On Board Unit for Electronic Toll Collection Service in Supporting Make Indonesia 4.0

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Abstract

Indonesian Toll Management Bureau envisages implementation of the On Board Unit (OBU) usage as part of its integrated payment system in lieu of cash and e-card system. Observations and surveys were conducted vis-a-vis 48,013 toll-road users to determine the suitable OBU types and its potential contributions toward efficient tollgate queuing time. Subsequently, it is expected to concurrently determine the appropriate promotion tools that support toll-road users particularly in non-tapping payment system of OBU. House of Quality and V/C Ratio are the basis of the problem formulation in this research. The study shows that a flexible mount OBU device which displays its current available balance are desired by most toll-road users. Moreover, toll-road users expect the single piece microwave OBU device to be waterproof, heatproof, and durable. Comparing to e-card system, its usage reduces the queuing time by 50% to 60%. Additionally, the study shows that collaboration with gas station is the most appropriate promotion model. These research findings provide beneficial feedback for both toll-road authorities and related business stakeholders.

Keywords
Electronic Tolls Collection, House of Quality, V/C Ratio, LoS

1. Introduction

Make Indonesia 4.0 is one of the flagship programs of the government of the Republic of Indonesia under the leadership of President Joko Widodo (Ministry of Industry of the Republic of Indonesia, 2018). In line with this, Bank Indonesia (the Indonesian central bank) issued a National Non-Cash Movement program, which was warmly welcomed by the Toll Road Regulatory Agency, and implemented by toll road developers and operators who obtained operating permits from the Government. Since October 31, 2017, all toll road payment transactions have been successfully transferred to become non-cash transactions, through the use of e-toll cards. The E-toll card is a tool set by the government in the Electronic Toll Collection (ETC). The implementation of non-cash transactions is mainly sought to improve services for toll road users, especially in terms of effectiveness and time efficiency of transactions.

Over time and in line with the vision of the Indonesian government, the Toll Road Regulatory Agency continues to strive to improve its services. Today's technological advancements enable the development of other devices for Electronic Toll Collection, in addition to e-toll cards that still require users to stop their vehicles at the toll door to make toll payments. This kind of payment process requires a relatively long time and causes a buildup of vehicle queues during rush hour. The model of toll road payments that can be done in parallel is expected to increase process efficiency and reduce bottleneck at the toll booth. The solution model for electronic toll collection has been implemented in various developed countries (Kitajima, 2017), known as Multi-Lane Free-Flow (MLFF) tolling. This MLFF system is a non-touch transaction model where users can make transactions without having to physically contact payment equipment. At present, the On Board Unit (OBU) as a device that supports the MLFL system, has been used by a small number of toll road users even though its use is still limited to single-lane free-flow tolling

systems, because the construction of the MLFL system still requires time (Prabowo, 2018). OBU is a toll road payment device that uses a sensor system for the completion of an untouched transaction, which is expected to significantly improve the payment queue time in the tollgate.

Apart from the possibility of increasing time efficiency, which is supported through the use of OBU, marketing of OBU devices is still less interesting, which may be due to the price (Diallo, 2012; Beneke, Brito, & Garvey, 2013) which is relatively high compared to e-toll cards. The Toll Road Regulatory Agency's plan to implement the MLFF transaction system at all toll gates, through OBU devices, opens up opportunities for further exploration to find a more suitable OBU design, so that it can be a non-touch transaction device that is demanded by toll-road users (Calvo-Porral & Lévy-Mangin, 2017). Furthermore, the tendency of consumptive behavior of Indonesian people in general (Tempo.co, 2017; CNNIndonesia, 2018) triggers thinking about the importance of appropriate promotion models, to increase the purchase of OBU devices (Ye & Zhang, 2014; Santini, et al., 2015), so that the target of using OBU as a transaction tool in the toll booth can be fulfilled. Thus, the government's plan to implement the MLFF tolling system no longer has significant obstacles when the technology for the MLFF system has been decided, and the development of the MLFF system has been implemented.

The purpose of this study is to recommend the use of OBU devices that can be accepted by most people in Indonesia, through the design of OBU devices that are fit for the needs of toll road users, promotion models that are suitable for users from the Greater Jakarta area (Jakarta-Bogor-Depok-Tangerang- Bekasi) to increase the use of OBU devices, and decrease the queue or the efficiency of the transaction time at the toll gates.

2. Literature Review

Toll road is defined as a public road that is part of the road network system and is a national road, where users are required to pay according to the applicable toll rate (Minister Regulation, 2018). The government's goal of building toll roads is primarily to expedite traffic in developing regions, improve economic growth through improving the distribution of goods and services, improve distribution of development outcomes, and ease the burden of government funds through participation of road users (Toll Road Regulatory Agency, 2019) Meanwhile, based on Minister of Public Works Regulation No. 16, the minimum service standard for toll roads, the payment transaction at the entrance gate is a maximum of 5 seconds for each vehicle with a maximum queue length of 10 vehicles under normal conditions (2014). The Multi Lane Free Flow (MLFF) transaction model is a solution for time-based tolling schemes (Manzi, 2015) that can reduce the risk of bottlenecks in the toll gate area.

On Board Unit (OBU) is one of the Electronic Toll Collection (ETC) tools designed using technology that can be used for payment systems at the toll electronic substation, where drivers do not need to stop their vehicles to make payment processes (Chu, et al., 2013) . Some studies, such as Satyasrikanth, Penna, and Bolla (2016), Bhardwaj, Chandan, and Kumar (2018), show that the implementation of ETC can reduce queues at toll booths, improve transaction process efficiency, reduce the cost of using human resources as a tariff collector toll road, better audit control, and expansion of capacity at the toll booth does not need to be accompanied by infrastructure development. The Joewono et al. (2017) shows that there is still a lack of interest in toll road users in Indonesia for non-cash payments, and an emphasis on the importance of an integrated payment model, for the convenience of users in carrying out transactions related to transportation or not, without using various cards. Intention (Chen, Fan, & Farn, 2007), awareness of the toll discounts offered and the toll saving (Holguin-Veras & Preziosi, 2011) from toll road users determine the level of ETC service adoption.

The level of service (LoS) of a roadway has six levels, A to F, where A is the best level that reflects free-flow operations and F is the worst level that reflects breakdowns in vehicular flow, while levels B, C, D, E , is in between (Fricker & Whitford, 2004). Minister of Transportation Regulation No: KM 14 of 2006, regarding traffic management and engineering on the road, establishes volume-to-capacity ratio (V / C ratio) as the basis for calculating level of service. Koloway (2009) describes the relationship between V / C and LoS for urban traffic, in Table 1.

Collective culture which is the tendency of the culture of society in Indonesia in general, encourages collective behavior, so that through proper management (Taras, Kirkman, & Steel, 2010; Hofmann & Jones, 2005) can facilitate the government in encouraging the use of selected OBU for ETC. Rockstuhl, et al. (2012) show that responses in collective culture are influenced by collective interest, and the importance of the OBU model is

integrated with non-transport activities to increase interest in using OBU devices (Joewono et al., 2017). Thus this study can assume that OBU device models that are integrated with non-transport activities such as shopping or various forms of routine shopping can increase the interest of toll road users to use the OBU device as an MLFF transaction model, replacing the toll e-card, as well as waiting time efficiency generated through its usage system at each toll gate.

Table 1. V/C and LoS relationship for city traffic

LoS	Average Speed (km/hour)	V/C	Flow Description
A	≥50	≤0.40	Free flow moves (free traffic flow, without obstacles), the driver is free to choose the speed according to the specified limit.
B	≥40	≤0.58	The flow is stable, not free (good traffic flow, the possibility of a slowdown), the operating speed is limited, there are obstacles from other vehicles.
C	≥32	≤0.80	Stable flow, limited speed (traffic flow is still good and stable with acceptable deceleration), the obstacles from other vehicles are getting bigger.
D	≥27	≤0.90	The flow begins to be unstable (it starts to feel a disturbance in the flow, the flow starts not good), the operating speed decreases rapidly due to obstacles that arise.
E	≥24	≤1.00	Unstable flow, sometimes jammed (service volume is at capacity, flow is not stable).
F	<24	>1.00	Jam, long queue (vehicle volume exceeds capacity, flow has jammed).

3. Method

The first online survey, conducted for 48 days, produced data that could be processed from 311 respondents. The survey was designed to identify general user profiles, constraints faced when transacting for respondents who have used the OBU tool, reasons for not using for respondents who have not used OBU devices, desired OBU device models, and cooperation programs that are expected to increase interest in using OBU devices in order to support the government's plan to use OBU devices in the overall toll transaction. The survey results continued with Pareto's calculation to determine the factors that should be the focus of treatment.

Based on the results of the first online survey, the second online survey tool was designed, to get an assessment of importance (1 to not important to 5 to be important) to the following factors:

- OBU device design (OBU device size does not exceed the palm, heat / water /slam resistant component, available information on how to use the OBU device, information on the LED screen is easy to read, attractive colors);
- the use of OBU devices (easy to place on the vehicle, easy top-up, the speed of the vehicle at the toll gate is 60-80 km / h, speed in receiving signals from the transmitter, accuracy in transactions, 5-year usage period, issued by various state / private banks, and the balance is stored in the application on the smartphone);
- OBU device support (toll booth with OBU device transceiver, affordable price, top-up can be done from various public places, giving points, 24-h call center);

Data generated from the second online survey, which was conducted for 20 days and produced 112 respondents, was translated into the calculation of House of Quality (HoQ). The aim is to determine the design of the OBU tool that is closest to people's desires and prioritize technical requirements that must be done first.

Recommendations on promotion models and suitable cooperation in accordance with the characteristics of each group are carried out using the clustering process. Housing, employment, monthly income, promotion programs, and collaborations are attributes that are used to perform cluster analysis. Calculation of Average Within Distance with an Elbow Method is run through RapidMiner software, to produce optimal K values, so that K-mean clustering can be done.

Level of Service (LoS) from the toll gate, in this study, was calculated by calculating the V / C ratio of 47,590 vehicles entering 27 toll gates in the CTC branch toll road (Cawang-Tomang-Cengkareng), using the V / C ratio formula as follows:

$$\text{V/C Ratio} = \frac{\lambda N}{3600/\beta \text{ x number of booths}}$$

where:
λ is a vehicle density conversion factor; assuming the density of vehicles is normal, then $\lambda = 1$;
N is a vehicle that enters the toll gate for 1 hour during peak hour;
β is the average length of the transaction when using the OBU device or toll e-card, at the toll gate;
Number of booth is the number of toll booths in each toll gate.

4. Calculation and Results

The results of the dissemination of online surveys conducted in this study resulted in 311 respondents, which showed, that most of the respondents were aged between 17-25 years (73.31%), male sex (68.17%), living in Jakarta (61.74%), student status (60.77%), earning between Rp. 1,000,000 to Rp. 3,000,000 per month (31.19%), have a Sedan / Jip / Pick Up / Small Truck / Bus vehicle (98.71%), and know the OBU tool (71.38%), and respondents who do not use the OBU tool are 73.31% (228 respondents).

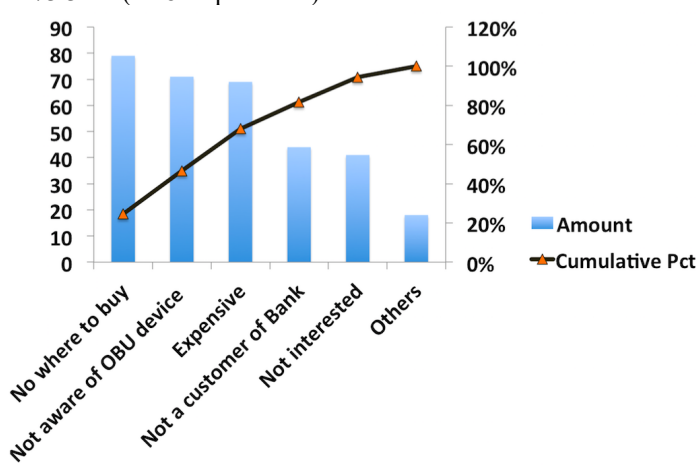

Figure 1.
Pareto chart about the reasons for not using OBU

Some of the reasons why respondents online are not or have not used the OBU tool, are because they do not know where to buy the OBU tool (24.53%), do not know about the OBU tool (22.05%), relatively expensive price (21.43%), do not have Bank Mandiri ATM (13.66%), not interested in using OBu tools (12.73%), and other reasons (5.59%). Pareto calculations in Figure 1 show some reasons for non-users of the OBU tool that should be the focus for action, namely where the OBU is not known, not aware of the OBU device, price sensitivity, and not the customer.

For respondents who have used the OBU tool (83 respondents) stated that the OBU device currently circulating is very easy to use (53.01%), has an appropriate size (65.06%), its usage has accelerated transaction time (93.98%) compared to e- toll card. However, some obstacles were still experienced by users, such as the lack of substations with OBU sensors at the toll gate (29.82%), lack of cooperation with other Banks other than Bank Mandiri (29.82%), and sensors that were not sensitive enough (28.95%). Pareto's calculation in Figure 2 shows constraints that must be the focus for action, namely the lack of substations that have OBU sensors, lack of cooperation with other banks other than Bank Mandiri, and OBU sensors that are less sensitive.

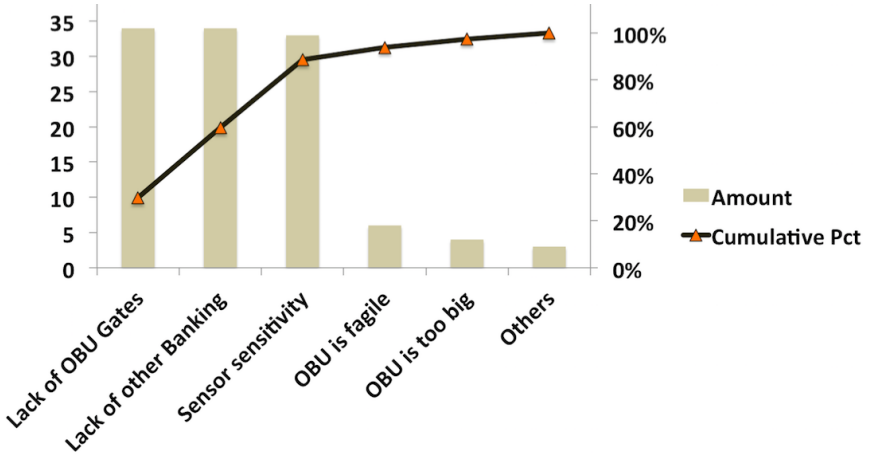

Figure 2. Pareto chart about complaints from OBU users

Some people's expectations of OBU tools, which mainly have affordable prices (31% or 166 respondents), availability of more toll gates with OBU censors (27% or 143 respondents), are easily obtained (22% or 119 respondents), and more sensitive sensor (17% or 93 respondents), depicted in Figure 3. While for government plans for the use of OBU devices for all toll road transactions, there was high enthusiasm (82%), as the online survey described in Figure 4. Pareto calculations showed , that relatively cheap price, the increase in the number of toll booths with OBU sensors, and the ease of buying OBU are factors that need serious treatment, as can be seen in Figure 5.

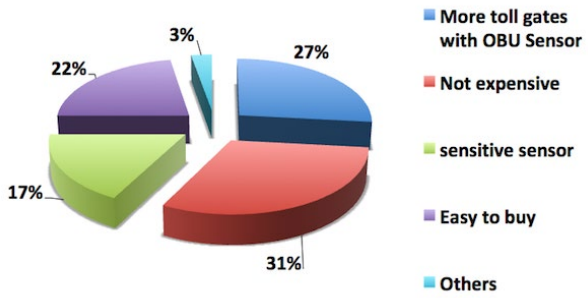

Figure 3. Expected OBU device

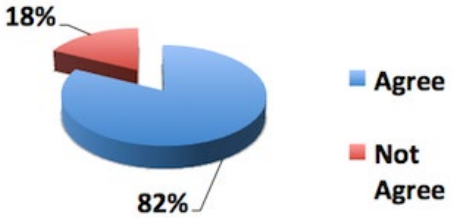

Figure 4. The application of 100% OBU device

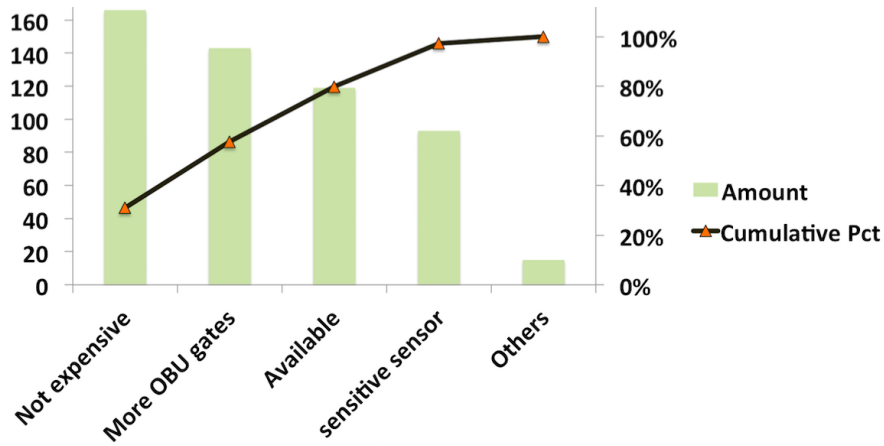

Figure 5. Expected factors of OBU device to be focus on

For the desired OBU device design, most respondents want an OBU device with Radio Frequency Identification (RFID) that can be placed on a windshield (35.69%), with Double Piece Infrared (22.51%), and with RFID on the headlamp (12.22%) or on a license plate (12.22%). As for the desired payment concept, 45.02% expects the balance to be stored on existing cards such as the existing e-toll card, 39.55% choose the balance stored in the application with the top-up system, and 14.79% choose the debit model. In general, respondents expect the price of OBU devices to be cheaper than one hundred thousand rupiahs (42.44%) or not more expensive than two hundred thousand rupiahs (39.23%). Sales program by giving a discounted price for OBU devices at a certain time (30.87%), giving points when transacting to get a certain promo (31.19%), and cooperation with other companies to get a discount on the purchase of OBU devices (29.26%), are programs that are seen as attracting attention to the respondents. The collaboration program with fuel stations (SPBU), is the most preferred collaboration (53.70%), including cooperation with shopping centers (21.86%).

Figure 6. 3D Design OBU Single Piece Microwave

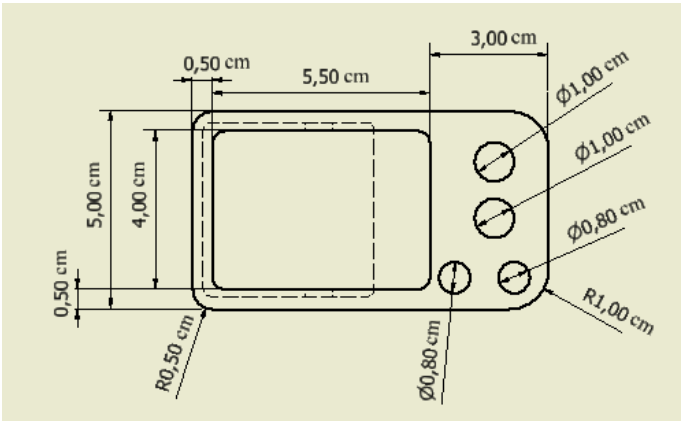

Figure 7. 2D Design OBU Single Piece Microwave

Based on the calculation of the House of Quality (HoQ), the recommended OBU device is OBU Single Piece Microwave, the OBU device that is integrated with the smart card. The design of the OBU device proposal includes dimensions, additional designs and components. The proposed dimensions do not exceed the palm for the convenience of installation and placement in the vehicle. The addition of the LED screen is intended to facilitate the reading of information from the OBU device, such as the status of the balance and the status of the success of the transaction. Another additional feature is the buttons, intended to support the ease of use of functions in the OBU tool. Components from OBU devices are recommended to have resistance to hot air, water, and collisions. The components on the OBU tool are adjusted to their level of resistance, so that the OBU tool can be resilient, resistant to water and heat. Figure 6 and Figure 7 illustrate the OBU Single Piece Microwave design that has taken into

account the recommendations of the HoQ calculation, and is approved by the toll road manager. Currently, the OBU device that is being circulated is OBU Double Pieces, where the e-toll card must be entered manually into the OBU device, while the OBU Single Piece that is currently being tested, does not have a screen.

Table 2. K-means clustering

Cluster Model

cluster 0: 35 items
cluster 1: 67 items
cluster 2: 173 items
cluster 3: 36 items
Total number of items: 311

Attribute	**cluster_0**	**cluster_1**	**cluster_2**	**cluster_3**
Domicile	4.200	4.716	4.214	1.139
Occupancy	5.886	.239	1.908	1.667
Income	3.057	3.373	0.676	1.694
Promotion program	1.457	1.299	1.526	1.278
Collaboration program	2.457	2.433	2.428	2.556

Table 3. K-means clustering: Promotion Program

Cluster	Characteristic	Residence	Promotion Program			
			Discount	Cooperation	Installment	Points
0	Entrepreneur with a monthly income of 8-15 million rupiah	DKI Jakarta	▯	▯	-	▯
1	Private employee with a monthly income of 8-15 million rupiah	Tangerang	-	▯	-	
		DKI Jakarta	-	▯	-	▯
2	University student with a monthly income of 1-3 million rupiah	DKI Jakarta	▯	▯	▯	-
3	University Student with a monthly income of 3-8 million rupiah	Bekasi	▯	▯	-	▯

Table 4. K-means clustering: Cooperation Program

Cluster	Characteristic	Residence	Cooperation Program		
			Shopping Center	Restaurant	Gas Station
0	Entrepreneur with a monthly income of 8-15 million rupiah	DKI Jakarta	-	▯	▯
1	Private employee with a monthly income of 8-15 million rupiah	Tangerang	-	▯	-
		DKI Jakarta	-	-	▯
2	University student with a monthly income of 1-3 million rupiah	DKI Jakarta	▯	▯	▯
3	University Student with a monthly income of 3-8 million rupiah	Bekasi	-	-	▯
		Bogor	-	-	▯

Calculation of Average Within Distance with an Elbow Method that is run through RapidMiner software, produces an optimal K value (k = 4), so the results of K-means clustering can be displayed as found in Table 2. Calculation of Elbow Method, which calculates the average distance between each data with the centroid cluster, the number of k used is k = 4, which means the respondents' data are grouped into 4 groups with the same characteristics in each group. The results of the k-means clustering analysis for promotion programs can be summarized in Table 3, while the collaboration program can be summarized in Table 4. Thus, the collaboration between PT Jasa Marga Tbk. with gas station companies that provide various benefits to toll road users to get OBU device discount, is very potential to support increased use of OBU more broadly.

Table 5.
Comparison of V / C ratio between e-toll card transactions and OBU devices

No.	Toll Gate	Volume sample (vehicles)	Number of Booths	V/C Ratio E-toll card (a)	V/C Ratio OBU device (b)	Δ (in %) (a-b)/a
1.	Cililitan	6645	18	.33	.15	54.55
2.	Halim	5249	13	.34	.16	52.94
3.	Cawang	1068	5	.18	.09	50.00
4.	Tebet 1	776	3	.22	.10	54.55
5.	Tebet 2	1051	4	.22	.11	50.00
6.	Kuningan 1	740	2	.32	.15	53.13
7.	Kuningan 2	1102	4	.23	.11	52.17
8.	Semanggi 1	1112	3	.32	.15	53.13
9.	Semanggi 2	1200	4	.26	.12	53.85
10.	Pejompongan	1160	3	.33	.16	51.52
11.	Senayan	1594	3	.45	.22	51.11
12.	Slipi 1	924	4	.20	.09	55.00
13.	Slipi 2	776	2	.33	.16	51.52
14.	Tanjung Duren	775	2	.33	.16	51.52
15.	Tomang	2600	9	.25	.12	52.00
16.	Jelambar 1	1115	3	.32	.15	53.13
17.	Jelambar 2	347	2	.15	.07	53.33
18.	Angke 1	775	2	.33	.16	51.52
19.	Angke 2	417	3	.12	.06	50.00
20.	Cengkareng	5989	18	.30	.13	56.67
21.	Kapuk	5397	17	.29	.13	55.17
22.	Kamal 1	2673	7	.33	.15	54.55
23.	Kamal 2	570	2	.24	.12	50.00
24.	Kamal 3	1596	5	.27	.13	51.85
25.	Kamal 4	421	4	.09	.04	55.56
26.	Pluit 3	1406	4	.30	.14	53.33
27.	Benda	112	2	.05	.02	60.00

LoS in this study is indicated through the V / C ratio. Observations made on 496 vehicles at the Cililitan Toll Gate, Substation 9 (e-toll card sensor) and Substation 10 (OBU sensor) show that the average transaction time using the e-toll card takes 3.07 seconds per vehicle on average (with a sample of 273 vehicles), while using the OBU device it takes an average of 1.46 seconds per vehicle (with a sample of 223 vehicles). Table 5 shows that the lowest V / C ratio for the e-toll card is in the Toll Gate Object, which is equal to .05 with the daily volume of vehicles in the peak hour of 112 vehicles, and the number of substations available is 2 substations. LoS on Object Toll Gate is ‘A’ which is free flow moves with the driver free to choose the vehicle speed according to the specified limit (Koloway, 2009). The highest V / C Ratio falls on Toll Gate Senayan which is equal to .45 with the daily volume of vehicles in the peak hour amounting to 1,594 vehicles with 3 substations available. Thus, the service level at the Senayan Toll Gate is included in the 'B' category where the flow is still stable but the driver starts not to be free to choose the vehicle speed (Koloway, 2009). The highest vehicle volume actually occurs at Cililitan Toll Gate, which is equal to 6,645

vehicles. However, Toll Gate Cililitan is included in the 'A' category because the amount of both tolls provided is sufficient to be able to accommodate the number of incoming vehicles that can freely move according to the specified speed limit (V / C ratio = .33).

The observation of the use of the OBU device, which is shown in Table 5, also shows that the smallest V / C ratio for the transaction process using the OBU device occurs at the Toll Gate, with a value of .02 and the highest occurs at Toll Gate Senayan with magnitude .22. When compared between the use of OBU devices and the e-toll card as electronic toll collection, on the toll road the CTC branch shows, that the use of OBU devices improves the toll road payment transaction processing time by 50% to 60%. This means that transactions using the OBU device at the 27 CTC branch of the Jasa Marga toll gate, save transaction time by 50% to 60% for each vehicle that uses it.

5. Conclusions and Discussion

The results of this study recommend the use of OBU devices that can be accepted by most people in Indonesia, through the design of OBU devices that are fit for the needs of toll road users, promotion models that are suitable for users from the Greater Jakarta area (Jakarta-Bogor-Depok-Tangerang-Bekasi) in order to increase the use of the OBU device, and decrease the queue or the efficiency of the transaction time at the toll gates. More than 80% of respondents supported the government's plan to implement the use of OBU devices as ETCs throughout Indonesia, noting that OBU devices that were circulated had affordable prices, were easy to obtain, and provided an adequate toll booth for toll road transactions using the OBU device. The use of OBU is still rare nowadays, especially because respondents are less aware of where OBU devices can be purchased; even among them there are many who are not aware of the presence of OBU device technology for ETC; prices that are still expensive, and many respondents who are not bank customers of OBU device providers. The lack of a toll booth that provides ETC with OBU devices, is also a complaint from OBU users that needs attention to be addressed, including the OBU sensor which is felt to be insensitive, and lack of collaboration with various other banks. The results of this study recommend an OBU device that is integrated with a smart card (single piece microwave), with a size that fits in the hand, easy installation and placement in the vehicle, and has an LED screen (to show OBU status and balance checking), and features communication to support the ease of use of functions on the OBU device. Furthermore, the results of this study also recommend OBU devices with components that are waterproof, impact and hot weather resistant.

In addition to providing recommendations for OBU device designs that are fit for users, this study also aims to obtain forms of cooperation that are interesting to toll road users to encourage the purchase of OBU devices, so that the government's goal to carry out non-cash payments throughout Indonesia can be accommodated. The form of collaboration between toll road managers and SPBU companies, which can provide relief for the purchase of OBU devices, is highly recommended by the results of this study. With the increase in the use of OBU devices as electronic toll collection, not only are touchless toll transaction plans accommodated, but also a significant decrease in the queue (50% -60%) can also be more evenly distributed throughout the country. Corrected queue levels can significantly support environmental reservations and various other forms of reservation, including health. The duration of transactions using the OBU device as an ETC in a matter of 1.46 seconds, is also able to meet the government's target of setting a standard transaction for one vehicle for 2.3 seconds.

Finally, the results of this study certainly still require generalization and follow-up to further research, for example by using other calculation models that can better accommodate the complexity of the actual conditions, and other sampling techniques. In line with the National Non-Cash Movement (Hutauruk, 2017), in the future, more research is expected to be able to explore forms of payment transactions that support the implementation of Multi Lane Free Flow on toll roads throughout Indonesia, which is suitable for most users in Indonesia, and various forms of cooperation and promotions to be able to continue to increase its use.

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