.10	1.16
		2	0.85	0.90	0.95	1.01	1.07

Furthermore, traffic volume calculations are carried out when ERP is implemented. This analysis was carried out using logistic regression analysis, whose data were obtained through the results of respondents from the questionnaires that had been distributed. Wang et al. used the logit model to investigate the influence of several socio-psychological factors on the likelihood of acceptance of policies related to electric vehicles (Wang et al., 2017). Mehrolia et al. also studied perceptions of delivery services during the Covid-19 pandemic through binary logistics (Mehrolia et al., 2021). The logistic regression formula used is:

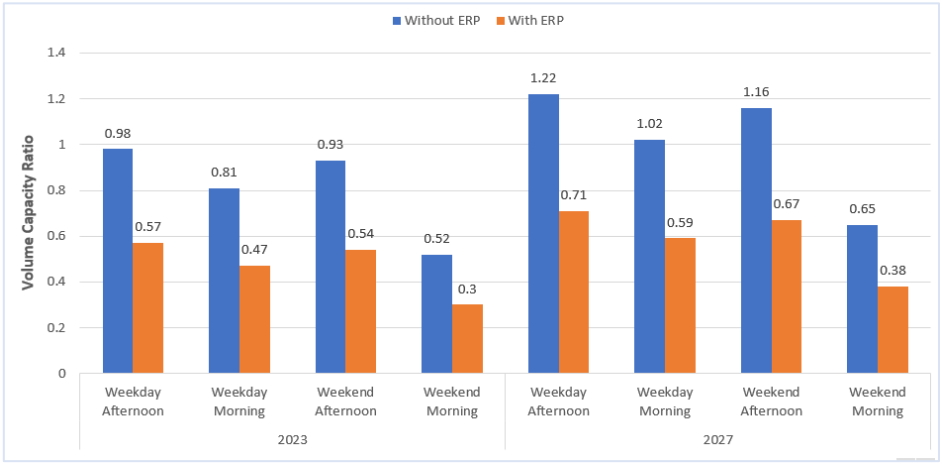
$$\text{Logit (p)} = \frac{e^{-(\alpha + \beta 1X1 + \beta 2X2 + \cdots..)}}{1+e^{-(\alpha + \beta 1X1 + \beta 2X2 + \cdots..)}} \qquad (2)$$

The dependent variable in this logistic regression model consists of perceptions of route changes and mode shifts. In contrast, the independent variables consist of gender, age, occupation, income, transportation costs, travel destinations during weekdays and weekends, the mode used, ability to pay, and the type of mode used if changing. An overview of the results of the questionnaire data by respondent shows in Graph 1.

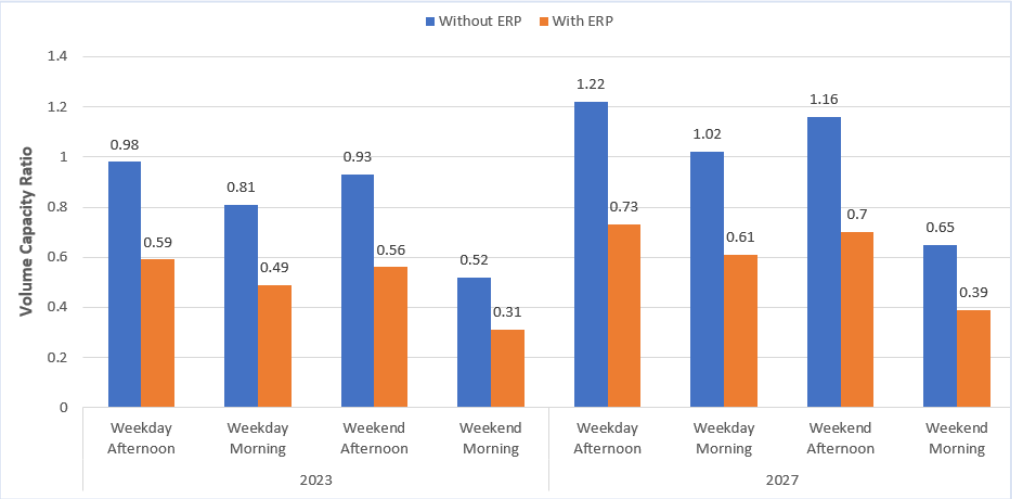


Graph 1. Characteristic of Respondents

Based on the results of the analysis of the binary logistic function, it was found that 204 users of A.P. Pettarani are not willing to pay for the ERP, of which 159 respondents were correctly predicted to change routes, and 45 respondents were incorrectly predicted/had the possibility of not moving. Meanwhile, road users willing to pay for the ERP on A.P. Pettarani street were 178 respondents, including 122 respondents precisely predicted to stay through the street, while 56 respondents wrongly predicted/could move. The analysis found that after ERP implementation, based on the perception of route change, there was a 42% reduction in traffic volume, so traffic performance in the next five years can be estimated to increase due to the volume capacity ratio decreased, as shown in Graph 2. While based on the perception of mode shift, there will be a 40% reduction in traffic volume when ERP implementation is implemented so that traffic performance in the next five years will increase, as shown in Graph 3.



Graph 2. Comparison of traffic performance predictions in Segment 1 for the next five years in conditions without and with ERP intervention based on the perception of route shifts



Graph 3. Comparison of traffic performance predictions in Segment 1 for the next five years in conditions without and with ERP intervention based on the perception of mode shifts

Based on the graph of the perception of route shifts and perceptions of mode shifts, it can be seen that ERP implementation effectively reduces traffic volume on A.P. Pettarani street. It reached the level of service (LOS) F in 2027 but can increase to level C with ERP implementation.

In implementing ERP, it is necessary to have the correct value for the application of costs for motorists who will pass A.P. Pettarani street. For this reason, the Willingness to Pay (WTP) method predicts what tariffs can be applied. WTP is the willingness of road users to spend a certain amount of money to be paid if they pass A.P. Pettarani street to implement ERP. Can be calculated using the formula:

$$WTP = \frac{\Sigma(\text{selected rate x number of respondents})}{Total\ Respondents} \quad (3)$$

The analysis of WTP was carried out based on data from 382 respondents who had chosen the nominal contained in the distributed questionnaire. Based on the results of the study, the WTP values for 4-wheeled and 2-wheeled vehicles are as follows:

Table 3 Distribution of WTP Value of 4-Wheeled Vehicles

Value of WTP	Total Respondents	Cumulative percent	Total
Rp 12.000	9	2%	Rp 0,283
Rp 10.000	142	37%	Rp 3,717
Rp 8.000	231	60%	Rp 4,838
	Total		Rp 8,838

Table 4 Distribution of WTP Value of 2-Wheeled Vehicles

Value of WTP	Total Respondents	Cumulative percent	Total
Rp 6,000	9	2%	Rp 0,141
Rp 5,000	113	30%	Rp 1,479
Rp 4,000	260	68%	Rp 2,723
	Total		Rp 4,343

Based on Tables 3 and 4, the average WTP value of respondents for 4-wheeled vehicles or more is Rp 8,838, and for 2-wheeled vehicles is Rp 4,343. The average value of the respondents' WTP obtained can determine the number of tariffs in the ERP policy on Jalan A.P. Pettarani.

Annual tariff adjustments to the Electronic Road Pricing policy on Jalan A.P. Pettarani Makassar City can be adjusted to the guidelines of the Toll Road Regulatory Agency (BPJT). BPJT evaluates and adjusts tariffs every two years based on the inflation rate and evaluates compliance with SPM (Minimum Service Standards) on toll roads or other paid roads (Republic of Indonesia, 2022).

4. CONCLUSIONS

The results of data analysis show that on the existing traffic conditions on A.P. Pettarani, the traffic flow was approaching unstable with Level of Service D on weekdays morning. It heads to level E in the afternoon, so drivers begin to experience short-duration traffic jams. Meanwhile, on weekends, traffic conditions remained stable in the morning with Level of Service C, although vehicle speed and movement were controlled by higher traffic volume. However, when it led to the afternoon, the traffic flow condition was approaching unstable, and there was short-duration congestion with Level of Service E. If this condition is not resolved immediately, the traffic conditions will worsen in 2027. The traffic performance forecasting results show that in 2027 the flow would reach traffic saturation because it reached VCR > 1 at Level of Service F.

The analysis result of a perception of route change and perception of mode shift shows that ERP implementation could solve this condition. It can be seen that by ERP implementation, traffic volume on the A.P. Pettarani was effectively reduced. The results show a decrease in traffic volume of 42% based on the perception of route changes after implementing the ERP. Meanwhile, based on the perception of modal shift, there will be a 40% reduction in traffic volume when the ERP implementation is implemented, which previously reached Level of Service F in 2027, and then increased to level C. Furthermore, If the ERP is implemented, then the tariff that is willing to be paid by vehicle users is in the average value of Rp 8,838 for four-wheeled vehicles or more and Rp 4,343 for two-wheeled vehicles. This value is obtained through a WTP survey that has been done, with a minimum initial value of willingness to pay adjusted to the value of toll road rates and parking rates in Makassar City. This value can be used to determine tariffs in ERP policies.

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