Journal of Infrastructure, Policy and Development 2024, 8(8), 6341.
https://doi.org/10.24294/jipd.v8i8.6341

Article

Regulatory challenges in modernizing toll road transaction systems in Indonesia

Danang Parikesit[1,*], Prita Amalia[2], Valen Diyen[3]

[1] The Center for Transportation and Logistics Studies, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia
[2] Transnational Business Law Department, The Study Center for Infrastructure Law, Faculty of Law, Universitas Padjadjaran, Bandung 40132, Indonesia
[3] AHRP Law Firm, Jakarta 12950, Indonesia
*** Corresponding author:** Danang Parikesit, dparikesit@ugm.ac.id

CITATION

Parikesit D, Amalia P, Diyen V. (2024). Regulatory challenges in modernizing toll road transaction systems in Indonesia. Journal of Infrastructure, Policy and Development. 8(8): 6341. https://doi.org/10.24294/jipd.v8i8.6341

ARTICLE INFO

Received: 11 May 2024
Accepted: 3 July 2024
Available online: 27 August 2024

Abstract: The Government of Indonesia has modernized the toll road transaction system by implementing the multi-lane free-flow (MLFF) project, set to operate commercially by the end of 2024. This project leverages Global Navigation Satellite System (GNSS) technology to identify vehicles using toll roads and establish a transaction mechanism that allows the MLFF Project Company to charge road users according to distance, vehicle category, and tariff levels. The project has result in a complex business arrangement between the Indonesia National Toll Road Authority (INTRA), Toll Road Companies (TRCs), and the MLFF Project Company. The aim of this paper is to review the regulatory and institutional framework of the MLFF project and analyze its challenges. The methodology employed is a qualitative framework for legal research, utilizing international literature reviews and current regulatory frameworks. The study assesses the proposed transaction architecture of the project and identifies commercial, political, and other risks associated with its implementation. Based on the analysis, the research identifies opportunities for regulatory improvements and better contracting arrangements. This research provides valuable insights into the regulatory landscape and offers policy recommendations for the Government to mitigate the identified risks. This contribution is significant to the academic field as it enhances understanding regulatory and institutional challenges in implementing advanced toll road systems.

Keywords: multi-lane free-flow (MLFF); toll roads; concession risks; regulatory framework

1. Introduction

Many governments are now introducing paid services to use their highways, and toll roads have gained popularity because they allow governments to avoid spending their budgets on construction and maintenance, using investors' money to build and operate the roads under concessions instead. However, investors face complex challenges, including safeguarding land acquisition processes, providing appropriate financing schemes, designing, constructing, and implementing operations until the end of the concession period. Various domestic and foreign researchers have discussed the impact of toll road investment, and the Indonesian case study (Saich, 2013) highlights the necessity of a better-designed concession to maximize the benefits of toll road investment in Indonesia.

Indonesia's toll road network began in 1978 when the Government decided to impose a tariff on the freeway between the capital city of Jakarta and the second-tier city of Bogor, with a distance of 59 km or 37 miles. PT Jasa Marga (Persero) Tbk. (JM) was assigned by the Government to operate the toll road with land financed by

the Government. Starting in 1987, PT Citra Marga Nusaphala Persada Tbk. (CMNP), as a private company, began to participate in toll road investment as a toll road operator by signing a concession agreement with JM. From 1995 to 1997, efforts were made to accelerate toll road construction through a tender for 19 toll road sections of length 762 km. However, this effort was halted due to the monetary crisis in July 1997, which resulted in the Government postponing the toll road construction program.

Between 2005 and 2014, the Government underwent progressive institutional and legal reform to promote the use of private financing for developing the national toll road network. Key reforms included the enactment of the Law on Road in 2004, and the Law on Land Acquisition for Development in the Public Interest in 2012, the establishment of the Indonesia National Toll Road Authority in 2005, the introduction of Presidential Regulation on Public Private Partnership in 2005 and its subsequent amendments, and the creation of non-bank institutions such as PT. Sarana Multi Infrastruktur (SMI), Indonesia Infrastructure Finance (IIF), and MoF-backed Indonesia Infrastructure Guarantee Fund (IIGF) provided a robust foundation for toll road development in Indonesia (Parikesit and Laksmi, 2015). By 2014, the Ministry of Public Works and Housing managed 780 km of toll road, which grew to over 2600 km by 2023, comprising 69 toll road concessions operated by 48 toll road companies (TRCs), and generating 4.54 million daily transactions in 2022 (INTRA, 2023). The network is projected to reach 18,000 km within the next 15–20 years, increasing the demand for managing toll road operations. Despite the growth, logistics costs remain high, with the World Bank's LPI score of 3.15, and Indonesia ranked 46 in 2018. This situation presents an opportunity for improvement, with toll road networks serving as a critical backbone for moving goods and services throughout Indonesia.

Since 2017, the Ministry of Public Works and Housing has established a roadmap for digitalizing the toll transaction system, beginning with the transition from cash to non-cash transactions system using electronic money. A significant milestone was achieved with the Government's introduction of the Multi-Lane Free Flow (MLFF) system, utilizing Global Navigation Satellite System (GNSS) technology, through an investment tender initiated by business entities in 2019. This milestone was further reinforced by the enactment of Government Regulation Number 23 of 2024, which stipulates that the Government may conduct toll collection using electronic systems.

The introduction of GNSS-based MLFF also opens new avenues for modernizing Indonesia's toll road operating system. The implication of the Government's mandate regarding the choice of transaction technology and the executor to collect toll revenues is the shift in revenue risks from TRCs to the Government, alongside the reliability of these systems and technologies in serving transactions.

This paper examines the global state-of-the-art of the electronic toll collection system (ETC) and its implementation challenges, reviews the current regulatory and institutional framework of implementing the MLFF project, and addresses the need for further reform in the existing concession agreement to improve risk allocation among parties involved in the project implementation.

2. Methodology

The expansion of toll roads in Indonesia necessitates substantial investments, and

while several toll roads have been constructed to interconnect the Indonesian archipelago, the toll road sector still requires technological advancements. These advancements can potentially provide a competitive advantage for investors. This study investigates the regulatory and institutional obstacles in Indonesia's ongoing efforts to construct toll highways, with a particular focus on supporting the implementation of the MLFF project. This article delves into the evolution of toll roads in Indonesia, the diverse legislation governing them, and investment programs initiated by the Government. The approach utilized in this paper is normative juridical methods aimed at analyzing the legal foundations of principles to address pertinent legal issues, especially those related to implementing electronic systems in toll roads. The research methodology involves analyzing the legal principles enshrined in several regulatory frameworks in Indonesia, such as Law Number 2 of 2022 and Government Regulation Number 23 of 2004. The data analysis was conducted both normatively and qualitatively by interpreting the regulation and other related documents, such as concession agreements. This project aims to generate regulatory innovation input and establish an institutional framework for technological innovation on toll roads, including recommendations for concession agreements.

3. Literature review

3.1. Understanding the concept of toll roads

The idea of a paid road has long been in the minds of political leaders and policymakers. The World Development Report (World Bank, 1994) provides a modern policy foundation that has become a compass for developed and developing countries to mobilize non-government funds. This concept manifests in various forms, such as the Private Finance Initiative or PFI (Grout, 1997) and the generic Public-Private Partnership (PPP) (Amalia and Budhijanto, 2018; Fisher and Babbar, 1996; Ke and Chang, 2010).

PPP considerations must be distinct from the basic assumptions regarding network economics, which emphasize that the more connected an area is to other regions, the greater the opportunity to obtain economic and social benefits. Toll road projects are also driven by transport economic theories, which suggest that road users choose routes they perceive as more cost-effective than alternatives. Known as the first and second Wardrop principles (Wardrop and Whitehead, 1952), road users rearrange themselves to seek the most efficient traffic allocation to achieve the lowest generalized costs possible. This principle leverages the possibility of imposing road user charges below their ability to pay (ATP) and willingness to pay (WTP). The difference between the ATP, WTP and the actual out-of-pocket cost borne by road users can be monetized as potential revenue for toll road investors.

3.2. Electronic toll collection

Since its introduction and review in the early 80s (Hensher, 1991), the ETC has evolved significantly, offering toll facility operators the ability to handle substantially more traffic capacity than traditional toll collection. The earliest toll collection methods involved manual processes such as individual toll tickets, stickers, or

returnable cards. Various researchers have extensively discussed the current and future implementations of GNSS technology in the transport sector (Egea-Roca et al., 2022; Jing et al., 2022; Quddus et al., 2007). The standardization of the ETC was established in 2019 under ISO 17573-1, Electronic Fee Collection—System Architecture for Vehicle-Related Tolling, which consists of two parts: reference model and terminology (ISO, 2019). This standard replaced earlier ISO standards, incorporating improvements that facilitate the generation of new technologies and the identification of technology risks. The Indonesia MLFF system architecture adheres to the principles outlined in the ISO standard. A significant feature of the system is that it uses GNSS technology to recognize the location and movements of vehicles passing along the available routes.

The implementation procedure of the MLFF project involves several steps as described below **Figure 1**. The system is activated by an electronic on-board unit (e-OBU) to initiate toll declaration. The global positioning system performs map matching in the central computer system. Upon the completion of the toll-road journey, map matching is finalized, and the toll-road user is informed about the total toll fees to be paid (INTRA, 2023). Intelligent cameras were installed to verify the position and ensure the validity and legality of vehicles using the toll roads. The data are synchronized with traffic police records to ensure effective law enforcement. The payment system will be implemented using a transaction protocol approved by the Indonesian Central Bank. The Indonesian Central Bank's regulation also stipulates requirements for payment system providers and transaction protocols.

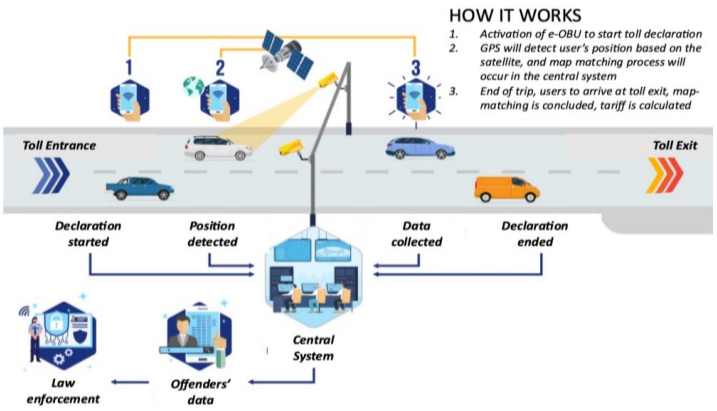

Figure 1. MLFF System Architecture (INTRA, 2023).

3.3. Commercial risks of technology adaptation

The adoption of driver-assisted technology in intelligent vehicles introduces various risks. Early work on the subject (Varaiya, 1993) identified several issues and solutions for applying intelligent vehicles/highway systems (IVHS). More recent research (Chen et al., 2007; Tseng and Pilcher, 2022; Waqas and Ioannou, 2023) had highlighted political, technological, and safety challenges in implementing the intelligent transport system (ITS), ETC. These studies consistently identify the benefits of transitioning from manual to electronic toll collection, such as reducing congestion at the toll gates, saving energy, reducing emissions by minimizing vehicles' idle time, and improving services. One study on the digitalization of toll road payment outlines that ITS aims to create an intelligent transportation network, which is

designed to assist users in obtaining information, facilitating transactions, enhancing the capacity of infrastructure and facilities, alleviating congestion, improving safety and comfort, and reducing environmental pollution (Resdiansyah and Malik, 2023). This technological shift also enhances the image of policymakers by demonstrating their readiness for the new technology. However, it has been described in various research papers that bureaucracy and red tape administration often cannot handle technological innovation. However, they identified political risks when implementing ETC technology, namely, the issue of control over the system when it was provided as a concession to a private party (Tseng and Pilcher, 2022).

In a broader context, adapting to new technology exposes both public and private sectors to investment and financial risks, there are two approaches to measuring the benefits of adopting Radio Frequency Identification (RFID) as a new technology (Bunduchi et al., 2011), namely direct benefits such as lower transaction and production costs, and indirect strategic benefits, such as improved buyer-supplier relationship and competitive advantages. The relational context is crucial, as adopting process innovations that span organizational boundaries requires consideration of costs (and benefits) extended to all partners involved.

Privacy is considered an essential issue in implementing such technology (Ogden, 2001). Trust should be developed between the provider and user and maintained between the technology provider and TRCs. Trust is one of most critical relational variables in adopting innovation between organizations. A lack of trust among innovation partners can create conflict, increase tension among potential adopters, and raise the costs associated with introducing innovations.

When the Government adopts new technology in the public sector, the risks of losses to existing private sector operators should be considered. Conversely, the new technology providers, especially those in greenfield projects, should be incentivized. In the case of Indonesia, the investors in the MLFF project were compensated with a fixed service fee during the concession period and additional fees associated with new toll road sections being added to the system (INTRA, 2023). Commercial risks arise between existing TRCs and new ETC providers.

3.4. Conceptual principles of toll road concession

The basic concept of concession is to transfer or to delegate a full or partial right to specific tasks of government agencies to private sector parties to undertake government public obligations. Infrastructure services are categorized as government obligations. This particular service differs from the service provided to the government via construction contract, service contract, or supply contract. This transfer or delegation of authority aims to address financial obligation related to capital or operational expenditure, with concessioners assuming financial risks associated with the transfer/delegation of authority. In return, concessioners receive commercial returns in agreed-upon terms, as stipulated in a document called “a concession agreement”. Number of literatures outline the principles of infrastructure concessions (Clifton and Duffield, 2006; Miranda, 2007; Ortiz and Buxbaum, 2008; Shaw et al., 1996; Serina, 1999), and more specifically on toll roads (Bel and Foote, 2009; Nicolini-Llosa, 2002).

Generally, the literature concurs that while the ultimate ownership of the physical asset or right to supply remains with the government, concessioners are granted the opportunity to commercialize or are entitled to receive financial returns, assuming commercial risks during the concession period. Concession models range from leasing, franchising, and BOT arrangements to new and innovative PPP frameworks. For projects with a sizeable capital expenditure, concessioners face more considerable risks from upfront investment commitments, necessitating protection from various risks, as follows.

Commercial risks: Commercial risks pertain to project costs and revenues during the concession period. The cost of equity and debt translates into the weighted average cost of capital. Direct costs include construction, maintenance, rehabilitation, and reconstruction of assets and expenses for managing the business and operating the facilities. Sometimes, the project sponsor must acquire land and compensate the original landowners. Project sponsors must maintain their confidence in securing construction costs (or, in the case of brownfield projects, the cost of acquisition), while relying on revenue from traffic forecasts and economic development. Case like Australia's traffic shortfall due to overestimated forecasts highlight the importance of accurate consultancy (Bain, 2009; Hensher, 2017).

Management control and political risks: Project sponsors have limited control over management and political risks in business cooperation between government agencies and the private sector. Factors such as the land acquisition process, permit durations, regular and time-based tariff adjustment, tariff reduction for cultural or social events, and commitment to a viable gap fund can create barriers or frustration for the private sector.

ESG risks: Global political leaders have increasingly expressed the importance of implementing environmental, social, and governance principles in recent years. Multilateral development banks are often called "safeguard policies," which enable fair policies and fair treatment among stakeholders and ensure that projects are accountable. The basic argument for PPPs, among others, is to have agility, flexibility, and innovation in the private sector, leading to efficiency and competitiveness, activities that the government may not be able to undertake.

Residual risks: Residual risks are uncertainties often not allocable to specific parties in a contract. Therefore, it is essential to have a clear framework for appropriately mitigating these risks, ensuring they do not become detrimental factor to the investment.

Legislation regulates the scope of toll road concessions, encompassing technical planning, financing, construction, operation, and preservation. Toll collection is an integral part of the operation, and concessioners are permitted to carry out the operation according to law, granting concessioners the right to conduct toll collection. Through the Law on Road, the Government seeks to separate the roles of operator and regulator to ensure efficiency and transparency, exemplified by the establishment of INTRA.

4. Findings

4.1. Current regulatory and institutional challenges

In 2022, the Government and the Parliament of Indonesia agreed to amend the Law on Road, enacting Law Number 2 of 2022, which updated the previously enacted Law Number 38 of 2004. Recently, Government Regulation Number 23 of 2024 was issued to implement the Law on Road, fulfilling the requirements set forth by Law Number 2 of 2022. These legal updates introduce several new provisions related to toll road business, one of which grants the Government the authority to determine transaction technology and conduct toll collection through a cooperation scheme with appointed business entity. This policy has undoubtedly increased the risk exposures for TRCs compared to the previous policy based on their concession agreements.

The underlying regulation and legal framework of a commercial arrangement between INTRA and TRCs were Law Number 38 of 2004 and its subsequent legal derivatives. This framework included a set of risk allocations between the Government, represented by INTRA, and each TRC. Government contracting agency signs the toll road concession contract for up to 50 years, granting the TRC the right to monopolize toll collection for specific section or segment in the toll road network. The TRC must invest in technology and allocate human resources to collect toll tariffs from users traveling along the concession's roads. With the Government's decision to take over the revenue collection responsibility and delegate it to MLFF Project Company on its behalf, TRC management control over the toll road business cycle will expire. This, in turn, exposes new risks to lenders and financiers, negatively impacting the project's commercial viability.

Before the enactment of Government Regulation Number 23 of 2024, the commercial arrangement between INTRA and MLFF Project Company was undertaken under the mandate of Ministerial Regulation Number 18 of 2020, which focused on the provision of non-cash contactless toll road transactions. INTRA undertook an investment tender from an unsolicited project proposed by a private company. Upon grant approval, the MLFF Project Company would develop an MLFF system that allows its central system to communicate and exchange information with the database of the traffic police. This system aims to provide data on traffic violators and traffic offenders for further law enforcement, and most importantly, to create a transaction platform for toll road users to pay their tariffs. The significant issues for TRCs are the loss of control over the flow of funds and the confidence in MLFF Project Company to mitigate the technical and commercial risks of the project. This new framework increased the vulnerability of TRCs for commercial use. Addressing this issue using the existing engagement is considered insufficient. Therefore, it is critical to review possible amendments to the existing TRC concession agreement based on the new regulations.

4.2. Risk allocation in MLFF technology implementation

The fundamental challenge in establishing toll revenue collection systems and technologies by the Government, lies in balancing the requirement for 100% collectability, a prerequisite for a TRC as a business entity—and the less than 100% tolerance for fulfilling payment obligations to the toll road users set by the service level agreement between the Government and the MLFF Project Company. Technological errors are commonly included in the investment business model in

technology-based industries. Technology risk, which generally ranges from 0.1% to 1%, is a residual risk that either TRCs or the MLFF Project Company cannot manage. Although there is a mechanism for administrative fines and other legal processes for toll road users who do not pay toll fees (non-paying customers), this residual risk is perceived as one that the Government must mitigate because it is seen as the most capable party to manage this risk. The use of the MLFF system with any technology is typically carried out on toll road concessions that use a return-on-investment scheme using availability payments, differing from the user tariff-based concession in Indonesia.

Given that MLFF Project Company is not a party to the toll road concession, it provides the MLFF system to the Government based on the MLFF system PPP agreement. The concept involves the Government collaborating with the MLFF Project Company to provide MLFF system services to TRCs, who, in turn, pay a service fee to the Government. This setup positions the Government as a vendor providing services to TRCs, relieving TRCs of toll collection risks.

When the MLFF system is implemented, TRCs can no longer control toll collection risk; meanwhile, demand risk remains with the TRCs. Considering that toll revenue is the primary source of the TRCs in obtaining return on investment, it is in the TRCs' interest to ensure that the income received by the TRCs is 100% of toll revenue, based on the volume of vehicles crossing the toll road and the class of vehicles according to the applicable toll tariff (100% of Toll Revenue). Since the replacement of the payment system is a government policy and TRCs are directed to use service from the MLFF Project Company that the Government has appointed, TRCs' require a guarantee of 100% of Toll Revenue from the Government, who is seen as the party best positioned to mitigate toll collection risk and has a legal relationship with both the MLFF Project Company and TRCs.

The application of MLFF system increases the potential risk of toll collection due to the absence of a mechanism to prevent toll road users who do not pay or pay less from entering and using the toll roads, which is currently carried out through barriers installed in each lane at the toll gate. Apart from that, there is a possibility that the MLFF system provided by MLFF Project Company may malfunction, preventing it from detecting toll road users and collecting the toll fees that must be paid by the toll road users. This situation may require the availability of funds to cover any shortfall in TRCs toll revenue caused by unlawful road users or system malfunction, ensuring that 100% of Toll Revenue is guaranteed.

In addition, a mechanism is necessary to ensure that the data used to determine 100% of Toll Revenue is accurate and reflects the actual volume and class of vehicles using toll road services. Later, this data will form the basis for reconciliation between TRCs and MLFF Project Company.

The return on investment for the MLFF Project Company will be made through a service fee paid by the TRCs to the Government, with a proposal that the service fee will be shared among 40 TRCs. According to the Government's information, its payment obligation to MLFF Project Company will commence on the commercial operation date based on the MLFF system PPP agreement, when the public begins using the MLFF system. Therefore, even if the MLFF system is not yet fully implemented or is still in a transitional period, the Government will still have a

financial obligation to the MLFF Project Company once the commercial operation date is reached.

Toll collection is crucial for TRCs due to their investment returns depend on this mechanism. Hence, TRCs must have confidence in and ensure the readiness and accuracy of the MLFF system before its implementation. This step is essential to verify that the MLFF system is reliable, and the entire ecosystem is institutionally and technically available to mitigate the arising risks. Consequently, TRCs should play a role in testing the MLFF system, including agreeing on the parameters and mechanism for conducting the trials. Given the changes in risk allocation due to the technology policies implemented by the Government, it is necessary to revise the concession agreement. Such revisions are appropriate if the MLFF system has successfully passed the parties' agreed-upon trials, including the TRCs.

4.3. Regulatory ecosystem and amendment of the concession agreement

The proposed revisions to the concession agreement incorporate several key elements to address the evolving regulatory ecosystem. First, the Government must guarantee that TRCs will obtain 100% of Toll Revenue. Additionally, provisions should ensure the availability of funds to cover TRCs' losses resulting from user unlawful act and issues with the MLFF system. Another essential element is the mechanism to ensure that the data used in toll collection using the MLFF system is current and accurate. Furthermore, the agreement should include stipulations regarding service fee for the MLFF system and a provision for compensation in the event of vehicle volume decreases after a certain agreed period due to the implementation of the MLFF system.

With the changes in risk allocation as a result of technology policies implemented by the Government, it is necessary to amend the existing concession agreement. Changes to the concession agreement are considered appropriate once the MLFF system has successfully passed the agreed trials involving all parties, including the TRCs. The proposed provisions that must be accommodated in the revised concession agreement are briefly elaborated below.

Government guarantee: Considering that the Government is deemed as the party that is suitable to mitigate the toll collection risk and legally acts as the intermediary between the TRCs and the MLFF Project Company, the Government shall bear the financial obligation to cover the TRCs' losses in obtaining 100% of Toll Revenue. The Government may transfer this obligation to the MLFF Project Company under the MLFF system PPP agreement. Nevertheless, it is worth noting that from the perspective of TRCs, the responsible party remains the Government, and TRCs' claim will be directed against the Government.

Availability of funds to recover TRCs' losses: If the Government passes its obligation to the MLFF Project Company, then the source of funds to recover TRCs' losses or guarantee 100% of Toll Revenue should be provided by the MLFF Project Company. Notwithstanding this assumption, and since the Government is the ultimate party responsible, there remains a possibility that the financial obligation will affect the state budget if the MLFF Project Company fails to provide sufficient funds. Another proposed alternative is to use a public service agency that may generate funds

not only from the state budget but also from the collection of administrative fines paid by toll road users as a source of funds.

Data accuracy: As the first nation to implement an MLFF system using GNSS technology and e-OBU, it is necessary to ensure the accuracy of such system not only at the project's inception but throughout the concession period of the MLFF project. Data accuracy offers comfort and certainty to the stakeholders and affected parties, including the TRCs, through a rigorous trial process and scrutiny.

Service fee: The fee that TRCs pay for toll collection services should be lower than current operating costs of their toll collection system. Estimating the total and disaggregated distributed service fee requires a stringent protocol and audit to ensure the MLFF project's credibility.

Provision of compensation: The transformation of the toll collection system may result in a temporary decrease in vehicle volume. Given the complexity of using the MLFF system, this reduction may last longer than usual, resulting in losses for TRCs. Therefore, it is deemed necessary that, since the implementation of the MLFF system being part of the Government's policy, any losses incurred by TRCs beyond the agreed period should be borne by the Government, provided that the TRCs can justify that the decline is solely caused by the MLFF system implementation.

5. Conclusions

This paper identified critical regulatory issues in implementing the MLFF project in the Indonesia toll road network. This project uses GNSS as a technology platform and grants the MLFF Project Company concessions through a competitive bidding process. The introduction of the MLFF system will benefit toll road users and improve the efficiency of TRCs by reducing operating costs. While it is inevitable that the modernization of the toll road transaction system will be part of the Indonesian national toll road roadmap and that the MLFF system is seen as a milestone in the business transformation through the digitalization of services, INTRA faces legal and regulatory challenges in managing the complex concession among the TRCs, INTRA, and MLFF Project Company. The Government, through INTRA, granted a concession to MLFF Project Company while engaging with TRCs in separate concessions. This complex business arrangement creates new risks for existing TRCs.

The Government should take necessary mitigation actions to shift, reduce, and compensate for these risks to honor the concession contract and maintain the investment climate for future toll road development projects. In particular, the existing concession agreement should be amended to balance the risk exposure borne by the TRCs and to preserve investors' and lenders' confidence in existing and future toll road projects.

This research suggests that risk mitigation should cover five components: 1) the Government guarantee to ensure that all contracting parties can fulfill their return on investment; 2) availability of funds to recover losses to TRCs through the establishment of a "pooled" funds created by the Government; 3) assurance of the quality of data collected and acquired by the MLFF system; 4) a robust framework for calculating the service fee paid to the MLFF Project Company, and 5) provision of financial compensations.

In the future, it is recommended that the selection of toll road technology providers should not be part of the Government's role. In line with the Government's direction outlined in Road Law, the Government should only act as the regulator, allowing the private sector to fully act as the operator, which includes appointing its service provider related to the toll road business. The Government should be able to protect itself against possible commercial and political risks. As per the basic concept of PPP, the private sector, with agility, flexibility, and governance to induce efficiency and take risks, is better positioned to induce efficiency and manage risks. Future research should review the global practices in implementing such technology policies to develop a common regulatory framework.

Author contributions: Conceptualization, DP; methodology, DP and PA; validation, DP, PA and VD; formal analysis, PA and VD; investigation, VD; resources, DP and PA; data curation, DP and VD; writing—original draft preparation, DP and VD; writing—review and editing, DP and PA, VD; visualization, DP; supervision, DP and PA; project administration, PA; funding acquisition, DP. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: The authors thank the Indonesia National Toll Road Authority for the data and information provided to undertake this research and publish the article. Acknowledgment should be given to the Center for Transportation and Logistics Universitas Gadjah Mada to support the research.

Conflict of interest: The authors declare no conflict of interest.

References

Amalia, P., Budhijanto, D. (2018). The Force of Strategic Infrastructures: The Role of Public-Private-Partnership to Strengthen Sustainable Developments in Indonesia. Central European Journal of International and Security Studies, 12(4), 547–563.

Bain, R. (2009). Toll Road Traffic and Revenue Forecast—An Interpreter's Guide. Robert Bain.

Bel, G., & Foote, J. (2009). Tolls, Terms and Public Interest in Road Concessions Privatization: A Comparative Analysis of Recent Transactions in the USA and France. Transport Reviews, 29(3), 397–413. https://doi.org/10.1080/01441640802432144

Bunduchi, R., Weisshaar, C., & Smart, A. U. (2011). Mapping the benefits and costs associated with process innovation: The case of RFID adoption. Technovation, 31(9), 505–521. https://doi.org/10.1016/j.technovation.2011.04.001

Chen, C., Fan, Y., & Farn, C. (2007). Investigating Factors Affecting the Adoption of Electronic Toll Collection: A Transaction Cost Economics Perspective. In: Proceedings of the 2007 40th Annual Hawaii International Conference on System Sciences (HICSS'07). https://doi.org/10.1109/hicss.2007.298

Clifton, C., & Duffield, C. F. (2006). Improved PFI/PPP service outcomes through the integration of Alliance principles. International Journal of Project Management, 24(7), 573–586. https://doi.org/10.1016/j.ijproman.2006.07.005

Egea-Roca, D., Arizabaleta-Diez, M., Pany, T., et al. (2022). GNSS User Technology: State-of-the-Art and Future Trends. IEEE Access, 10, 39939–39968. https://doi.org/10.1109/access.2022.3165594

Fisher, G., Babbar, S. (1996). Private Financing of Toll Roads. World Bank.

Grout, P. (1997). The economics of the private finance initiative. Oxford Review of Economic Policy, 13(4), 53–66. https://doi.org/10.1093/oxrep/13.4.53

Hensher, D. (1991). Electronic Toll Collection. Transportation Research Part A: General, 25, 9–16.

Hensher, D. A. (2017). Toll roads—a view after 25 years. Transport Reviews, 38(1), 1–5. https://doi.org/10.1080/01441647.2017.1330850

Indonesia National Toll Road Authority (INTRA). (2023). The year 2022 Indonesia National Toll Road Authority Annual Report. Ministry of Public Works and Housing.

ISO. (2019). ISO 17573-1, Electronic fee collection—System architecture for vehicle-related tolling, Part 1: Reference model, Part 2: Terminology. ISO.

Jing, H., Gao, Y., Shahbeigi, S., et al. (2022). Integrity Monitoring of GNSS/INS Based Positioning Systems for Autonomous Vehicles: State-of-the-Art and Open Challenges. IEEE Transactions on Intelligent Transportation Systems, 23(9), 14166–14187. https://doi.org/10.1109/tits.2022.3149373

Ke, Y., Wang, S., Chan, A. (2010). Risk Allocation in Public-Private Partnership Infrastructure Projects: Comparative Study. Journal of Infrastructure Systems.

Miranda, N. (2007). Concession Agreements: From Private Contract to Public Policy. The Yale Law Journal, 117(3), 510. https://doi.org/10.2307/20455800

Nicolini-Llosa, J. L. (2002). Toll Road Concessions in Argentina: What Can Be Learned. Transportation Research Record: Journal of the Transportation Research Board, 1812(1), 10–21. https://doi.org/10.3141/1812-02

Ogden, K. (2001). Privacy Issues in Electronic Toll Collection. Transportation Research Part C: Emerging Technologies, 9, 123–134.

Ortiz, I. N., & Buxbaum, J. N. (2008). Protecting the Public Interest in Long-Term Concession Agreements for Transportation Infrastructure. Public Works Management & Policy, 13(2), 126–137. https://doi.org/10.1177/1087724x08326175

Parikesit, D. and Laksmi, I. (2015). Critical Review of Indonesia PPP Regulations and Frameworks: Challenges and Ways Forward. IIGF Institute.

Quddus, M. A., Ochieng, W. Y., & Noland, R. B. (2007). Current map-matching algorithms for transport applications: State-of-the art and future research directions. Transportation Research Part C: Emerging Technologies, 15(5), 312–328. https://doi.org/10.1016/j.trc.2007.05.002

Resdiansyah and Malik, I. B. (2023). Critical Review of Toll Road Development in Indonesia, Sustainability in the Operation and Maintenance of Toll Roads: Digitalization of Toll Road Payment System. IIGF Institute and UGM Center for Transportation and Logistics Studies.

Saich, A. (2013). The Sum is Greater than the Parts: Doubling Shared Prosperity in Indonesia through Local and Global Integration. Harvard University.

Serina, Q. (1999). An Overview of the Legal Aspects of Concession Agreements in Latin America. ILSA Journal of International and Comparative Law, 5, 371–375.

Shaw, L., Gwilliam, K., Thompson, L. (1996). Concessions in Transport, TWU Discussion Paper. The World Bank.

Tseng, P. H., & Pilcher, N. (2022). Political and technical complexities of electronic toll collection: Lessons from Taiwan. Case Studies on Transport Policy, 10(1), 444–453. https://doi.org/10.1016/j.cstp.2022.01.005

Varaiya, P. (1993). Smart cars on smart roads: Problems of control. IEEE Transactions on Automatic Control, 38(2), 195–207. https://doi.org/10.1109/9.250509

Waqas, M., & Ioannou, P. (2023). Automatic Vehicle Following Under Safety, Comfort, and Road Geometry Constraints. IEEE Transactions on Intelligent Vehicles, 8(1), 531–546. https://doi.org/10.1109/tiv.2022.3177176

Wardrop, J. G., & Whitehead, J. I. (1952). Correspondence. some theoretical aspects of road traffic research. Proceedings of the Institution of Civil Engineers, 1(5), 767–768. https://doi.org/10.1680/ipeds.1952.11362

World Bank. (1994). World Development Report 1994: Infrastructure for Development. Oxford University Press.