Critical examination of multilane free-flow tolling system implementation in Indonesia

Taufik Sugian Sumardi[1,2*], *Hiroyuki* Oneyama[1], *and Masami* Yanagihara[1]

[1]Department of Civil Engineering, Tokyo Metropolitan University, Minamiosawa 1-1, Hachioji-shi, Tokyo 192-0397, Japan
[2]Directorate General of Highways, Ministry of Public Works and Housing, Jl. Pattimura No. 20 Jakarta Selatan, DKI Jakarta 12110, Indonesia

Abstract. After operationalization, Indonesia's multilane free flow (MLFF) tolling system will meet new challenges. Many think that this tolling method will be beneficial not only for the toll road user but also for toll road operators (TROs) and transportation authorities. On the contrary, the drawbacks are also being considered in several reports and discussions. Moreover, too little research to shed light makes the complexity of the MLFF tolling system remain largely uncharted. This paper critically examines the Indonesian MLFF tolling system, questioning prevailing assumptions and encouraging further study. Employed literature review of all related documents that mentioned electronic toll collection, specifically on MLFF and open road tolling (ORT) system, this study offers valuable insights into the practical effects in real-world situations. The toll road authority should re-evaluate some regulations concerning minimum service standards imposed on the TROs. The privacy issues as an excess of using Global Navigation Satellite System (GNSS) that tracks each toll road user appears to become mainstream, while others deserve attention. The traffic information provision as a tool of traffic management should be considered as one of the solutions to provide valid traffic information derived from a scientifically sound method based on verifiable probe data.

1 Introduction

In his cabinet meeting in April 2016, the president of Indonesia, Joko Widodo, ordered the elimination of vehicle queues at all toll road plazas. He also mentioned that the transaction at the toll gates should be through applications connected with the toll road users' bank accounts [1]. This statement was a directive message that toll road payment in Indonesia must be upgraded to the Electronic Toll Collection (ETC) system.

Supporting this idea, the Minister of Public Works and Housing (MPWH) issued The Public Works and Housing Ministerial Regulation No. 16 of 2017 about Cashless Toll Transaction on Toll Road. It regulates the electronic card-based ETC and states the deadline for nationwide implementation. The establishment of bodies that provide and manage the ETC transactions is also being regulated. Moreover, it aligns with The National Cashless

* Corresponding author: sumardi-taufik-sugian@ed.tmu.ac.jp

Movement (GNNT) enacted in 2014. On October 31, 2017, all the toll road sections in Indonesia used the electronic card-based ETC, leaving the old cash transaction system.

The electrification of toll road payments continued as a transition into a more complex toll collection system. By the end of 2018, the multilane free flow (MLFF) was planned to be operationalized. MLFF was defined as a cashless and touchless toll collection system that allowed toll road users to pay the fare without stopping at the gate when exiting the toll road system. However, none of the levy mechanisms and technology explanations exist to support the implementation. The plan failed to be executed [2,3].

In 2020, The Public Works and Housing Ministerial Regulation No. 18 regulates cashless and touchless toll transactions to support the implementation of MLFF. Therefore, there were intense discussions between MPWH, the TROs Association, and the Central Bank of Indonesia about integrating electronic transactions within the toll road networks. In the same year, MPWH issued a feasibility study Roatex [4] containing the detailed system and the investment plan for MLFF implementation. This document also mentions the MLFF employment timeline from the first stage, which combines electronic card-based payment with the single lane free flow (SLFF) at the existing gates until the MLFF systems are fully operated.

Even though there was an international bidding winner to initiate the construction of MLFF in 2021, the system's complexity, which requires the involvement of many parties, made several action plans fail. Nonetheless, the system was installed in several gates in 2022 [5] and is projected to be operated entirely at the end of 2023 [5]. Until this paper is submitted, the project's progress is still unknown. Moreover, since most of the MLFF information comes from the news based on the MPWH and Indonesian Toll Road Authority (ITRA /BPJT) statement, no detailed explanation of the system leads to unbiased understanding among the toll road users. Too little research to shed light makes the complexity of the MLFF remain largely uncharted. In fact, 67% of the toll road users did not know a new MLFF tolling system would exist [6].

This paper critically examines the Indonesian MLFF tolling system, questioning prevailing assumptions and encouraging further study. The primary source of this paper is the feasibility study of the "Multi Lane Free Flow Toll Collection in Indonesia" made by Roatex Ltd Zrt, Hungary, in 2020. In addition, the Indonesian Consumers Association (YLKI) research report of "*Survey Persepsi Pengguna Terhadap Pelayanan Transaksi Pembayaran di Gerbang Tol Se-Jabodetabek*" is a supported document that is considered legitimate. We gained access to both documents through the ITRA.

2 The prevailing assumption of MLFF

The first toll road section Indonesia has is Jagorawi Toll Road. "Jagorawi" was chosen from the cities where that toll road connects Jakarta-Bogor-Ciawi. It was designed in 1963, but the construction began in 1973, with an initial cost of 280 million rupiahs per kilometres. The toll road was done with two stages of construction. The first stage was Section A, which connects Cawang (Jakarta) to Cibitung (28 km). President Soeharto officially opened it on March 9, 1978. The second stage is Section B (24 km), which connects Cibitung and Ciawi and was open to the public at the end of the year. By the time it was open to the public in 1978, the cost had risen to 400 million rupiahs per kilometres. Another source mentions 575 million rupiahs per kilometres. This toll road section used an open toll collection system where users pay the fare before they enter the toll road, meaning that one price for every destination.

After several toll road sections were developed, the closed toll collection system was deployed. The system required the driver to stop to take the ticket at the entry gate and pay the fare at the exit gate. Service at the entry and exit gates is regulated to prevent and reduce

congestion. This regulation is one of the minimum service standards (MSS) TROs must follow. In 2001, PT. Jasa Marga issued subscription tickets that can be purchased at each toll gate. The ticket gives a ten percent fare discount for those who frequently use a certain route. The subscription ticket also significantly reduces the service time since no cash transaction is involved at the exit gate. Moreover, from the TRO side, the changes that should be provided can also be reduced.

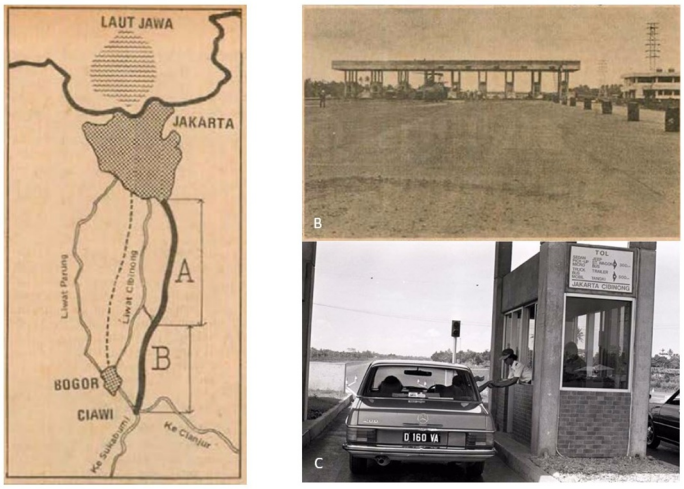

Fig. 1. The first toll road in Indonesia. a) The toll road connects Jakarta-Bogor-Ciawi; b) Cawang (Jakarta) Toll Gate; c) Transaction on a Toll Booth (Source: Tempo, 1978).

The electronic toll collection system was introduced in January 2009. It is a "touch and go" transaction using e-money as an integrated circuit (IC) card in the open and closed toll road system. Several banks issued their e-money with their own IC reader and writer devices. This condition leads to a problem of interoperability between the readers at the gate. TROs have to provide several IC readers representing each bank so the user can tap their e-money according to the one they have. After three years of adjustment, there is only one universal IC reader and writer at each toll booth for the toll transaction.

Indonesia's National Medium Term Development Plan 2020-2024 (RPJMN) targeted 2,500 Km of new and/or in-operation toll roads across the nation. By the end of April 2021, the length of the toll road in Indonesia is 2,391 Km with 33 TROs within 50 sections, including the toll bridges. In September 2023, the toll road length grew 15% to 2760 km. The number of TROs also increased to 59 concessionaires that manage 71 sections. MPWH has achieved beyond the target of RPJMN.

Table 1 shows five technologies compared with 11 factors to consider in choosing the appropriate system for Indonesian MLFF. The five technologies are Radio frequency Identification (RFID), Dedicated short-range communications (DSRC), Automatic number-plate recognition (ANPR), GNSS, and Vignette. The 11 factors compared are (1) the cost of the initial investment for road-side infrastructure, (2) the yearly cost level of the system, (3) equipment requirement and potential costs in case of expanding the tolled road network, (4) the additional investment need and operational costs in case of expanding the tolled road network, (5) The type of the toll road where the system can operate most efficiently, (6) useful lifespan of system equipment, (7) Technology of communication with the vehicle, (8) System requirement about database of the registered vehicles, (9) Primary toll collection scheme, (10) Applicability for distance-based charging scheme, and (11) capability of introducing dynamic traffic management measures, such as congestion charges.

Table 1. Comparison of tolling technologies (Adapted from Roatex [4])

	Passive RFID	**DSRC**	**ANPR**	**GNSS**	**Vignette**
Road-side infrastructure	Expensive Rating: 1	Expensive Rating: 1	Expensive Rating: 1	Only for enforcement Rating: 10	Only for enforcement Rating: 10
Operating expenditures	Mid Rating: 5	High Rating: 2	High Rating: 1	Low Rating: 9	Low Rating: 10
Equipment installed in the vehicle	RFID tag - low cost Rating: 9	OBU - mid-cost Rating: 5	No Rating: 10	OBU - high cost Rating: 1 GNSS e-OBU no cost Rating: 10	Vignette Rating: 10
Cost of expansion	High Rating: 1	High Rating: 2	High Rating: 1	Low Rating: 10	Low Rating: 10
Characteristics of ideal toll road	Limited express road network, high traffic flow Rating: 1	Limited express road network, high traffic flow Rating: 1	Middle-sized network, normal traffic flow Rating: 1	Sizable network, low traffic flow Rating: 1	Middle-sized network, normal traffic flow Rating: 1
Data communication	Radio frequency Rating: 6	Radio frequency Rating: 6	Optical solution Rating: 1	GSM communication Rating: 9	Optical solution Rating: 2
Need for central database	Only for enforcement Rating: 10	Only for enforcement Rating: 10	Yes Rating: 2	Only for enforcement Rating: 10	Only for enforcement Rating: 10
Primal charging schemes	Distance-based	Distance-based	Distance-based	Distance-based	Time-based
Distance-based tolling capability	Yes	Yes	Yes	Yes	No
Dynamic traffic management capability	Yes Rating: 10	Yes Rating: 10	Yes Rating: 10	Yes Rating: 10	No Rating: 1
Overall rating	53	47	37	OBU-70 ; e-OBU-79	55

According to Roatex [4], the appropriate system of MLFF in Indonesia is a Global Navigation Satellite System (GNSS)-based system tolling system. The choice is based on a rating system of some factors compared to ETC's state-of-the-art technologies. The chosen system eliminates the gate, and the service capacity will be the same as the road capacity. Also, it sets the key performance indicators (KPI) of the service elements provided for the system by 100% of toll road users, with the accuracy thresholds of 99% toll declaration and toll tariff, effective enforcement support system, dense enforcement data collection, clearing and payment settlement, and enable network extension.

After operationalization, MLFF will meet new challenges. Many think this tolling method will benefit the toll road user, the TROs, and transportation authorities. It is believed that MLFF would significantly decrease transaction time, enhance throughput [7], and make toll services more efficient [8] and comfortable [9]. These will, in turn, reduce greenhouse gas emissions into the atmosphere. Moreover, MLFF enables flexibility in defining toll rates with relative ease in realizing dynamic pricing. However, it takes the technical, economic, and political aspects before implementing the system.

There were attempts to reveal consumer behaviour from upgrading ETC from cash to cashless transactions [10] and from cashless to touchless [6]. Also, the effect of ETC on the transport system revealed that reduced service time could ease accessibility and improve the TROs' performances in fulfilling the MSS [11].

The question arises in searching for keyword(s) in tracing the literature. The keyword "MLFF" is used mainly by Indonesian researchers. However, the term MLFF is also found in Lee et al., [12] as an area-wide integrated charging system. Limited findings on the word MLFF give the impression of the different representations of the tolling system used in academic society. The phrase "Multilane free flow", "Multi lane free flow", "Multi-lane free flow", "Multilane free-flow", "Multi-lane free-flow" also did not bring satisfactory results. It is assumed that the word MLFF is not so popular or even not the proper term for the system.

The term open road tolling (ORT) brings many results from the quarry. However, ORT usually combines with cash transactions and the DSRC system. More of the review of ORT can be found in Klodzinski et al., [13]. Most countries already using the MLFF system only imposed the payment system on business vehicles such as trucks and buses.

3 Findings

The Indonesian MLFF tolling systems will be unique and considered one of a kind because of these characteristics:

1. The system will be imposed on all vehicles classification
2. The GNSS-based MLFF tolling system will be the only system that exists in Indonesia
3. Nationwide toll road networks will adopt the system
4. Only one Central Transaction Service Provider (CTSP) manages all the transactions.

The e-OBU as an application in the user's smartphone will reduce and eliminate the cost that burdens the toll road users. This e-OBU is used to make a declaration about entering and exiting the toll road system, meaning that during the travel, the GNSS must be able to detect the exact location of each vehicle. Location signal and GSM coverage loss are the issues preventing the smoothness of the levy system. Also, the users must ensure that their smartphone is in standby mode with the power on.

The system will generate abundant data, which contradicts the prior conditions that describe the limited data derived from the detectors. This situation implies that the traffic volume can be easily taped from the server with the most minor aggregates. The system can quickly reveal, for example, the vehicle classification proportion, the total volume of the vehicle that operates in the toll road networks, the seasonal volume of traffic, and the growth number of vehicles.

There will be no physical difference between the toll and surface roads. The boundary between them only exists in digital cartography. Therefore, proper signings and markings are required to distinguish the border between them. In the toll road system, toll plazas represent the critical nodes of the traffic network that cause delays and pollution [14]. Indonesia had experiences in removing toll gates, especially those in midblock that caused long queues of vehicles. These gates usually act as the border between two sections with different concessionaires. The ITRA removed those gates because they mainly contribute to massive

congestion. Some of the removed gates that contributed to easing the flow inside the toll road are Pondok Gede Timur Gate on the Jakarta-Cikampek toll road in 2010, Cikopo Gate on the Cikampek-Palimanan toll road in 2016, Karang Tengah Gate on Jakarta-Tangerang toll road in 2017, Cibubur Utama and Cimanggis Utama Gates on Jagorawi toll road in 2017, Kayu Besar Gate on Jakarta Outer Ring Road toll road in 2018, and Cikarang Utama Gate on Jakarta-Cikampek toll road in 2019.

The GNSS system in the toll collection system will not be stand-alone. The system must be coupled with a mobile communication system (GSM), and its cost will be paid by the user apart from the toll itself.

Using gantries as a substitute for toll gates will burden the TROs because they are costly. The gantry should only be used for enforcement as planned at the beginning of the feasibility study.

4 Conclusion

There are growing issues among the toll road users that the new toll collection system will be implemented. However, the few details they received reduced the system familiarity. This paper introduces the Indonesia MLFF toll collection system based on the feasibility study done in 2020 and compares similar terms and definitions used by several researchers in many countries.

The privacy matters as an excess of using GNSS that tracks each toll road user appear to become mainstream, while others deserve attention. Several concerns, such as socialization and system adaptation, should be given appropriate time for the toll road user. In the past, there were open and closed toll systems in Indonesia. If the MLFF system is implemented, toll roads in Indonesia will become all-closed, requiring toll users to declare at the beginning and end of the toll road.

The ITRA should revise the regulations of MSS imposed on the TROs. The service time at the toll gates should be changed because no more gates will remain after the new system is entirely operated. For example, the items that should be added to the MSS are the position track failure and communication failure thresholds. Also, the minimum latency and the number of satellites captured by e-OBU should be included in the regulation.

The current toll plaza design requires a sufficient land area to place several entry and exit booths according to vehicle demand at each inlet or outlet. When MLFF is implemented, the remaining additional land can be used as an emergency lane for toll users with trouble paying.

Proactive traffic management should be deployed to anticipate the lag between data collection and the strategy to control traffic [15]. The available transport infrastructure is more efficient when travel demand management tools, such as travel information, help travelers make better choices in route selection [16]. Papageorgiou et al. and Sheu & Yang noted the importance of VMSs for traffic congestion management and improved traffic efficiency [18,19]. A VMS is a significant component in intelligent transportation systems because it provides various types of information, such as traffic conditions, speed limits, and alternative routes [20].

Acknowledgment
We express our appreciation to the ITRA for providing permission to access the documents entitled "Multi Lane Free Flow Toll Collection in Indonesia" in 2020 and *"Survey Persepsi Pengguna Terhadap Pelayanan Transaksi Pembayaran di Gerbang Tol Se-Jabodetabek"* in 2023.

References

1. D. Parikesit, in Focus Gr. Disccussion Dalam Transform. Digit. Dalam Pengemb. Jalan Tol Di Indones. (Jakarta, 2021)
2. A. W. Finaka, Indones. Baik (2018)
3. A. Budiharjo and S. R. Margarani, J. Keselam. Transp. Jalan (Indonesian J. Road Safety) **6**, 1 (2019)
4. Roatex Ltd Zrt, (2020)
5. BPJT (2022)
6. Yayasan Lembaga Konsumen Indonesia, Laporan Penelitian Survey Persepsi Pengguna Terhadap Pelayanan Transaksi Pembayaran Di Gerbang Tol Se-Jabodetabek (2023)
7. B. C. R. Rota and M. Simic, Procedia Comput. Sci. **96**, 1637 (2016)
8. X. Hao, X. Sun, and J. Lu, Procedia - Soc. Behav. Sci. **96**, 433 (2013)
9. J. Dias, J. N. Matos, and A. S. R. Oliveira, Procedia Technol. **17**, 130 (2014)
10. T. B. Joewono, B. A. Effendi, H. S. A. Gultom, and R. P. Rajagukguk, Transp. Res. Procedia **25**, 4454 (2017)
11. R. A. Hidayatul, How Electronic Toll Collection Deployment Affects Transport System Efficiency: The Study of Indonesia Toll Road Network, Ritsumeikan Asia Pacific University, 2019
12. W. H. Lee, S. S. Tseng, and C. H. Wang, Comput. Commun. **31**, 2925 (2008)
13. J. Klodzinski, E. Gordin, and H. M. Al-Deek, Transp. Res. Rec. 72 (2007)
14. V. Astarita, M. Florian, and G. Musolino, IEEE Conf. Intell. Transp. Syst. Proceedings, ITSC 692 (2001)
15. B. L. Smith, B. M. Williams, and R. Keith Oswald, Transp. Res. Part C Emerg. Technol. **10**, 303 (2002)
16. R. Arnott, A. de Palma, and R. Lindsey, 1 (1989)
17. J. B. Sheu and H. Yang, Phys. A Stat. Mech. Its Appl. **387**, 4327 (2008)
18. M. Papageorgiou, I. Papamichail, A. D. Spiliopoulou, and A. F. Lentzakis, Transp. Res. Part C Emerg. Technol. **16**, 535 (2008)
19. C. Shaokuan, L. Mingjun, G. Liping, M. Chao, L. Wei, and Z. Jinzi, Proc. - 2008 Int. Work. Model. Simul. Optim. WMSO 2008 416 (2008)
20. P. Jindahra and K. Choocharukul, IEEE Trans. Intell. Transp. Syst. **14**, 388 (2013)