Master's Thesis

How Electronic Toll Collection Deployment Affects Transport System Efficiency: The Study of Indonesia Toll Road Network

by:

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September 2019

Master Thesis Presented to

Ritsumeikan Asia Pacific University

In Partial Fulfillment of the Requirements for the Degree of

Master of International Cooperation Policy

Summary

Traffic congestion represents a significant threat to accessibility and mobility in Indonesia. In the case of the toll road, the stop and go movement along the toll road plaza as the effect of the payment mechanism often causes the delay at toll gates, which results in traffic congestion. As the situation becomes more serious, a technology innovation called the Electronic Toll Collection (ETC) has been deployed in Indonesia toll road network to curb the transaction time in toll payment and thereby increase the level of service. Previous research indicated that the ETC implementation brings benefits for both toll road users and operators in many ways.

The study utilizes a quantitative method of econometric panel regression using data from selected toll gates in the Indonesia toll road network from January 2017 to December 2018 to analyze how the ETC deployment affects transport system efficiency. The findings indicate that the intervention of ETC implementation significantly decreases the transaction time in toll gates by 93.5%, *cateris paribus*. Thus, the intervention eases the accessibility and yield efficiency in transaction time. Furthermore, an adapted strategy after the implementation could be considered, especially regarding the trend of surging traffic on toll roads that may cause bottlenecks after entering toll gates.

Keywords: transport efficiency, accessibility, electronic toll collection, toll payment method, congestion, regression

JEL Classification: D62, R41, R48

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List of Abbreviations

BPJT	: *Badan Pengatur Jalan Tol* – Indonesia Toll Road Authority
DV	: Dependent Variable
EDC	: Electronic Data Capture
ETC	: Electronic Toll Collection
FEM	: Fixed Effect Model
GTO	: *Gerbang Tol Otomatis* - Automatic Toll Gate
ITRA	: Indonesia Toll Road Authority
ITS	: Intelligent Transportation System
IV	: Independent Variable
Jabodetabek	: Jakarta Bogor Depok Tangerang Bekasi
Jagorawi	: Jakarta Bogor Ciawi
JIUTR	: Jakarta Intra Urban Toll Road
JORR	: Jakarta Outer Ring Road
MSS	: Minimum Service Standard
MLFF	: Multi Lane Free Flow
MPWH	: Ministry of Public Works and Housing
MTC	: Manual Toll Collection
PLS	: Partial Least Square
REM	: Random Effect Model
SPM	: *Standar Pelayanan Minimal* – Minimal Service Standard

Acknowledgment

First, I would like to express my sincere gratitude to my advisor Otsuka Kozo Sensei, for the continuous support of my master thesis, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all the time of thesis completion. Besides my advisor, I would like to thanks the Development Economics' Joint Seminars Committee: Yamagata Tatsufumi Sensei and Kim Sangho Sensei, for their encouragement and extensive feedback and comment during the presentation. My sincere thanks also go to Vid Adrison, Ph.D., as Program Director of MPKP of University of Indonesia, and to Muhammad Halley Yudhistira, Ph.D., Program Secretary, for their insight and suggestions for my thesis.

Secondly, I would like to express my gratitude to the all faculty members at Ritsumeikan APU as well as MPKP Program University of Indonesia, for invaluable knowledge and shared experience. I send my appreciation to the entire staff in both universities, who have been so helpful and cooperative in giving their support at all times to help me achieve my goal. My highest appreciation also for Pusbindiklatren BAPPENAS, who provides scholarship during my study in this field.

After that, I am grateful to all of those who support me during the data obtaining for the thesis, my colleagues from MPWH, especially BPJT big family. Also, for the member of JD 03 MPKP UI, it is pleasure to have known, learned, and discussed many things while we were working together. For fellows DD APU's awardee, having the opportunity to experience and share this meaningful Beppu's daily is such an extensive process, I am honored. Not to mention for the classmates and common's room group member, thanks for fruitful conversation and shared experience during stressful thesis deadline.

Lastly, nobody has been more important to me in the pursuit of this phase than the members of my family. I want to thank my parents; whose love and guidance are with me in whatever I pursue. My sister, Ana, and her family, Yogya's family and the rest of my big family, many thanks for the great support during the study. Most importantly, I wish to thank my loving and supportive husband, Arief Sucianto, and my wonderful daughter, Alissa Netania Arif, who provide unending inspiration and always believe with whatever path I choose. I owe times and many things to both of you during this study completion. This achievement is for you, dear.

Beppu, 14^{th} June 2019

Alfi Hidayatul Rahmawati

Certification Page

I, Alfi Hidayatul Rahmawati (Student ID 51217625) hereby declare that the contents of this Master's Thesis are original and true, and have not been submitted at any other university or educational institution for the award of degree or diploma. All the information derived from other published or unpublished sources has been cited and acknowledged appropriately.

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2019/06/14

Chapter 1: Introduction

This chapter elaborates the background of the study, states the research question and objective as well as the significance of the study and limitation to provide a basic understanding of the research.

1.1. Background

The mobility of people in urban areas has increased in line with the country's development. As mobility increases, traffic demand also rises. Road infrastructures, including toll roads, need to be developed to address this demand. Toll road development is also intended to achieve equitable development to improve the efficiency of service distribution to support economic growth, especially in high-level region development (Sihombing, 2013).

One of the severe urban problems in many countries is the level of traffic congestion. The standard strategy to combat traffic congestion is to rise the road capacity or to invest in new roads development. However, the supply of new road often cannot meet the increasing demand for vehicles who utilizes road' transportation. Therefore, those efforts have not equivalent to vehicle growth. The result is, congestion kept up worsened.

The vehicles demand tends to increase as the new roads do exist. The situation recurs until the costs of the added trip equal to the existing trip, create competition that ends up in congestion (Arnott and Small, 1994). In the case of Indonesia, providing public transportation infrastructure is less significant in reducing the congestion since the new rail capacity attained short-term diversion to the private vehicle's drivers. The current mass transportation infrastructure is still an unreliable means to support their mobility. Furthermore, as the road users tend to be inelastic, they immediately fill up the traffic after that short time diversion.

In the economical transportation concept, it is believed that the delivery of new roads may decrease travel time, although it will increase vehicular traffic (Fields, Hartgen, Moore, & Poole, 2009). Currently, the high growth of economic development and urbanization have increased mobility and accessibility of people and service travel on toll roads. However, the problem of congestion also may exist during toll payment in toll booths, which induce higher fuel consumption and increase emission rate as a result of slowdown vehicles speed and repeated stop and go (Demir, Bektaş, & Laporte, 2011).

The queue of vehicles when conducting payment in toll plazas cause a significant problem of congestion in toll roads. The manual payment method often causes longer transaction time because users wait for their change after payment. Therefore, implementing a transaction mechanism device that eases the payment and reduces transaction time is a must. To cope with the problem, the government introduces the use of an automatic payment system which is widely known as ETC.

The ETC payment system enables technology communication device for toll payment automatically at the toll road, as a part of the intelligent transportation system (ITS) (Chen et al., 2007). The benefit of ETC is among others to eliminate queueing on toll gates, improve the safety of public monitoring, and provide other significant impact relate to more commercially operations (Golob & Regan, 2001). Compared to manual toll collection (MTC), the implementation of ETC contributes to decreasing fuel consumption and emission because of reducing repeated stop and go driving (Bartin, Mudigonda, & Ozbay, 2008).

The government of Indonesia issued the Ministry of Public Works and Housing Regulation No. 16/PRT/M/2017 (MPWHR) regarding Electronic Payment System in Toll Road, which stipulates four processes of toll road electronic payment system: electrification, toll road integration, toll road integration with electronic toll collection consortium, and multilane free flow (MLFF). The implementation of full electrification stage has been conducting since October 2017, and by the end of 2018, the MLFF should be applied. Nowadays, all toll road segments in Indonesia have been implementing the full electronic payment system using tap and go card at the toll booths.

1.2. Research Question and Objective

The current traffic volume that tends to increase and generate congestion in toll roads, especially at the toll plazas during payment, need further investigation. This study seeks to analyze to what extent the implementation of ETC as a technology-based solution and a method for curbing congestion in toll gates affects transport system efficiency, and raises the question, "How does ETC deployment affects transport system efficiency in Indonesia?"

1.3. The Significance of the Study

Theoretically, the findings of this study offer contribution to the existing literature on the transport system and policy, particularly in developing countries. Furthermore, the result of this study will provide information for policymakers to consider further and conduct adapted strategies to speed up ETC deployment and control traffic flow, to achieve a better quality of service at toll roads.

1.4. Limitation

This research is limited to observe 75 locations of toll gates from 27 toll road segments in Indonesia, during 20 months period from January 2017 to December 2018. This research focuses on the transaction time at toll gates for individual transactions observed during the period, as mentioned earlier. Subsequently, this research is limited to the occurrences on toll plazas during transaction time, starts when the vehicles stop in toll gates to make toll payment until they pass through the gates and drive. The queuing time before the toll payment and other activities after pass the gates are excluded from the study.

1.5. Research Outline

Introduction**:** This chapter will describe the background of the study, the research question, and the objective. Included in this chapter is also the significance of the study and its limitations.

Literature Review: This chapter will describe the initial conceptual term for this study. Previous studies related to the terminology and keywords that are used in this study will be further elaborated in this chapter to present the research gap.

Methodology: This chapter will elaborate on the data source and the empirical model that will be used in this study. Furthermore, a description of the area study and methodology that is utilized will be presented here.

Result and Discussion: This chapter will analyze the gathered data by using panel data regression with Stata software. The results and findings from the aforementioned quantitative approach will be discussed and presented in this chapter.

Conclusion and Recommendation: This chapter will conclude the study, as well as provide a policy recommendation. Moreover, this chapter will suggest further routes of research to follow up on the finding of the study.

Chapter 2: Literature Review

The research question and objective that stated in the previous chapter appertain to this study will encompass analysis of a range of literature reviewed in this study that focuses on ETC and transport system efficiency from previous research.

2.1. Transport System Efficiency

Previous transport efficiency researches have focused on three aspects, namely economic, environmental, and social equity (Hall, 1995; Litman 2007; Richardson, 2005). To measure those three aspects of efficiency, the researchers have proposed many studies. Litman (2008) and Jeon, Amekudzi, & Guensler (2010) presented comprehensive indicators to achieve the aspect of sustainability transportation. Ramani suggested five ideal to pertain sustainability over toll road; congestion reduction, safety enhancement, economic opportunity expansion, air quality improvement, and transportation assets value increasing. Richardson (2005) found a relevant field for toll road sustainability monitoring: safety, congestion, fuel consumption, vehicle emissions, and accessibility.

The discussion of accessibility has been conducted for a long time ago in the area of transportation planning. Levinson (2004) studied four cluster area to measure the efficiency among others are mobility, utility, productivity, and accessibility. By justifying of the usage, each of the measurement has its strength and weakness in estimating the transport system. Accessibility refers to the easiness of arrived at the destinations or of actively involved to participate rather than moving from one place to another easily along the network (El-Geneidy & Levinson, 2007).

In the context of this study, accessibility means faster and easier toll payment. In Indonesia, as enacted in the Ministry of Public Work decree No. 392/PRT/M/2005, the toll operators should fulfill the Minimum Service Standard (MSS) at toll roads. The MSS parameters that should be achieved at toll roads include the physical condition of the toll road and the service provided to the user. Including in providing the level of service is the accessibility that is measured using indicators of transaction time in the gates, open or closed gate system, and length of queueing. The values of these parameters are routinely evaluated using direct field surveys in order to maintain or increase the level of service.

2.2. Electronic Toll Collection

In 1978, Indonesia began the toll road history as the 59 km Jagorawi toll road has been operating, which connects Jakarta, Bogor, and Ciawi. The progress of toll road delivery in Indonesia is relatively slow; as recorded by 2007, the length of toll road operated is only 553 km. Restarting in 2002, the acceleration of toll road development began by inviting the participation of the private sector through the Public-Private Partnership (PPP) initiative. Until 2016, a total of 33 toll road segments has been operating with 980 km length in total (Badan Pengatur Jalan Tol, 2016).

The increased supply of toll road cannot fulfill the high demand due to the increasing number of vehicles. This condition leads to unpredictable traffic congestion in toll roads, especially in Jabodetabek area. Heavy toll road congestion has become one of the significant urban problems for many countries worldwide (Zavitsas, Kaparias, Tomassini, 2010).

A new technology-based system that proposed to be the solution for toll road congestion and to meet the demand for the expansion of current toll road systems, called ETC, is started to be implementing. ETC is a recent innovation that prospective users consider due to its simplicity (Purnama, 2012) with the use of electronic payment using a smart card in toll roads, bridges, and tunnels (Haan & Zoomers, 2016). The integrated function of ETC card was first introduced in Norway for toll payment, parking, and gas (Gabriel, 2008). Previous researchers have found that ETC implementation provide advantages, some of them include reducing congestion in toll gates, decreasing queueing and eases traffic flow, as well as reducing consumption vehicle' fuel since the vehicles do not have to frequently conduct stop and go driving while paying the toll (ITS Technology Enchantment Association, 2003). A given example of ETC implementation system by Worrall (1999) which is known as E-Pass, has decreased the emission of vehicles, eased traffic flow, and provided a better opportunity to interact with users.

Using the ETC system, hindrances in manual toll collection (MTC) will be reduced, thereby achieving more efficient transaction time, as this minimizes human error and technical difficulties (Al., 2011). The new implemented ETC system reduces both the delay and also the number of operator staff in toll gates (Levinson and Chang, 2002). The extensive ETC deployment has had considerable leverage in toll road practice, because of its flexibility in affecting the behavior of travel user (Worrall, 1999).

Prior studies have identified many functions of ETC in toll road. These include provide a significant part in management of infrastructure and provision of traveler information (Aguado, Echebarria, & Barrutia, 2011), a part of the prospected development trends (Liu, Sang, & Wu, 2017), an irreplaceable function to eliminate congestion and decrease traffic accidents (Huang, Wei, Guo, & Cao, 2017), offers comprehensive measure to traffic demand understanding (Kim, Kurauchi, Uno, Hagihara, & Daito, 2014) and a method that provide time effectiveness of travel time benefit (Hall, 1995).

2.3. Transport System Efficiency and ETC

Studies of ETC deployment to transport system efficiency have been conducted using different dimensions of efficiencies. In San Fransisco, a study was conducted to investigate the effectiveness of toll pricing policy during peak hours in toll roads using the quantitative method, Different in Different and Regression Discontinuity, with traffic volume and delay time as dependent variables. The findings indicate that the changing policy reduces traffic volume in observed locations during peak hours (Foreman, 2016).

In 1995, Portugal utilized ETC system as the first country that employed the same and single payment system for all toll road in the country (Coelho, Farias, & Rouphail, 2007). Coelho et al. (2007) conducted study on how to calculate the quantification impacts of toll facilities (traffic demand, service time, and service type) and system performance variables (stops, queue length, and emissions) of traffic volume and emission on toll roads corridors in Lisbon, and found that 61–80% CO_2 reduction could be achieved by entirely changing from MTC to ETC. A study conducted in Orlando summarizes how the ETC implementation contributes to the significant improvement of the increasing of lane capacity, decreasing service time, and reducing maximal queuing time in toll plazas (Al-Deek, Radwan, Mohammed, & Klodzinski, 1996).

The method of the design construction and measurement of vehicle emissions become the focus of current researchers. Tseng, Lin, & Chien (2014) studied CO_2

estimation emissions, transaction times, and externalities caused by traffic volume at the four northern-central highway toll plazas in Taiwan and found significant advantages regarding external costs in transaction time. Pérez-Martínez, Ming, Dell'Asin, & Monzón (2011) conducted a research to compare effect of three kind toll payment system to fuel consumption and consequent CO_2 emissions in Spain and found that the energy efficiency has correlated with the type of toll payment system used in toll plazas and, therefore, it is suggested to implement free flow for further method of payment for tolling. In Turkey, a conducted study used traffic emission estimation according to traffic volume and calculated fuel consumption and found that technology innovation and traffic demand decreasing contribute to emission reduction (Ozan, Haldenbilen, & Ceylan, 2011).

The precursory studies of the literature review are narrowed down to three primary relevant sources, as shown in the table below.

Table 1 Summary of Literature Review

Author	Objective	Methodology	Variable	Result
Foreman, 2016	Toll Pricing Effectiveness	DiD and Regression Discontinuity Design	Traffic Volume, Delay Time	Policy Changes reduce traffic volume in peak hour
Tseng et al., 2014	Impact of ETC to the external cost	Manual comparing primary data	Transaction time, emission rate, external cost	ETC lane contributed to reducing transaction time and CO2 emission
Al-Deek et al., 1996	Evaluated traffic operation after using ETC	Experimental design using before after treatment	Service time, queuing line	Technology intervention contributed to improving toll road capacity and increased service delivery

Source: Author Summary

Chapter 3: Methodology

A description of the research design, data source, research site, as well as data collection and analysis, are presented in this chapter. In responding to the research question, this study utilizes a quantitative approach that will be elaborated in chapter. n

3.1. Research Design

The quantitative method of panel data regression analysis uses data from the officers, as mentioned above, was conducted for this study. The dependent variable is the average transaction time in the toll gate, which we refer as "transaction time." The assumption is that unobservable factors that might simultaneously affect the left-hand, and right-hand size of the regression are time-invariant. There are transaction time data for before and after ETC deployment, wherein the before and after concept will offer some insight to a particular model of panel regression. We use the selected approaches to capture the change effect of the policy intervention around the introduction date using considered variables.

The basic framework for this discussion is a regression model that is explained by Greene (1997). According to Greene, the favorable key position of using a panel data set compares to a cross-section is that the panel set will enable the researcher great flexibility in constructing different individual behavior. The regression model based on the following specific form

$$y_{it} = \alpha_i + \beta' x_{it} + \varepsilon_{it}$$

The effect for the individual αi is constant over t time and specific in cross-section unit i. Two basic frameworks could be generalized for this model, the fixed effect and random effect, which had been considered for this study. To estimate the effect of the ETC deployment, we use this following testable empirical model:

$$TransT_{it} = \alpha + \beta_1(Intvni) + \beta 2(Auto_i) + \beta_3(LogAvg_i) + \beta_4(Topup_i) + \varepsilon$$

Where $TransT_{it}$ represents our outcomes and the dependent variable of average transaction time in toll gate. αis the effect of the policy intervention of ETC deployment using β dummy variable of before and after implementation; *Autoi* is time-varying controls such as the number of electronic toll gates; *Topupi* is top up gates existence; *LogAvgi* is log average daily traffic, and ε is an error term. That regression model is the basic model that is used in this study.

Samples from January 2017- December 2018 are used for baseline regression. Assigned dummy variable of sample specification, this study seeks to examine the sensitivity of the treatment to a different specific sample.

3.2. Data Source

Data for this research will be taken from the Indonesia Toll Road Authority (ITRA), the toll road regulator in the country. The data are modified from the Monthly Self-Assessment Report from all Toll Road Operators, and data of Minimal Service Standard (SPM) from ITRA. Monthly Self-Assessment Reports are submitted to ITRA as stipulated in Head of ITRA Circular Letter Number 01/SE/P/2017 on 23 January 2017. The assessment is arranged based on the Guidebook of Self-Assessment as attached at the letter.

Minimum Service Standard (MSS) is a necessary service quality that has to be achieved by toll road operators. The parameters of MSS include road conditions, average travel speed, accessibility, mobility, safety, rescue facilities/ rescue units and rescue assistance, and rest area and environment.

The following table provides information about variable and data source that are used in this study.

Table 2 Variables and Data Sources

No	Variable	Required Data	Data Source	How to Obtain the Data
1.	Transaction Time *Trans*$_{it}$	Average transaction time in each of toll gate location before and after treatment	75 sample site toll gate location	Secondary data of Minimal Standard Service Report from ITRA
2.	Intervention *Intvn*$_i$	When the implementation of fully ETC is started, dummy variable	Ministry of Public Works and Housing Regulation No. 16/PRT/M/2017 (MPWHR) regarding Electronic Payment System in Toll Road	Secondary data from ITRA
3.	Number of Automatic Toll Gate (GTO) *Auto*$_i$	Number of GTO operated in each toll gate location	75 sample site toll gate location	Secondary data from ITRA
4.	Existing of TopUp Gate *Topup*$_i$	Whether the top up gate is existing in the location, dummy variable	75 sample site toll gate location	Secondary data from ITRA
5.	Average Traffic *LogAvg*$_i$	Monthly daily traffic who pass through a certain toll gate divided by the number of days in a month, log variable	75 sample site toll gate location	Secondary data from ITRA
6.	Open and Closed Gate System	Whether the toll gate utilizes open or closed transaction system, dummy variable	75 sample site toll gate location	Secondary data from ITRA

Source: Author summary

3.3. Research Site

As a part of the national highway network, toll road refers to a public road in which in utilize it, and the user is subjected to pay a certain amount of fee that is called as toll payment. It is essentially an alternative to non-toll roads, in which road users save travel time, as well as provide better service compared to that of using non-toll roads. Such an advantage is at the expense of additional costs, where non-toll road users are exempted from tariffs.

The toll payment is appointed per kilometer based on the type of vehicle. The toll amount is set by the Ministry of Public Works and Housing (MPWH). Once every two years, as part of the investment component, the toll tariffs were adjusted based on local inflation. There are two types of toll road gate system; they are the open transaction system and the closed transaction system. The open transaction system means the users make toll payment transactions when entering the toll gate and conduct no other transaction while leaving the road. Meanwhile, in the closed transaction system, users require to perform twice transaction, taking a card when entering the gate and conduct toll payment when leaving the road.

Recently, the growth of toll road development is very high, now with 44 road segments in operation. However, as the toll road supply increases, the demand for vehicles also rises, which causes congestion, especially in the capital city of Jakarta and its surrounding areas. Since options for public transport are limited, commuters tend to use private vehicles as their main mode of transportation and choose toll roads as primary roads. Based on data from ITRA, there are five toll roads with the highest traffic volume, namely Jakarta-Cikampek, Jakarta-Bogor-Ciawi, Jakarta-Tangerang, Cawang-Tomang-

Pluit (CTC), and Surabaya-Gempol (Badan Pengatur Jalan Tol, 2018). Four out of five corridors connect Jakarta to the surrounding areas or known as the Jabodetabek Area. Meanwhile, Surabaya-Gempol toll road is located in Surabaya, the capital city of East Java Province, which is the second largest city in Indonesia after Jakarta.

3.4. Data Collection and Analysis

This research focuses on toll gates that operated from January 2017 to December 2018. The data are secondary data gained from ITRA.

Table 3 Toll Roads Observed in this Study

No	Toll Road Segment	Location	Firstly Operated	Length (km)
1	Belawan - Medan - Tanjung Morawa	Trans Sumatera	1989	43
2	Tangerang - Merak	Trans Jawa	2002	73
3	Jakarta - Tangerang	Trans Jawa	1984	33
4	Prof. Dr. Ir. Sedyatmo	Jabodetabek	1985	14,3
5	Cawang - Tomang - Grogol – Pluit	Jabodetabek	1987	23,55
6	Cawang - Tj. Priok - Ancol Timur - Jbt. Tiga/Pluit	Jabodetabek	1989	27,05
7	JORR W1	Jabodetabek	2010	9,85
8	JORR W2 Utara	Jabodetabek	2013	7,87
9	Pondok Aren - Ulujami	Jabodetabek	1999	5,55
10	Serpong - Pondok Aren	Jabodetabek	1999	7,25
11	JORR (W2S - E1 - E2 - E3)	Jabodetabek	2007	31,12
12	JORR Seksi S	Jabodetabek	1995	14,25
13	Jakarta - Bogor - Ciawi	Jabodetabek	1978	59
14	Cinere-Jagorawi (SS Cimanggis-SS Raya Bogor)	Jabodetabek	2012	3,5
15	Semarang Section A, B, C	Non-Trans Java	1983	24,75
16	Jakarta - Cikampek	Trans Java	1988	83
17	Cikampek - Purwakarta - Padalarang	Non-Trans Java	2005	58,5
18	Padalarang - Cileunyi	Non-Trans Java	1991	64,4

19	Cikampek-Palimanan	Trans Java	2015	116,75
20	Kanci - Pejagan	Trans Java	2010	35
21	Surabaya - Gempol	Trans Java	1986	49
22	Surabaya - Gresik	Trans Java	1993	20,7
23	Ujung Pandang Section I and II	Trans Sulawesi	1998	11,6
24	Makassar Section IV	Trans Sulawesi	2004	6,05
25	Waru - Bandara Juanda Interchange	Non-Trans Java	2008	12,8
26	Surabaya-Mojokerto Section 1A and 4	Trans Java	2011	20,36
27	Bali Mandara	Non-Trans Java	2013	9,7

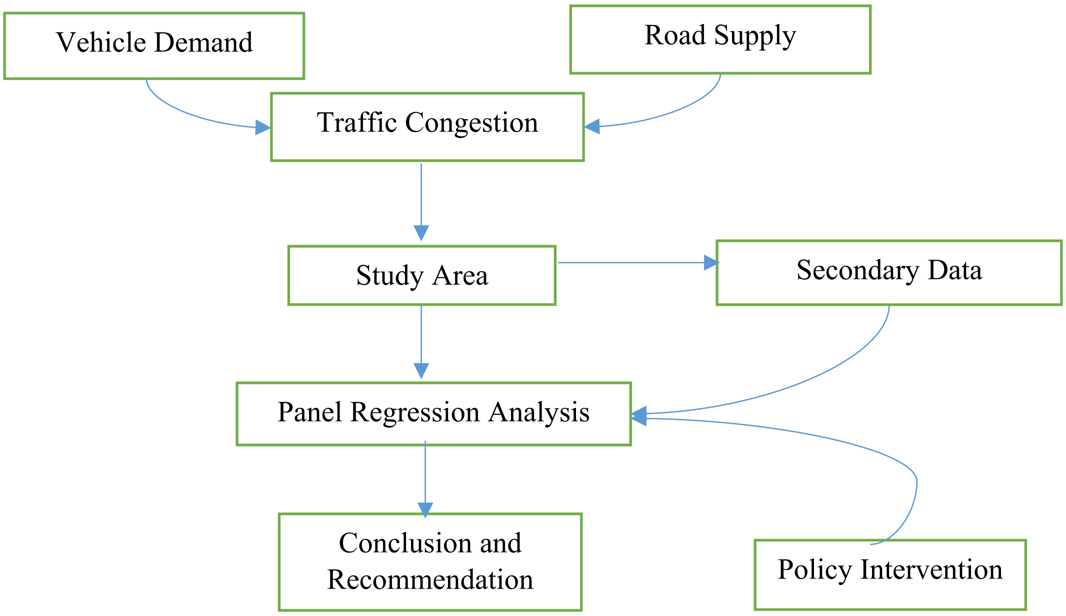
Source: ITRA, modified

The expected data obtained here are 1) transaction time, 2) the number of automatic toll gates that are operated in the toll gates location, 3) the average traffic, and 4) the existing top-up gate. Transaction time is how long it takes for each vehicle to make payment. The number used for this research is the average time from when the toll road user taps the electronic money to the machine until the barrier opens. The number of automatic toll gates (GTO) means how many automatic toll gates were in operation in each gate locations during the months of observation since the number of operating GTO varies every month. The average traffic is the number of vehicles that pass-through toll gates, obtained by the sum of vehicles that pay in toll gates per month, divided by the number of days of that month. Finally, the existing of top-up gate refers to whether there is a top gate that exists at the toll gate locations, as not every toll gate has a top up gate.

The variables are considered to build a model for the study and to support the primary variable for the dummy intervention of ETC implementation. The dummy variable of sample classification is also included in the calculation to further understand the impact of the policy implementation of different sample type.

The following figure is the flow chart of the research. Obtained secondary data will be analyzed using a quantitative panel regression method to find the fitted model which could correctly describe the situation. We will use the chosen model to analyze the results further and to develop discussions within the scope of the study.

Figure 1 Research Flowchart



Chapter 4: Results and Discussion

The primary purpose of this study is to analyze how ETC deployment affects transport efficiency by studying Indonesia toll road networks. In order to achieve this objective, the methods described in the previous chapter had been utilized. This chapter presents results and findings from the data as mentioned above, which is processed using Stata software, for further discussion using previous researches in the literature review.

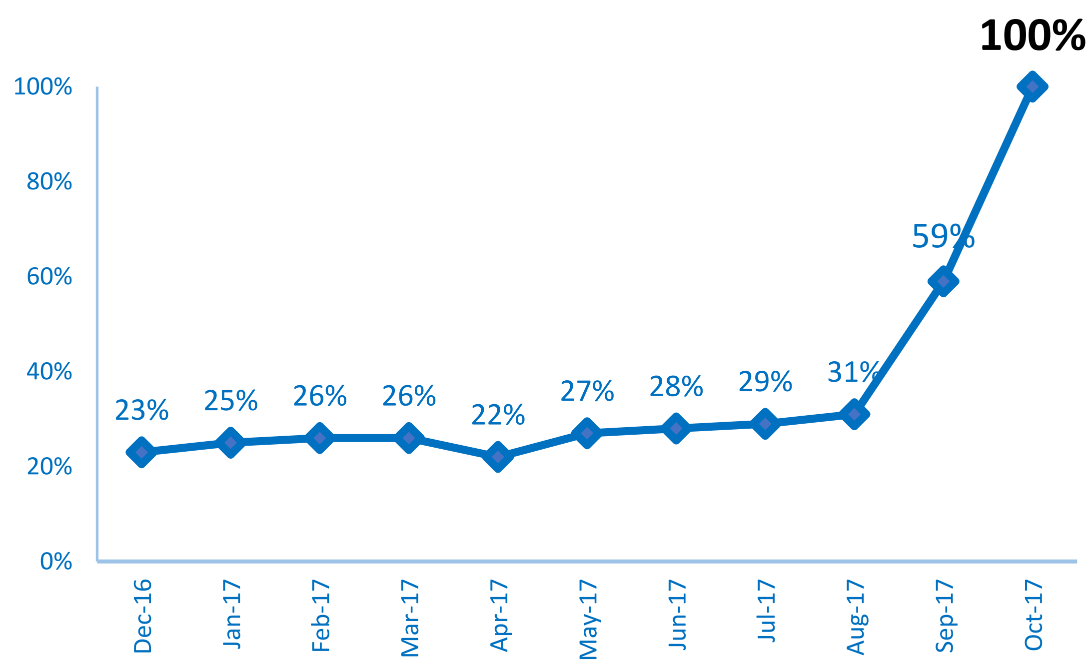
4.1. Electronic Toll Collection in Indonesia

The toll payment system in Indonesian toll roads uses fare per kilometer, and the amount depends on the type of vehicle. Every two year, the MPWH evaluate the tariff and set tariff adjustment based on inflation. There are several types of toll payments employed in Indonesia, among others are cash and ETC. Between those two types of payments, the users tend to choose cash payment as the standard method.

The ETC using two kinds of systems, the first one is semiautomatic, and the other one is fully automatic types. Toll Road in Indonesia uses a semi-automatic system in which vehicle must stop to tap the smart card on ETC device during toll payment and waiting until the gate is open. In other countries where ETC system using fully automatic type, the vehicles do not have to stop because the transaction payment is conducted using a particular device that is installed in the vehicles and connected to the other devices on the gates wirelessly.

Until early 2017, MTC payment using cash is the primary payment method in Indonesian toll road, both for the open transaction system and the closed system, which generates traffic accumulation while queueing in toll booths for toll payment, resulted in severe congestion, especially in the urban area. ITRA as the toll road regulating body in Indonesia has initiated and supported the implementation of ETC in some toll road corridors, the first pilot project for this initiative is in Jakarta Intra Urban Toll Road (JIUTR). By October 2017, the government scheduled to deploy full ETC in all toll gates. The typical utilized ETC in Indonesia is prepaid smart card, often referred to a chip card, or an integrated circuit card (ICC). The smart card is defined as a pocket-sized card (or smaller) with an integrated circuit embedded in it (Saraswati et al., 2005). In selecting financial institution partner for toll payment management, the government offers freedom to toll road operators. The operators can choose which institutions suited best with their requisite need. The most important consideration is they could provide the best service to the users for employing ETC system.

Figure 2 Progress of ETC Implementation in Indonesia Toll Road Network

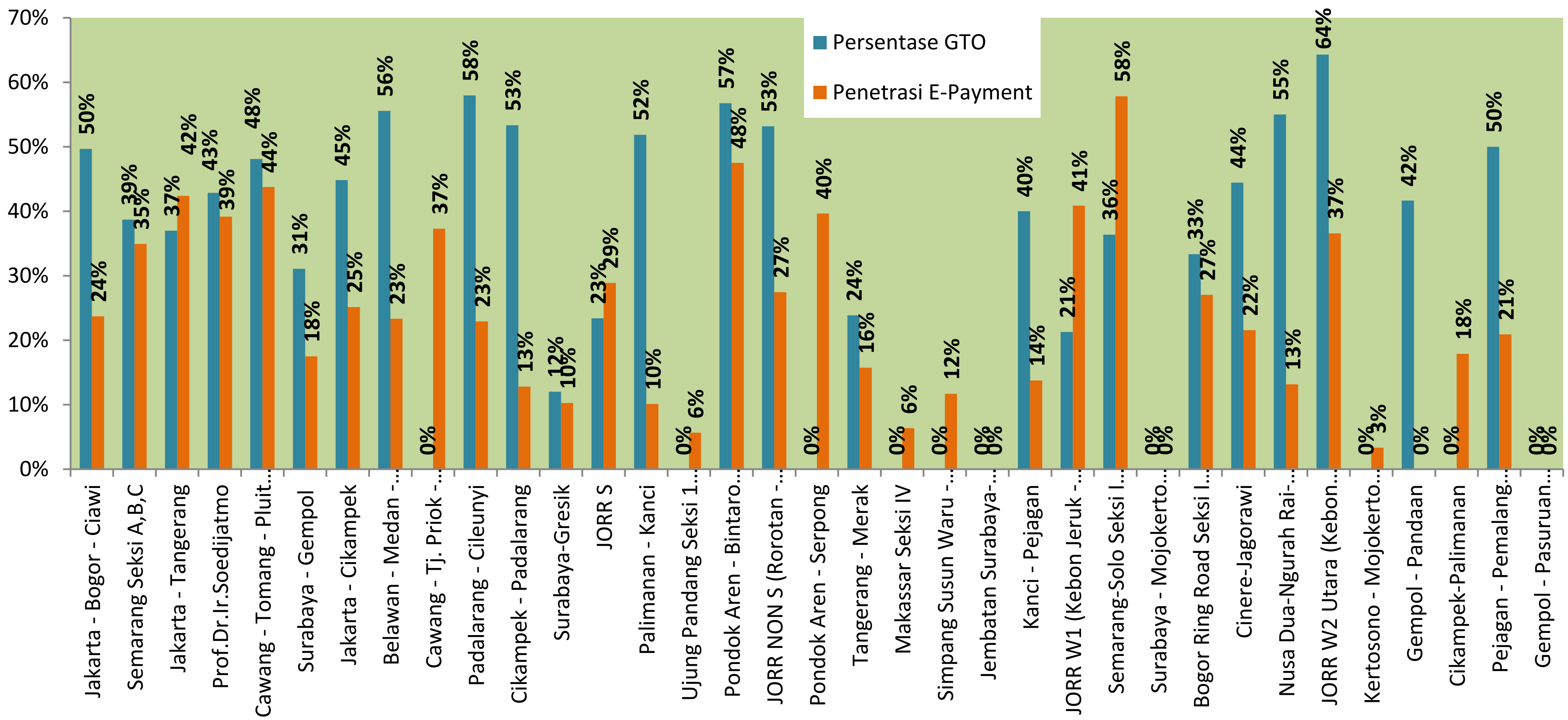


Source: Indonesia Toll Road Authority, modified

The early roadmap of electronic payment in the Indonesia toll road network was first initiated in 2008, in which the toll road operators signed the memorandum of understanding with State Owned Bank Association (Himbara) regarding the development of the electronic payment system during the 2008-2018 period. However, during 2008-2016, only limited toll roads implemented the electronic payment system. By 2016, it was recorded that the percentage of toll gates that utilized e-payment increased to 23 percent, and gained a slight increase to 31 percent in August 2017.

By September 2017, the e-payment system reached a significant percentage at 51 percent, after the MPWH regulation regarding ETC was enacted. The regulation stipulates that 100 percent of ETC deployment has to be achieved by the 31st October 2017, and all toll road operators have to utilize the ETC system in all their toll gates.

The table shows the GTO percentage to manual toll gates and penetration of toll road users using ETC. From the table it is concluded that the percentage of GTO is varied for every toll road segment, and so does the ETC penetration. The highest percentage of GTO compared to the manual toll gate is in Jakarta Outer Ring Road W2 corridor, at 64 percent. The ETC penetration reached the highest percentage in the Semarang ABC toll road segment in which it achieved 56 percent from total transaction instead the GTO percentage was only 36 percent. There are toll road segments that have a zero percentage of GTO but reached a certain number of percentage of ETC, among others, are in the following corridors: Gempol-Pasuruan Section A2, Cikampek-Palimanan, Waru-Juanda Airport Interchanges, Makassar Section 4, Pondok Aren-Serpong, and Ujung Pandan Section 1 and 2. The penetration of ETC user nonetheless there is no GTO means that the gates using hybrid operation in which the manual toll collection was conducted by operator staff; and the users pay toll by using a smart card; thus the staff will swipe the card to the EDC machine. The interesting fact was that in the Pondok Aren segment, the number of ETC users were very high reached 36 percent although GTC gates have not been operated. The situation might reflect that the acceptance of users to shift from manual payment to the smart card is quite high.



Source: Indonesia Toll Road Authority, modified

Figure 3 Comparison of GTO Percentage & ETC Penetration in Toll Road per June 2017

4.2. Results

4.2.1. Data Description

This study estimated data before and after treatment of ETC to transport efficiency in toll road networks in Indonesia. There are 44 toll road segments in Indonesia, which has been operating as of 2017. However, regarding the limitation of data availability, this study utilizes the observation of 75 toll gate locations from 27 segments within 20 months. Most of the unutilized toll gates no longer exist because of integration programs; therefore, data during time observations are incomplete.

Table 4 Research Data Description

No.	Variable	Observation	Mean	Std Deviation	Min	Max
1	Transaction Time	1480	2,3672	1,1938	1,02	7,2
2	Dummy Intervention	1480	0,5432	0,4986468	0	1
3	Log Average Daily Traffic	1471	10,0506	0,6553	8,2705	11,9726
4	Number of GTO	1480	7,9932	6,724	0	40
5	Dummy TopUp	1480	0,4848	0,4999	0	1

Data Source: Author Calculation

Statistical data shows the highest traffic occurred in Ramp Cikarang Utama gates on July 2017, because of the homecoming ritual during Moslem *Eid Holiday*. Cikarang Utama Ramp is a toll gate that connects traffic from the Jabodetabek toll road network to another Java toll road network. All vehicles from the Jabodetabek pass through the gates before entering another toll road network. Therefore, for transaction time, the highest is Tanjung Morawa Ramp on January 2017, located at Belawan-Medan-Tanjung Morawa Toll Road Corridor in North Sumatera Province, in which average transaction time is 7.2 seconds. In contrast, the fastest toll gates are in Cawang and Kuningan. These two toll gates are part of JIUTR that connect Bekasi and Tangerang city to the central business in the Jakarta metropolitan area.

Moreover, the highest number of GTO is in Cikarang Utama ramp, in which there are 40 toll gates operates on December 2017 to August 2018. On the other hand, the least GTO operates located in 4 toll gates, namely Cikupa Entrance Merak, Tamalanrea, Parangloe, and Kaluku Bodoa toll gates, they are located in Tangerak-Merak, Makassar Section IV, and Ujung Pandang Section I&II Toll Road segment, respectively. The zero number GTO operates for Cikupa Entrance was in January to March 2017, whereas for Tamalanrea, Parangloe and Kaluku Bodoa, it was from January to September 2017. Therefore, those last three toll gate location had not utilized GTO before fully ETC deployment on October 2017.

4.2.2. Regression Analysis

The following table 4 shows, panel data regression results using some model specification. The fixed effect model (FEM) is chosen after we conduct estimation using several models, namely Partial Least Square (PLS), random effect model (REM), and fixed effect model using the same dependent and independent variable. After choosing the FEM, heteroskedasticity, and autocorrelation problems were found. Afterward, the researcher conducted a robustness test and used the FEM Robust as the final result of the panel regression.

The estimation was conducted to predict the transaction time (measured in seconds) using policy intervention, number of GTO, existing top-up gate, and log average daily traffic variables. A regression equation was found $F(4,74) = 60.36$, $p<.000$, R2 of .240. It was predicted that the transaction time is equal to 2.918 - .935(policy intervention) - .051(number of GTO) - .312(existing top up) + .051(log average daily traffic), in which policy intervention is coded as 1 = after implementation and 0 = before implementation; number of GTO is measured in unit; top up is coded as 1 for existing top-up gate and 0 if otherwise; and log average daily traffic is measured in unit. When the policy intervention of ETC deployment

Table 5 Panel Data Regression Results

Dependent Variable Transaction Time in Toll Gate *(seconds)*				
	PLS	RE	FE	FE Robust
Main Independent Variable Policy Intervention	-1.352***	-0.964***	-0.935***	-0.935***
	(-20.85)	(-22.20)	(-21.46)	
Number of Automatic Toll Gate	0.0268***	-0.0452***	-0.0508***	-.050782**
	(5.33)	(-9.00)	(-9.88)	
Log Average Daily Traffic	-0.228***	0.0713	0.0512	.05116584
	(-4.79)	(0.97)	(0.63)	
Existing of TopUp Gate	-0.253***	-0.310***	-0.312***	-.31192164***
	(-4.00)	(-6.59)	(-6.62)	
Constant	5.300***	2.722***	2.918***	2.9181307**
	(11.39)	(3.66)	(3.56)	
Number of Observation	1471	1471	1471	1471
Number of ID	75	75	75	75

R-squared	0.3378	0.2520	0.2396	0.2396
P Value	0.000	0.000	0.000	0.000

Note: Level of Significance 0.01 (***), 0.05% (**), 0.1% (*); Robust Standard Error in parenthesis

Source: Author calculation

is implemented, the transaction time is expected to decrease by 0,935 seconds, *cateris paribus* (p<.000). Moreover, for one unit increase in GTO number, it is expected that the transaction time will decrease by 0.051 seconds. The existing of the top-up gate in toll plaza will reduce the transaction time by 0.312 seconds, holding all other variables constant (p<.000). However, transaction time increase by.051 seconds every 1000 rise of average daily traffic (p<.000; *cateris paribus*). Given that ETC not yet implemented, increased zero number of GTO, top up gate does not exist, and average daily traffic is stagnant, each vehicle needs 2.918 seconds average time to pay toll at the gates.

The regression result for FEM and FEM Robust are relatively similar, showing that the primary independent variable is significantly and negatively correlated with the independent variable. The dummy intervention of ETC deployment significantly has a negative correlation with the transaction time in all specification models, with the .01 level of confidence. Dummy Top Up also consistently has a negative correlation with transaction time within all model specifications. Meanwhile, there is only one variable that shows a positive correlation with the dependent variable in all model, which is log daily average traffic. The number of automatic toll gates indicates negative relation in REM, FEM, and FEM Robust, but shows positive correlation in the PLS model.

From the regression results, it can be concluded that factors that significantly affect the accessibility of transaction time in toll booths using FEM robust data estimation. The estimation shows that variable intervention statistically has a negative correlation to transaction time and that ETC deployment affects in cutting transaction time. Implementing ETC will reduce the transaction time by 93.5 percent with the .01 percent level of confidence. When all toll gates operate ETC system, toll road users will use less time when making payment. The problem of waiting during the exchange when using cash payment can be avoided. Therefore, the payment service will be more effective. We conclude this condition as gaining efficiency in term of accessibility.

The negative correlation between ETC implementation and curbing transaction time has been examined in previous research on how ETC correlated with transaction times and externalities incurred by vehicular traffic at four toll plazas on the northern-central highway in Taiwan and found significant benefits regarding external costs in transaction time due to ETC implementation (Tseng et al., 2014). According to the study, switching from manual line to the ETC line has been relatively effective in decreasing transaction time and contributes to reducing the external cost by 60 percent.

The variable number of automatic toll gates statistically has a negative correlation with transaction time. The increasing number of automatic toll gates has been operated can contribute to reducing transaction time by 5 percent. When the number of toll gates increases, toll road users will get faster service when conducting payment, because they only need to tap the card to the machine and continue on their way. This method is much easier than paying at the toll using cash, in which, often, users must wait for their change while paying.

Variable of the top up gate is a significant predictor for transaction time. The current top-up gate in toll booth location contributes to the reduction in transaction time to 31 percent, in comparison to those without a top up gate. If the top up gate is available, toll users could reduce the probability of delay time when the card is dysfunction or the money in the prepaid card is running out. Thus, the transaction time could be conducted without delay.

4.2.3. Regression Analysis with Open and Closed Gate System Dummy Variable

A regression analysis using the dummy variable of an open transaction system (code 1) and a closed transaction system (code 0) has been conducted to investigate the sensibility of how the ETC deployment affects transaction time using this variable. We included the open and closed dummy variable to understand whether the ETC implementation impact differently to transaction time by using that dummy variable. This variable is important to anticipate the future implementation of toll road integration in which could probably change the gate transaction system to further achieving free flow traffic movement.

First, we added a dummy variable in the regression model in the previous section in order to capture the impact of open and closed gate system to the dependent variable. The multiple fixed effect regression is conducted to predict transaction time based on policy intervention, the number of GTO, existing top-up gate, log average daily traffic, and type of gate system. A significant regression equation was found F(5,1391) = 536.31, $p < .000$, with R^2 of .302. The predicted transaction time is equal to 3.075 – .940 (policy intervention) – .043 (number of GTO) – .267 (top up) - .270 (gate system) + .050 (log traffic), where policy intervention is coded 1=after implementation 0=before implementation; number of GTO is measured in unit; the top up is coded at 1=top up gate exist and 0=do not exist; the gate system is coded as 1=open and 0=closed; and log average traffic are measured in unit. Transaction time decreased by .043 second for each additional unit of GTO, after policy intervention reduced transaction time by .940 second than before implementation; existing up top up gate cut transaction time by .267 second, compared to non-existing top up gate; open type gate system curbed transaction time with .270 second than closed gate system; and 1000 unit increase of traffic volume contributed to an additional .050 second transaction time.

Table 6 Regression Result with Added Dummy Variable

Dependent Variable Transaction Time in Toll Gate (second)	
	FE
Main Independent Variable Policy Intervention	-.93893289***
Number of Automatic Toll Gate	-.0436***
Log Average Daily Traffic	.0495
Existing of TopUp Gate	-.2669***
Open and Closed Gate System	-.27***
Constant	3.0755***
Number of Observation	1471
Number of ID	75
R-squared	0.3016
P Value	0.000

Note: Level of Significance 0.01 (***), 0.05 (**), 0.1 (*); Robust Standard Error in Parenthesis

Source: Author Calculation

The findings are also consistent with the previous estimation before adding a dummy variable of the gate system in which the IV have the same correlation to affecting the DV. However, the statistical significance remained almost unchanged ($p<.000$), the estimation result of adding dummy gate system showed that IV policy intervention, number of GTO, existing top-up gate, and open system gate were significant predictors for transaction time. On the other hand, the log average daily traffic was statistically limited predictors.

When estimated the policy intervention and open gate system to predict the transaction time, we found an interesting result. A regression equation of $F(2, 1403) = 1227.59$, $p<.000$ and R^2 is .400. The transaction time is equal to 3.511-1.241(policy intervention) -.574(open gate system), where 1 and 0 are code for after and before policy implementation, respectively; and 1 for open gate system and 0 if otherwise. Transaction time decline by 1.241 seconds if ETC is deployed and ease by .574 seconds when the type of gate is an open system, in which $p<.000$, and holds others variable constant. Therefore, the interaction between policy intervention and open transaction is good combination to cut the transaction time.

Table 7 Regression Result of Policy Intervention and Open Gate System

Dependent Variable Transaction Time in Toll Gate *(second)*	
	FE
Main Independent Variable Policy Intervention	-1.2414496***
Open and Closed Gate System	-.57416538***
Constant	3.5114241***
Number of Observation	1480
Number of ID	75

R-squared	0.4004
P Value	0.000

Note: Level of Significance 0.01 (***), 0.05 (**), 0.1 (*); Robust Standard Error in Parenthesis

Source: Author Calculation

Furthermore, another prediction of transaction time is conducted using policy intervention and log average daily traffic. A regression equation of F(2,1394) = 1111.63, p<.0000 and R^2 is .312. the transaction time is equal to 2.565 – 1.358(policy intervention) +.053(logaveragetraffic), where 1 is after policy implementation and 0 is before the implementation; and average daily traffic is measured by unit. Transaction time is declined by 1.358 seconds if ETC is implemented compared to non-existing policy. Meanwhile, the transaction time rises by .053 second for every 1000-unit increasing of traffic, p<.000, *cateris paribus*. The result explains that when policy intervention of ETC deployment is conducted, transaction time could reduce by that number of seconds and the increasing of traffic demand has limited impact to rise transaction time. Therefore, the increase of traffic demand might result in the bottlenecking after entering toll booths and also might cause longer queuing line.

Table 8 Regression Result Policy Intervention vs Log Average Daily Traffic

Dependent Variable Transaction Time in Toll Gate *(second)*	
	FE
Main Independent Variable Policy Intervention	-1.3583507***
LogAverageDailyTraffic	.05360201
Constant	2.5653586***
Number of Observation	1471
Number of ID	75
R-squared	0.3121

P Value	0.000

Note: Level of Significance 0.01 (***), 0.05 (**), 0.1 (*); Robust Standard Error in Parenthesis

Source: Author Calculation

Lastly, we conduct regression with each of the variables in the model. A simple linear regression was estimated to foresee transaction time based on policy intervention implementation. A significant regression equation was found F(74,1404) = 45.34, p < .000, with R^2 of 0.319. The predicted transaction time in toll gate is equal to 3.109 – 1.365 (policy intervention) second when the intervention is applied. Transaction time decrease by 1.365 seconds if policy intervention is applied. This finding is similar to the result of multiple linear model that has been discussed previously.

Another regression was conducted to predict transaction time on the number of GTO. A regression equation was also found (F(74, 1404)) = 43.04, p < .000, with R^2 of .027. Predicted transaction time in toll gate is equal to 3.622-0.157 (the number of GTO) second when the number of GTO increased. Transaction time decrease by .157 second if the number of GTO increase. This research has indicated the same result to the estimation with multiple regression using this variable.

4.3. Discussion

The estimation results show low R square, although the p-value is also small. The findings indicate that there is a real relationship between the significant predictors and the response variable. In the case of this study, there could be an inherently higher amount of unexplainable variability. Unpredictable condition of variables utilized in the study could end up on this result. Additional predictors might increase the explanation power of the model used in this study.

The transport system and policy are complex fields. However, to simplify that one treatment could eliminate problems of congestion is too ambitious. The urban transportation system is too complicated for one measure to evaluate its success or failure (El-Geneidy & Levinson, 2007).

This study utilized limited time observation using data one year before and after the implementation of ETC. The result might reflect the immediate effects of policy intervention and could achieve different results if it were elaborated using a longer time frame and with different variables. As to the experimental result of the study, policy intervention bears significant impact on decreasing transaction time in the toll plaza. Interesting result is found when interact the basic regression model in this study with dummy variable of open and closed gate system, in which the transaction time could decrease in quite high number of seconds. This finding could be used to develop a simulation model to further utilize the innovation in transport policy regarding traffic congestion in the toll road, for example conducting ETC and toll road integration which end up in MLFF deployment.

Decreasing transaction time could mean the increasing number of traffic that enters the toll gate because the gate could serve more vehicles. In a way, it could provide better service to toll road user because of cutting transaction time means reduce the travelling time. However, it could cause bottlenecking that generates another traffic congestion. A comprehensive approach to eliminate road congestion is essential, because adding capacity and built more roads may not the answer since they would generate vehicle demand increase. Additional infrastructure policy to deliver more reliable public transport might provide more considerable effects.

Further studies to analyse external cost caused by the stop and go could be conducted using available data from this research. This study uses the average daily traffic and cannot provide enough information about peak hours and off-peak hours of traffic condition.

Chapter 5: Conclusion and Recommendation

The researcher has observed how the implementation of ETC has been adopted in reducing transaction time in toll gates. However, the study of how the implementation of ETC affects transport efficiency in Indonesia is still limited. This study utilizes a methodology of panel data regression analysis to examine the mentioned effect.

5.1. Conclusion

According to the findings from the previous chapter, to conclude this study, there are three main points to be disclosed. First, the results of this study are per the references from previous research, that the intervention and application of technology can decrease the transaction time in the toll gates. The variable of policy intervention, the number of GTO, and the availability of top-up gates contribute to the decrease transaction time. On the other hand, the log average traffic contributes to increasing transaction time. ETC deployment can reduce the transaction time at toll gates by 93.5 percent ($p<.000$, *cateris paribus*), thus yield efficiency in transaction time in toll plazas. Therefore, the intervention eases accessibility and can improve service efficiency.

Secondly, using the interaction variable of open and closed gate system, this study captures the effects of ETC deployment. An open toll gate system was a significant predictor for transaction time. Based on the estimation, the open toll gate contributed to reducing transaction time with 27 percent, in comparison to a closed gate system ($p<.0000$, holds another variable constant). The result shows the sensitivity of how the ETC deployment can affect the efficiency that is proxied by accessibility in different criteria of toll gates.

Third, the study concerning how ETC deployment affects transport system efficiency which uses accessibility as measurement and the transaction time as a proxy has statistically significant results and provides an excellent scrutinize for assessing the effectiveness of the implemented strategy. Thus, the endeavour could be utilized to provide better service delivery further to toll road users and indicates the possibility of performance improvement of toll road operators.

The study will be beneficial for the government for the further development of more user-friendly highway systems to achieve better toll road service delivery, through the implementation of ETC, since studies on the evaluation of ETC implementation policies in Indonesia are not available yet. The comprehensive road mapping holds the high possibility to relate the information technology with transport policy development.

There is a need to provide a practice of good governance that is adequately resilient in supporting the investment and the maintenance of ETC that may diverse in dimensions and configurations to ensure its success, and sure to move to further strategy in free flow achievement. In addition, a consistent move to build better ETC in conjunction with other comprehensive policies could contribute to easing the traffic flow and for the same time generating revenues further infrastructure investment and development.

5.2. Recommendations

Given the significant effect of the policy implementation, policymakers may reconsider a more comprehensive implementation of ETC deployment, as policy alone is not enough to control the congestion. Furthermore, complementary policy options should be sought to expect higher congestion reduction.

This study further suggests possible future research. The effect of ETC deployment policy, or any other similar transport policies, may also affect the public transport sector or other transport alternatives. Curbing transaction time in toll gates could cause the bottleneck after passing the toll plaza. This phenomenon should be anticipated with further implementation of transport policies. As the transaction time become more concise and efficient, there is a possibility of the increasing traffic volume after entering the toll gate. Congestion levels after pass through the gates might worsen since adding capacity for existing toll roads seems to be impossible. The number of vehicles using the road is a crucial determinant of susceptibility to traffic jams (Sugiyamal et al., 2008). Therefore, providing integrated and reliable public mass transportation is urgently required, considering the inelasticity of toll road users in Indonesia. Transport alternatives are limited, and public transport systems are underdeveloped, especially in Jakarta, where only around one-fifth of the trips in Greater Jakarta is by train or bus as of 2010 (JICA, 2012).

Furthermore, future work on toll road user's behavior towards the ETC implementation could be conducted to investigate the elasticity of user preference regarding future MLFF policy. Therefore, it is also interesting to perceive how

MLFF and other transport demand policy such as “odd and even” policy affect public transport as transport sector alternatives. It is also interesting to see whether the availability of MRT and LRT that will be operated, especially in Jabodetabek area, has a spillover effect on toll road traffic volume.

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