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ANALYSIS OF IMPLEMENTATION PLAN FOR ELECTRONIC ROAD PRICING (ERP) IN TRANSPORTATION SECTOR AT JAKARTA WITH SYSTEM DYNAMICS APPROACH

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Abstract- The focus of this study is to analyze policy design for Electronic Road Pricing (ERP) that has succeed to reduce congestion in other city like London, Stockholm, and Singapure. System Dynamics model is used as basic for implementation the ERP scenario. Output indicator that analyzed are travel time, Fuel consumption, and CO2 emission. This study shows that ERP can reduce travel time, fuel consumption, and CO2 emission. However, that three output indicators will increase again because the excalation of transport demand. The purpose of implementing ERP is to make the flow of vehicles smoother. This system is able to automatically function like a toll gate without having to reduce or stop the speed of vehicles that will enter the ERP area as it happens on toll roads. Based on the data from the simulation, ERP revenue is generated with the following assumptions: The ERP implemented is Complete road pricing so that it is implemented on a scale of one city of Jakarta, all car and motorcycle trips that have moved due to the ERP are assumed to have moved to public transportation that does not use road capacity such as Transjakarta and KRL. ERP revenue tends to increase from year to year with an average annual income of IDR 46,079,710,631,574.00 per year. This revenue tends to increase from year to year considering the increase in total commuting trips each year. This is due to the increase in the population of the city of Jakarta which has increased from year to year.

Keywords: Electronic road pricing (ERP), system dynamics, travel time, fuel consumption, CO2 emission

1. INTRODUCTION

The increase in human population and urbanization has increased the level of congestion throughout the world, and Indonesia is no exception. One obvious example is the state of transportation in the national capital, Jakarta. Jakarta is a city with the highest level of congestion in Indonesia. This is reflected, among other things, in the comparison between vehicle utilization and the total road area in Jakarta. With an increasingly uncontrolled increase in road utilization, it is predicted that in 2014 Jakarta will be totally stuck (Jakarta Local Government, 2011). According to Polda Metro Jaya data, the average growth in the number of motorized vehicles in the last five years has reached 9.5% per year, while the growth in road length is only 0.1% per year. In fact, ideally the road length growth is 10% - 15% per year. This resulted in increasing congestion in Jakarta from year to year (Butaru Editorial Team, 2009). Facing this problem, the government of Jakarta also does not remain silent. Several solutions have been implemented, such as the use of the busway, three in one, and the park and ride method in several areas. However, the congestion problem has not been completely resolved. Therefore, a Jakarta city transportation model is needed that functions to provide an understanding of all stakeholders and policy makers regarding urban transportation. In addition, this model is also equipped with electronic road pricing scenarios (electronic traffic fees). Electronic traffic fees have proven successful in overcoming similar problems in various countries such as Hong Kong, Singapore and the UK (Liu, 2010). Electronic road pricing (ERP) is a traffic retribution mechanism for private vehicles

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with the aim of travel demand management in order to reduce the number of private vehicles passing through an area or area with a certain level of vehicle density and usually at a certain time/hour. busy (Hau, 1990). Revenue from the ERP will be used to support supply side management, such as the construction of road transportation infrastructure including road construction and allocation of funds for public transportation (Liu, 2010). Examples of road transportation infrastructure in Jakarta are Transjakarta, toll roads, and so on. Thus, the existence of ERP can be an alternative solution to reduce the number of private vehicles, as well as improve public transportation facilities. In ERP implementation, researchers design models and analyze ERP implementation scenarios from the models that have been designed. can represent multiple interactions that occur simultaneously between variables combined with multiple feedback loops. This approach helps one to understand and interpret interactions easily. This can facilitate stakeholders and policy makers in making policies (Sterman J., 2001).

Furthermore, one of the advantages of a dynamic system is the ability to describe the dynamics of a system that evolves continuously and includes a delay factor. This is important because this model is designed to determine the impact over several periods, so delay is an important point. Delays represent many things such as changes in the perception of vehicle users, additional infrastructure and so on over a period of several years. Dynamic system modeling also assumes several relationships that are not linear (Sterman J., 2001) (for example, the relationship between congestion and travel convenience so that it has an impact on the attractiveness of using these modes of transportation). This is important because if this non-linear relationship is ignored, it means that it also ignores the basic principle of the system, namely the non-linear interaction of various factors in decision making. The software that researchers use in designing this model is Powersim. In the end, the model along with evaluation of the ERP scenario will answer the needs of the provincial government of DKI Jakarta to overcome the problem of congestion in Jakarta. This is important as material for consideration in making investments and in determining policies related to transportation in the city of Jakarta

A. Study Integrated Transportation Master Plan (SITRAMP)

In order to reduce congestion, the central and local governments Jabodetabek conducted a study entitled Study Integrated Transportation Master Plan (SITRAMP). This study involved an agency from Japan called the Japan International Cooperation Agency (JICA). This study is prepared to achieve the target of the master plan in 2030. In this study there are several projects that have been proposed since 2002 but until now there are still many that have not been implemented.Self-medication or self-medication is often done by the community.

B. Electronic Road Pricing (ERP)

1. Definition of Electronic Road Pricing (ERP)

One strategy in overcoming congestion and towards the system sustainable transport (sustainable transport system policy) is the management of travel demand (travel demand management). In general, the goal of a travel demand management policy is to encourage road users to reduce unnecessary trips (especially private vehicle users) and encourage the use of more effective, healthier and environmentally friendly modes of transportation. Travel demand management policies can be grouped into three groups, namely: economic instruments, cooperative agreements, and regulatory instruments (Susantono, 2010).

a. Economic instruments use incentives and/or disincentives to achieve sustainable transport goals. One of the economic instruments that is often applied in several cities in the world is road pricing.

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Road pricing is the imposition of costs directly on road users for passing certain road sections. Basically there are two objectives of imposing road pricing, namely to increase the income of a region or country, or a means to regulate the use of vehicles so that traffic jams do not occur. The main objectives of road pricing are to reduce congestion, become a source of regional income, reduce environmental impacts, and encourage the use of mass transportation. Congestion pricing is one of the economic instruments that aims to reduce the use of private vehicles. Electronic Road Pricing (ERP) is one of the names for congestion pricing. Electronic road pricing (ERP) is a policy of enforcing a paid road for every private vehicle that passes through it. ERP aims to reduce congestion on certain roads at certain hours, usually during peak hours, so as to reduce congestion in that area which also affects other areas. The ERP system uses electronic monitors and on-board units on vehicles so that they can be detected when entering ERP areas. The purpose of implementing ERP is to make the flow of vehicles smoother. This system is able to automatically function like a toll gate without having to reduce or stop the speed of vehicles that will enter the ERP area as happens on toll roads (Goh, 2002). With electronic road pricing, private vehicle users will be charged if they pass through a congested area or corridor for a certain period of time. In the end, private vehicle users must decide whether to continue their journey or change using other permitted modes to pass through the area or corridor.

2. Background to the Implementation of Electronic Road Pricing (ERP)

The background for implementing ERP is that the carrying capacity of roads in Jakarta is inadequate, losses due to congestion are very high (± 42 trillion), degradation of the public transportation system, and the trend of growth in the number of motorized vehicles is very high (Dinas Perkomunikasi, 2011). Based on information from the DKI Jakarta Transportation Agency, the increase in the number of private vehicles is very rapid, reaching 1,117 per day or around 9% per year. The current increase is not matched by the growth in road area. Road growth is relatively constant, namely around 0.01% per year. If improvements to transportation patterns are not carried out, then in 2014 Jakarta is predicted to be completely jammed. Congestion will have a negative impact, both in social, environmental and economic aspects. These negative impacts include wastage of fuel oil (BBM), increased air pollution, and decreased mobility. Previously, the Provincial Government of DKI Jakarta had implemented the three in one (3 in 1) rule on several roads in the capital city. This is intended to limit the number of vehicles during rush hour so that congestion can be reduced. However, in practice the regulation is considered ineffective in overcoming congestion. Weaknesses in implementing the three in one system include inconsistency in the enforcement of violations of the 3 in 1 rule, an inadequate number of law enforcement officers, and the emergence of a new social problem, namely the jockey phenomenon (Department of Transportation, 2011).

3. Implementation of Electronic Road Pricing (ERP) in Several Countries

Electronic Road Pricing has been successfully implemented in several cities in the world. Cities that have implemented this ERP system include (Susantono, 2010):

a. Singapore

Singapore is the first city to apply ERP (since 1998), originally called urban road user charging. The goal is to limit incoming traffic during peak hours to reduce congestion. Prior to ERP, Singapore used the Area-Licensing Scheme (ALS), in 1998, ALS was replaced with Electronic Road Pricing (ERP). Prices for entering ERP areas or corridors vary based on the average network speed. These varying rates are intended to maintain speeds between 45-65 km/h on expressways and 20-30 km/h on arterial roads. The impact of implementing congestion pricing or ERP in Sangapore is quite significant. The percentage of carpools and buses used increased from 41% to

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62%, and the volume of traffic going to areas where congestion pricing was implemented decreased by 44%.

b. London

ERP was applied in London on 17 February 2003. Purpose of ERP application in London is to reduce congestion, improve travel time reliability, and reduce air pollution. The ERP application in London has provided several positive results including:

- 15% reduction in traffic volume,
- Reducing congestion by 30%,
- 12% pollution reduction (NOx, PM10),
- Travel becomes more reliable,
- Reliability of the bus schedule has increased significantly,
- Decrease in traffic accidents
- Increased speed does not increase accident fatality,
- There is no major traffic impact in areas outside the area
- congestion charging,
- Being a source of income that is mostly used for
- improving public transport services.

c. Stockholm

ERP was officially applied starting August 1, 2007, after been tested since 2006. The goal is to reduce congestion, improve accessibility, improve environmental quality. Some of the positive results that can be noted are:

- Increased accessibility as indicated by a decrease in queues in the city center and areas near the city center by 30-50%.
- Reducing the total emissions of motorized vehicles between 10-14% in city centers, and between 2-3% for a total of one city.

4. Benefits and Impacts of Electronic Road Pricing (ERP)

According to the DKI Jakarta Transportation Agency (2011), the benefits of Electronic Road Pricing (ERP), including:

a. Government :

- Reducing congestion
- New sources of revenue from traffic
- Facilitate the application of traffic restrictions
- Shifting from private vehicles to public transport
- Increase the effectiveness and efficiency of demand management

b. Driver :

- Driving comfort
- Travel becomes more punctual
- Ease of payment
- Ease of switching modes to public transport

c. Public :

- Reduce the noise generated by the vehicle
- Reducing the level of air pollution that comes from vehicle fumes
- Minimization of economic losses due to traffic jams

If ERP is implemented, the driver is faced with a choice of choices, namely paying and enjoying the

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trip, changing the mode of transportation used, or canceling the trip. Impact of ERP policy implementation these are:

a. Achievement of efficiency in transportation aspects such as achieving smooth traffic which results in saving travel time and travel costs.
b. Improving environmental quality, TDM (Travel Demand Management) in environmental aspects is expected to reduce air pollution, and reduce noise and vibration pollution.
c. Structuring the land use system, TDM is expected to revitalize urban facilities according to their functions.
d. Improving the economy, TDM is expected to provide additional revenue for the government so that it gets additional funds to improve the quality of public transportation.
e. Ensuring equal rights for road users, TDM is expected to
f. provide justice for road users by providing heavier obligations for road users who contribute more to congestion. In addition, guarantees for pedestrians and residents of local areas are also expected to be realized.

2. METHOD

A. Type of Research

At this stage the researchers searched for and collected data in the form of data regarding the development of the transportation system in DKI Jakarta and DKI Jakarta statistical data obtained through BPS data, and agencies in the Regional Government of DKI Jakarta. At this stage the researchers also processed the data obtained to produce a development model for the city of DKI Jakarta. This section discusses the collection of data that is used as a basis for conceptualizing the problems that exist in the urban transportation system as a basis for implementing ERP scenarios. The concepts that have been obtained and understood from these data are then processed to obtain a framework as a basis for making simulation models and as a reference in determining the collection and processing of written data and numerical data.

3. RESULTS AND DISCUSSION

Table 1. Target Capital Share Public and Private Transportation

Target (SITRAMP)		
Year	Private Transportation	Public Transportation
2020	66.00%	34.00%
2030	64.00%	36.00%

Based on the results of the simulation, the capital share comparison between BAU conditions and the implementation of the ERP scenario is as follows:

Table 2. *Modal Share* Scenario BAU

Scenario BAU		
Year	Private Transportation	Public Transportation

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2010	60.49%	39.51%
2020	74.00%	26.00%

Table 3. *Modal Share* Scenario ERP

Scenario ERP		
Year	Private Transportation	Public Transportation
2010	60.49%	39.51%
2020	65.76%	34.24%
2030	73.98%	26.02%

Based on the two scenarios above, it can be seen that BAU's capital share cannot reach the target set by SITRAMP. The capital share ratio in 2020 proclaimed by SITRAMP is a maximum of 66% for private transportation and 34% for public transportation and a maximum of 64% for private transportation and 36% for public transportation.

Under the BAU scenario, neither the targets set for 2020 nor 2030 are achieved. On the other hand, the ERP scenario succeeded in achieving the SITRAMP target in 2020 with a capital share of 65.76% for private transportation and 34.24% for public transportation. On the other hand, the target for 2030 has yet to be achieved. Therefore, another scenario is still needed that will be integrated with the ERP scenario to achieve the SITRAMP target in 2030.

Table 4. Table 4. ERP revenue per year

Years	ERP Income
2002	Rp -
2003	Rp -
2004	Rp -
2005	Rp -
2006	Rp -
2007	Rp -
2008	Rp -
2009	Rp -
2010	Rp -
2011	Rp -
2012	Rp -
2013	Rp -
2014	Rp -
2015	Rp 44,581,408,930,779
2016	Rp 42,473,796,075,846
2017	Rp 43,285,731,002,161
2018	Rp 43,773,450,519,967

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2019	Rp 44,450,160,106,716
2020	Rp 45,009,174,723,151
2021	Rp 45,622,967,760,429
2022	Rp 46,124,736,091,604
2023	Rp 46,484,034,142,823
2024	Rp 46,942,213,974,096
2025	Rp 47,319,941,457,969
2026	Rp 47,578,726,609,651
2027	Rp 47,929,959,046,802
2028	Rp 48,194,732,716,337
2029	Rp 48,551,096,558,648
2030	Rp 48,953,240,388,210

Based table 4 above it can be seen that ERP revenue tends to increase from year to year with an average annual income of IDR 46,079,710,631,574.00 per year. This revenue tends to increase from year to year considering the increase in total commuting trips each year. This is due to the increase in the population of the city of Jakarta which has increased from year to year.

4. DISCUSSION

Electronic Road Pricing (ERP), as previously explained, is one of the efforts to overcome Jakarta's traffic jams. In accordance with a study conducted by SITRAMP, one of the methods for overcoming congestion is traffic demand management where the issue discussed in the study is ERP implementation (Freeways 2006). This chapter will explain the design of an ERP scenario which will later be injected into the basic model of the Jakarta city transportation system.

In chapter two, various types of scenarios have been described which include predictive scenarios, exploratory scenarios and normative scenarios. ERP is included in the exploratory scenario category because the implementation plan will only be realized in 2014. The model was run from 2011 so this scenario is included in the exploratory scenario category. In addition, the exploratory scenario also aims for long-term modeling which is also in accordance with the study conducted by SITRAMP which was also carried out on the basis model, namely until 2030.

The ERP scenario is also injected into an external variable, namely the percentage of car trips. Then based on the journal Understanding transport Demands and Elasticites, How Prices and Other Factors Affect Travel Behavior (Litman, 2012) that the decrease in the percentage of car trips affected by ERP costs is IDR 23,100 for cars and IDR 7,700 for motorbikes (Oriental Consultants ALMEC Corporation, 2011) is 22% for each mode of transportation. Furthermore, the ERP scenario will cause changes in the behavior of private car drivers which are marked by increases and decreases in overall driving time due to trips of cars and motorcycles that go up and down as well (Chen 2017). Car and motorcycle trips are the main contributors to driving time with the largest percentage of trips. This can be seen in Figure 3.7. The influence of this ERP is in accordance with external scenarios where the variables that are affected are external variables and strategic scenarios where the variables that are affected then become internal factors that can be affected by driving time (close loop) (Jufriyanto and Fathoni 2019). Therefore, this further confirms that the ERP scenario is an exploratory scenario which is a combination of external and strategic scenarios. Based on the data from the simulation, ERP revenue is generated with the following assumptions:

1. The ERP implemented is Complete road pricing so that it is implemented on a scale of one city

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of Jakarta.

2. All car and motorcycle trips that have moved due to the ERP are assumed to have moved to public transportation that does not use road capacity such as Transjakarta and KRL.

ERP revenue tends to increase from year to year with an average annual income of IDR 46,079,710,631,574.00 per year. This revenue tends to increase from year to year considering the increase in total commuting trips each year. This is due to the increase in the population of the city of Jakarta which has increased from year to year. Therefore, through this ERP revenue, it is hoped that it will be able to improve other Jakarta city transportation systems such as implementing road network development policy scenarios, rail road systems, urban planning, driving safety and security and road network development. This policy scenario can be combined with ERP implementation considering that if only ERP is implemented, then Jakarta will remain totally stuck in the next few years.

5. CONCLUSION

Based on the analysis of the Jakarta city transportation system model, the following conclusions are drawn:

1. The model of the Jakarta city transportation system as a Business As Usual (BAU) condition was developed with 4 sub-models consisting of Population sub-model, Vehicle preference sub-model, Sub-model congestion level and driving time, and Consumption Sub-model BBM as well as add ERP revenue sub-model by scenario ERPs.
2. The resulting output is in accordance with the objectives set out by SITRAMP namely the level of congestion (travel time), fuel consumption and CO2 emissions of the transportation system.
3. Obtained behavior over time in the form of an increase in time drive continuously for the BAU conditions resulted in a total traffic jam in Jakarta in 2014.
4. The Electronic Road Pricing (ERP) scenario contributed in the form of a decrease in travel time of up to 26.28% in 2014 but increase to 13% in 2030.
5. The Electronic Road Pricing (ERP) scenario contributed
6. in the form of reducing fuel consumption and CO2 emissions by up to 12.67% in 2014 but increase to 6% in 2030.
7. Annual ERP revenue starting from the year it was implemented 2014 was IDR 46,079,710,631,574.00 per year.
8. The capital share in the BAU scenario cannot achieve the target set by SITRAMP in 2020 and 2030. For the ERP scenario, the target in 2020 can be achieved but in 2030 the target is still not achieved.

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