Study of Implementation Planning of Electronic Road Pricing System on Jakarta

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Abstract

The growth of population and road users is increasing every year, and road network development that has not been carried out optimally has had a significant impact on the current congestion. This condition can be seen in several roads that experience an increase in vehicle's morning and evening rush hours. This situation makes the government have to implement traffic restriction policies congestion can be unraveled. One of them is the application of Electronic Road Pricing (ERP). This paper will discuss ERP system implementation plan. This research method was carried out through a field survey by collecting data from the ERP road section of the Blok M-Kota corridor with a sample of Jalan Medan Merdeka Barat. The analysis is carried out to determine the level of road services and the cost of congestion before and after ERP implementation. The results showed that the road service level on Jalan Medan Merdeka Barat is E, where the road characteristics have unstable currents, low speed, and vary, the volume is close to the road capacity. ERP is calculated to have the potential to reduce congestion costs by Rp.221,788/hour with a reduction in vehicle volume by 19% if ERP is implemented.

Keywords: Electronic Road Pricing, Traffic, Congestion Charge.

1. Introduction

Every year the growth of motorized vehicle users has increased relatively high. Until now, the government has carried out various kinds of traffic restriction engineering to reduce congestion. The government has been made to implement a 3 in 1 (three in one) and odd-even system (Hanna, Kreindler and Olken, 2017). However, the efforts that have been implemented seem to be still ineffective in its implementation, so that the DKI Jakarta Government must find a solution in overcoming the congestion that occurs. One of the emerging discourses is the implementation of an ERP system. ERP is the term for a system that implements congestion pricing in a road segment area. Where the goal is to reduce congestion that is happening at this time. The purpose of implementing an ERP system is to reduce the volume of vehicles passing through a road segment to solve congestion problems by installing the On-Board Unit (OBU) tool as a means of payment transactions. (Senapati and Najid, 2020).

Based on the paper Gu et al. (2018), identifying factors that influence public acceptance in the road pricing scheme are (1) privacy issues for road users because travel data will be recorded; (2) the problem of equity because there are socio-demographic differences among road users; (3) the complexity of the road pricing scheme, especially during the system trial process and the learning process for road users; and (4) uncertainty especially in the allocation of revenue from road pricing and its effectiveness. In the end, vehicles crossing these roads will be charged according to the level of congestion that occurs. The higher the congestion level, the higher the motorists' rate when traveling on roads with this ERP system.

This research was conducted in a more centralized manner and gave good results in avoiding problems beyond the researcher's reach. By only examining road users with light vehicles, heavy vehicles, and motorcycles, the survey implementation time was only during morning rush hours at 07.00-09.00 and in the evening 16.00-18.00 on Jalan Medan Merdeka Barat, and calculating the cost of congestion based on the results of field data calculations.

The purpose of this study is to determine the condition of the existing road and the impact that occurs when a traffic restriction system is applied to a predetermined and concise road segment into a summary regarding the implementation of the ERP system on the Medan Merdeka Barat. Further research is recommended for special attention from the government on alternative roads that motorists will pass if they want to avoid road points that implement ERP.

Based on the background, it is necessary to analyze the implementation of the ERP system, which will impact alternative road users around the Medan Merdeka Barat. So it is necessary to conduct a more in-depth impact review to implement the ERP system.

2. Literature Review

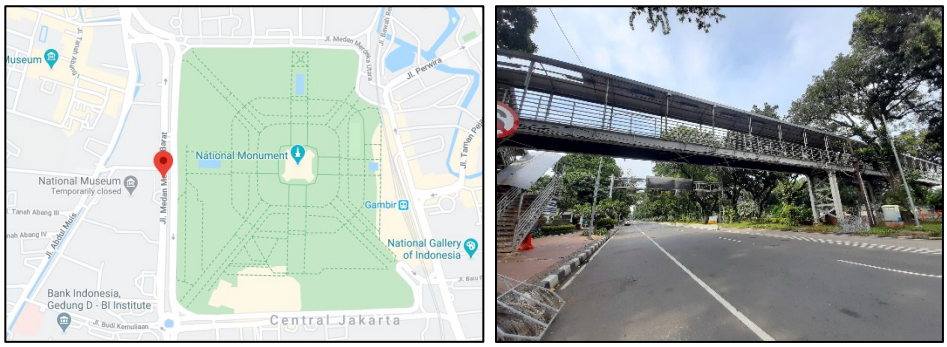


Figure 1 Survey Location

Congestion often occurs on city roads that do not have insufficient public transportation according to user needs. The provincial government implemented several traffic restriction policies to find solutions to reduce congestion, including the implementation of ERP. ERP implementation is considered an effective solution in successfully implementing traffic restriction programs, which have been implemented in many big cities, including Singapore, Stockholm, and London. (Selmoune *et al.*, 2020). In Indonesia, ERP has also received a positive response from road users in Jakarta. ERP can be implemented immediately to measure its effectiveness in reducing car users and changing road users' behavior in using public transportation (Sunitiyoso *et al.*, 2020).

Based on the paper Croci and Ravazzi (2016), the application of costs for congestion in urban areas can reduce the level of congestion effectively. This can be seen in the reduction of vehicle volume in London by 53% at the cost of congestion of £ 8. Furthermore, in Milan, it is 63.2% with a congestion fee of € 2 and € 5. The positive impact has also been on reducing the number of accidents and increasing public transport speed. A study conducted in Bosnia and Herzegovina, Glavic et al. (2017) indicates that the revenue allocation option from road pricing should be further analyzed because it is essential for road pricing policy acceptance. Road pricing is usually seen as an instrument for dealing with traffic by influencing geographic location, workers' income, and urban agglomerates (Vandyck and Rutherford, 2018).

Menon (2010) wrote that the ERP system could successfully operate the transportation system in big cities. This is because the public transportation system is widely accessible and can support private vehicles' transition to public transportation modes. Thus ERP can be applied to cities in Asia with consideration of traffic conditions. Apart from having a positive impact, ERP also negatively impacts, including a significant drop in real estate prices. This is related to the increase in ERP rates, where the decrease in transactions occurred by almost 19% in office and residential areas (Agarwal, Koo and Sing, 2015). Apart from having a positive impact, ERP also has a negative impact, including a significant decrease in real estate prices, which is related to an increase in ERP rates where the decrease in transactions occurred by almost 19%. The effect also occurred in office and residential areas, although not too significant. (Agarwal, Koo, and Sing, 2015).

In its implementation, road pricing has many main objectives, including reducing the level of congestion, becoming a source of regional income, reducing environmental impacts (air pollution, increasing CO_2), and encouraging public

transportation on a mass scale. There are several road pricing groupings based on objectives, including (Susanto, 2008):

Table 1 Road Pricing Classification

Nama	Description	Purpose
Road toll (fixed mates)	Charges for the use of certain roads	To increase income and investment.
Congestion pricing (time-variable)	Charges are based on traffic density, if the traffic is congested, the fees charged will be higher, but on the other hand, if the traffic is not congested, the costs will be low.	To increase revenue and reduce congestion.
Cordon fees	Charging of fees for the use of certain roads	Reducing congestion in downtown areas
HOV lanes	For four or more wheeled vehicles that cannot accommodate a large number of passengers, a fee will be charged.	To encourage the transition of private vehicle users, vehicles that have a sufficient capacity to accommodate the number of vehicles on the road can be used.
Distance-based fees	The fees charged to a vehicle depend on how far the vehicle is used.	To increase state revenue and reduce various traffic problems.
Pay-as-you-drive-insurance	Divides the payment evenly based on the distance traveled, so that vehicle insurance is a variable cost	Reducing various traffic problems, especially in traffic accidents
Road space rationing	Use of certain restrictions during heavy traffic times (for example, based on vehicle numbers)	To reduce congestion on main roads or in city centers.

3. Methodology

This data collection method is intended to obtain the required data as input for the analysis phase. The data to be collected in this study are divided into primary data (survey of vehicle volume and actual speed) and secondary data (ERP tariff plans, Central Jakarta City Traffic Performance Data, ERP Application Road Traffic Volume Data, Central Jakarta City Population). The survey method was carried out to obtain primary data in the research conducted. The survey referred to in this study is a survey of traffic volume and travel speed in the field, using two calculation methods, first determining the characteristics of urban roads according to Road Capacity Manual of Indonesia (Manual Kapasitas Jalan Indonesia-MKJI 1997) and the method of calculating the cost of congestion by determining vehicle operating costs and time costs according to National Standard of Indonesia (Standar Nasional Indonesia T- 15-2005). This was done to know the existing road conditions and the impact that would have occurred when the ERP was implemented.

This research was conducted so that the government and society could have an overview and view of the current conditions on the roads that the ERP system will implement. This was done in order to minimize the impact that would occur when the ERP was implemented.

Based on MKJI 1997, the characteristics of urban road traffic have several components of calculation, including free-flow speed (FV), capacity (C), degree of saturation (DS), and level of road service (LOS). To be able to calculate and determine these components, you can use the formulas below:

1. Traffic Volume

To calculate the total vehicle traffic volume (Q) (cur/hour) use the equation below :

$Q = LV + (emp\ HV\ x\ HV) + (emp\ MC\ x\ MC)$…….. ……..…….(1)

Information :

Q = traffic flow

LV = light vehicle

HV = heavy vehicle

2. Side Barries

To determine the free speed adjustment factor due to side friction, the field's number of side friction is multiplied by the weight factor.

3. Free Flow Speed

$FV = (FV_0 + FV_w)\ x\ FFV_{SF}\ x\ FFV_{CS}$ ……..…..……..…….(2)

Information :

FV = Free flow speed of light vehicles (km/hour)

FV_O = basic free flow speed of light vehicles (km/hour)

FV_W = Speed adjustment for road width (km/hour)

FFV_{SF} = Adjustment factor for side barriers

FFV_{CS} = Speed adjustment factor for city size

4. Capacity

$C = C_0\ x\ FC_W\ x\ FC_{SP}\ x\ FC_{SF}\ x\ FC_{CS}$……..…..……..……..(3)

Information :

C = Capacity (pcu / hour)

C_O = basic capacity (pcu / hour)

FC_W = Road width adjustment factor

FC_{SP} = Directional separation adjustment factor (only for undivided roads)

FC_{SF} = Adjustment factor for side and curb / curb obstacles

FC_{CS} = City size adjustment factor

5. Degree of Saturation

$DS = \frac{Q}{C}$……..……..(4)

DJ = Degree of saturation
Q = Traffic flow (pcu / hour)
C = Capacity (pcu / hour)

Table 2 Level of Service

Level of Service	Ratio V/C	Characteristics
A	< 0,60	Free flow, low volume, and high speed, the driver can choose the desired speed
B	< 0,60 < V/C <0,70	The flow is stable, and the speed is a little limited by traffic, the driver still has the freedom to choose his speed
C	< 0,70 < V/C <0,80	Stable flow, speed can be controlled by traffic

Level of Service	Ratio V/C	Characteristics
D	< 0,80 < V/C <0,90	Unstable starting current, low speed
E	< 0,90 < V/C <1,00	Flow is unstable, speed is low and varies, volume is close to capacity
F	> 1	The flow is obstructed, the speed is low, the volume is above capacity, and there is often a traffic jam for a long time

Source : Minister Degree of Transportation Regulations KM 14 (2006)

Road user costs' main components include vehicle operating costs (BOK), the value of travel time saving, and accident costs. BOK consists of two main components: variable costs (running costs) and fixed costs (standing costs or fixed costs). Its components variable costs include fuel consumption costs, oil costs, spare parts consumption costs, maintenance labor costs, and tire costs. Simultaneously, the fixed costs of its components include vehicle depreciation costs, vehicle crew costs, interest costs, and overhead costs.

Based on SNI BOK (2005), Vehicle operating costs can be calculated using the equation:

1. Vehicle Operating Costs

The method used to determine vehicle operating costs and time costs, concerning the calculation of vehicle operating costs. The congestion cost is calculated based on the model method of calculating the relationship between speed and congestion cost.

BOK = BT + BTT . …… …… …… …… …….. (5)

Information :

BOK = Vehicle Operating Costs

BT = Fixed Costs

BTT = Variable Costs

2. Value of Time

In order to calculate the cost / time value, use the gross regional basic income method according to the equation:

$$\lambda = \frac{\text{GRDP/person}}{\text{Annual Working Hours}} \text{ . …… …… …… …… ……(6)}$$

λ = Time Value (Rupiah / vehicle / hour)

GRDP = Gross Regional Domestic Income

3. Congestion Charge

Model of the Relationship between Speed and the Cost of Congestion according to Tzedakis (1980) in (Basuki *et al.*, 2008), can be calculated by the equation below:

$$C = N\ x\ \left[GA + \left(1 - \frac{A}{B}\right) V'\right]\ T \text{…… …… …… …… …… …… ……(7)}$$

Information:

C = Cost of Congestion (Rupiah),

N = Number of Vehicles (Vehicles),

G = Vehicle Operating Costs (Rp/Km),

A = Vehicle with existing speed (Km/hour),

B = Vehicle with Ideal Speed (Km/hour),

V = Value of Fast Vehicle Travel Time (Rp/hour),

T = Total Queue Time (Hours).

4. Results and Analysis

4.1 Analysis of Road Characteristics

Based on data from DKI Jakarta Provincial Transportation Department, it can be summarized in Table 3. From the data, total length of roads that will be implement ERP system is 38.36 km. The highest vehicle volume of 12.591 vehicles/hour is found out on Jalan MH. Thamrin with a vehicle travel speed of 11.40 km / hour, and the lowest vehicle volume is on Jalan Pintu Besar Selatan with a vehicle volume of 5.071 vehicles/hour with a travel speed of 12.80 km/hour.

Table 3 ERP Corridor Traffic Performance Data in 2020

Roads	Length (km)	PCU (smp)	V (km/hour)
Jl. Sisingamangaraja	1,75	5.208	7,20
Jl. Jend. Sudirman	4,90	12.059	11,80
Jl. Panglima Polim	1,85	5.184	8,40
Jl. Fatmawati (Sp. Ketimun 1 - Sp. TB. Simatupang)	3,85	5.161	9,60
Jl. Suryopranoto	0,71	8.586	3,60
Jl. Balikpapan	0,40	7.389	12,00
Jl. Tomang Raya	1,03	7.988	6,00
Jl. Jend. S. Parman	4,26	8.487	14,40
Jl. Gatot Subroto	6,97	8.790	8,40
Jl. MT. Haryono	3,53	7.104	8,40
Jl. Pintu Besar Selatan	0,45	5.071	12,80
Jl. Gajah Mada	2,83	7.014	10,60
Jl. Hayam Wuruk	2,83	6.632	11,00
Jl. Majapahit	0,50	9.710	12,30
Jl. Medan Merdeka Barat	1,00	8.599	12,10
Jl. MH. Thamrin	1,50	12.591	11,40

In the calculation of the analysis of vehicle traffic characteristics based on the results of a survey conducted on the Jalan Medan Merdeka Barat, it can be seen that the largest traffic flow is on Wednesday morning and evening rush hours of 4.106 skr / hour and 4.151 skr/ hour, that on weekdays the morning rush hour and the afternoon rush hour the obstacles are in the medium class. Whereas on weekends (weekends) the obstacles are in low class, the value of free flow velocity is different on weekdays and holidays, this is due to the effect of side obstacles on weekdays which are in medium class, and holidays in low class so that causing the adjustment factor to be different, the service level of Jalan Medan Merdeka Barat during peak hours is E. This is because based on the V / C ratio of 0.97 <1.00 where according to the characteristics of the flow is unstable, low speed and different, the volume is close to capacity.

Table 4 Level of Service Medan Merdeka Barat

Survey Time	Volume (pcu/hour)	Free Flow Speed Km/hour	Actual Speed Km/hour	Capacity	Degree Of Saturation
Monday, 07.00-09.00	3.122	54,15	18,25	4280,76	0,73
Monday, 16.00-18.00	3.045	54,15	19,5	4280,76	0,71
Wednesday, 07.00-09.00	4.106	54,15	11,75	4280,76	0,96

Survey Time	Volume (pcu/hour)	Free Flow Speed Km/hour	Actual Speed Km/hour	Capacity	Degree Of Saturation
Wednesday, 16.00-18.00	4.151	54,15	10,62	4280,76	0,97
Friday, 07.00-09.00	1.923	55,86	33,62	4417,38	0,44
Friday, 16.00-18.00	3.034	55,86	25,25	4417,38	0,69

4.2 Analysis of the Impact of ERP Implementation

In calculating the potential impact analysis, using the cost of congestion on roads that will be implemented by ERP and alternative roads that are affected due to the implementation of the ERP system. The calculation of congestion costs uses the calculation of congestion costs against vehicle operating costs and time costs.

Table 5 Recapitulation of Costs

Transportation Type	Variable Cost Rupiah/km	Overhead Cost Rupiah/km	Fixed Cost Rupiah/km
Sedan	528,81	17.540	18.068,81
Utilities	618,83	5.332,92	5.950,83
Small Bus	2.408,67	6.751,99	9.160,66
Big Bus	430,84	16.476,94	16.907,70
Light Truck	181,55	5.264,44	5.446
Medium Truck	174,46	4.966,75	5.141,22
Heavy Truck	689,27	14.528,08	15.217,35

4.2.1 Vehicle Operating Cost

The calculation of vehicle operating costs is based on equation (5) according to the vehicle type that passes through the road.

Table 6 Variable Cost Medan Merdeka Barat

Transportation Type	BiBBMj Rupiah/km	Boi Rupiah/km	Bpi Rupiah/km	Bui Rupiah/km	Bbi Rupiah/km	BTT Rupiah/km
Sedan	1.376,92	19.668,43	245,62	1.989,55	29.601,00	52.881,52
Utilities	1.238,56	19.668,43	74,53	1.989,55	38.911,95	61.883,02
Small Bus	2.110,58	4.880,63	187,71	6.363,06	22.7325,00	240.866,97
Big Bus	2.990,76	5.023,13	171,57	4.644,37	41.8019,00	430.848,83
Light Truck	3.200,20	4.880,63	33,15	2.943,84	170.493,75	181.551,56
Medium Truck	3.601,62	5.023,13	80,90	4.832,91	160.927,50	174.466,07
Heavy Truck	6.968,12	5.308,13	22,61	1.777,67	675.196,57	689.273,09

Information :

BTT = Variable Costs

BiBBMj = Cost of fuel oil consumption (Rupiah / km)

BOi = Oil consumption costs (Rupiah / km)

BPi = Cost of spare parts consumption (Rupiah / km)

BUi = Cost of maintenance labor (Rupiah / km)

BBi = Tire consumption costs (Rupiah / km)

4.2.2 Value of Time

Based on the results of the calculations in equation (6), the travel time costs are as follows :

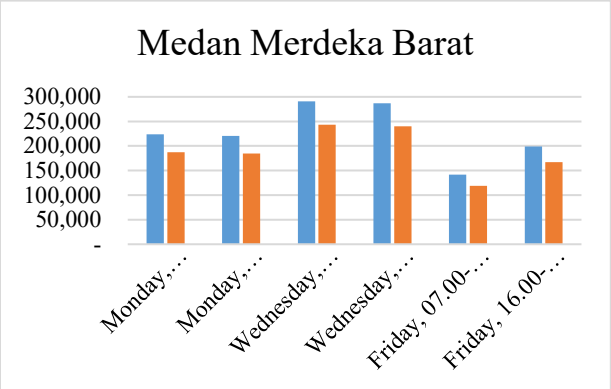
$$= \frac{193.428.851/1.149.176}{2080}$$

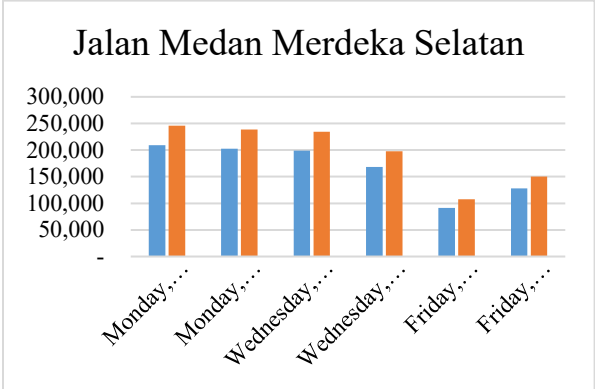
= 0,0809 rupiah/hour

4.2.3 Congestion Charge

Table 7 Congestion Charge

Roads	Before ERP Operates Rupiah/Hour	After ERP Operates Rupiah/Hour
Medan Merdeka Barat	1.362.856	1.141.077
Merdeka Merdeka Selatan	997.759	1.174.587
Budi Kemuliaan	204.118	225.960





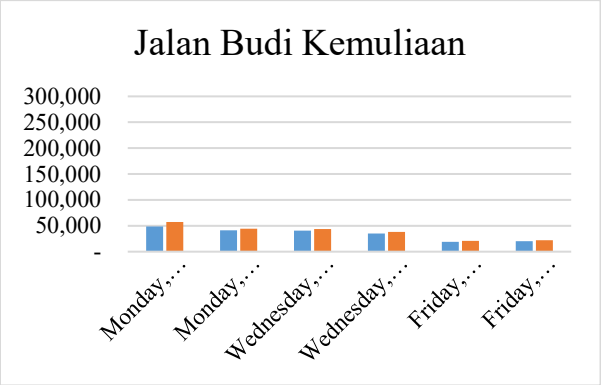


Figure 2 Before and After ERP Operates (Rupiah/Hour)

5. Conclusion

Based on the results of the research on the analysis of the implementation plan of the ERP system on the Jalan Merdeka Barat, it is concluded that the road conditions have a service level of E, where this value explains that the characteristic conditions of the road have unstable currents, low speed and vary, the volume is close to road capacity. For the impact due to the implementation of this system, it can be seen that ERP can save costs by Rp. 217,788 / hour and the potential to reduce congestion levels by 19%. However, the implementation of the ERP system will also impact alternative roads around Jalan Medan Merdeka Barat, where the alternative road will experience an increase in congestion costs for each volume of vehicles that pass through it.

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